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(Research Article)

Acute respiratory infections and acute bronchial asthma crises addressed by mathematical modeling

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Abstract

Acute Respiratory Infections (ARI) and Acute Bronchial Asthma Crises (AABC) are diseases that can be monitored well in advance. The objective of the research consisted in making a prognosis one year in advance of these two variables, obtaining highly significant correlations and small errors. Daily data from the hospital of Sagua La Grande, Villa Clara, Cuba, were used for the period from January 2006 to February 28, 2011. The prediction period or long-term independent sample comprised from March 1, 2010 to March 28, 2011, with a total of 365 cases. A modeling was also performed by first calculating the long-term forecast, where the predicted value was used as a predictor for the short-term model; errors were calculated for the independent sample, obtaining an improvement in the errors in the case of CAAB, where the mean error decreased from 18.7 cases to 1.68. It is concluded that it is possible to predict daily ARI and CAAB cases one year in advance using the Objective Regression Regressive methodology.

Keywords: Acute Bronchial Asthma Crises; Acute Respiratory Infections; ROR methodology; Mathematical modeling; Villa Clara

1. Introduction

ARI is the leading cause of medical consultations and morbidity in both developed and developing countries (Osés *et al*., 2017; Osés *et al*., 2018b; Fimia *et al*., 2023). The presence of ARI in children under five years of age is independent of living conditions and the degree of development of a country. In most countries, it is estimated that children under five years of age have four to eight episodes of ARI per year (Canafax, 2003; Osés *et al*., 2017; Alonso *et al*., 2022). In a study carried out, the same incidence rate was observed in cities in Costa Rica, Ethiopia, India and the United States (OPS, 2003a).

In the 21st century, children in the Americas still die in alarming proportions from causes preventable by relatively simple measures. Of the major problems affecting children, ARI plays a predominant role in morbidity and mortality (Benguigui, 2001; WHO, 2002; Canafax, 2003; OPS, 2003b).

According to community studies carried out in the pediatric population of different countries, it has been demonstrated how extremely frequent ARI are in these ages (WHO, 2002 and 2003). More than 140 000 children under five years of age die annually from pneumonia in America, and they constitute the first cause of consultation and hospitalization in pediatric ages. Available statistics indicate that between 30 and 60 % of the consultations of sick children are due to this cause and 30 to 40 % of them are hospitalized. Pneumonia and bronchopneumonia are the main reasons for hospital

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admission (Canafax, 2003; Miller, 2004; Osés *et al*., 2022). However, most cases are managed at the primary health care level (Canafax, 2003; Miller, 2004).

In Cuba, the first program against ARI was implemented in 1970 and in 1985, following an increase in the mortality rate due to this condition, a plan of measures aimed at achieving better control and prevention of these conditions was implemented (Perfeito & Russ, 2000; Riverón *et al*., 2000; León, 2005; Osés *et al*., 2022).

Spatial and temporal changes in seasonal, interannual and interdecadal climate variations affect human health by increasing the risk of disease transmission, including ARI (Osés *et al*., 2018b; Alonso *et al*., 2022; Osés *et al*., 2022). In this regard, stated that social, technological, environmental and climatic changes create conditions and opportunities for microorganisms to reproduce and proliferate, and with them the diseases they transmit, thus recognizing the social and technological component in the problem of climate and health (McMichael, 2003 and 2004).

The objective of the research was to perform a one-year ahead forecast of both ARI and AABC using mathematical modeling.

2. Material and methods

2.1. The Objective Regressive Regression (ORR) methodology

The Objective Regressive Regression (ORR) methodology creates, in a first step, dichotomous variables DS, DI and NoC, where:

NoC - Number of base cases,

DS = 1, if NoC is odd; DI = 0, if NoC is even. When DS is 1, DI is zero and vice versa. Subsequently, the module corresponding to the Regression analysis of the statistical package SPSS version 19.0 (IBM Company) is executed, specifically the ENTER method where the predicted variable and the ERROR are obtained.

Then the autocorrelograms of the ERROR variable are obtained, paying attention to the maximums of the significant partial autocorrelations PACF. The new variables are then calculated taking into account the significant lag (Lag) of the partial autocorrelation (PACF), both for the IRA and for the exogenous variables, in the case of the IRA these depend on 4 months ago. Finally, these regressed variables were included in the new regression in a process of successive approximations until white noise was obtained in the regression errors.

The ROR methodology was used for data prediction, long term models were obtained (1 year in advance) to predict ARI and AABC, with respect to the long term, climatic variables such as maximum temperatures and partial oxygen density are also used. The daily database corresponds to the municipality of Sagua la Grande, in the period from January 2006 to February 28, 2011. The prediction period or long-term independent sample comprised from March [1], 2010 to March 28, 2011, for a total of 365 cases. A modeling was also performed by first calculating the long-term forecast, for which the predicted value was used as a predictor for the short-term model; in addition, the errors for the independent sample were also calculated.

3. Results

Figure 1 shows the long-term model for ARI, while figure 2 shows the long-term model for AABC in the independent sample.

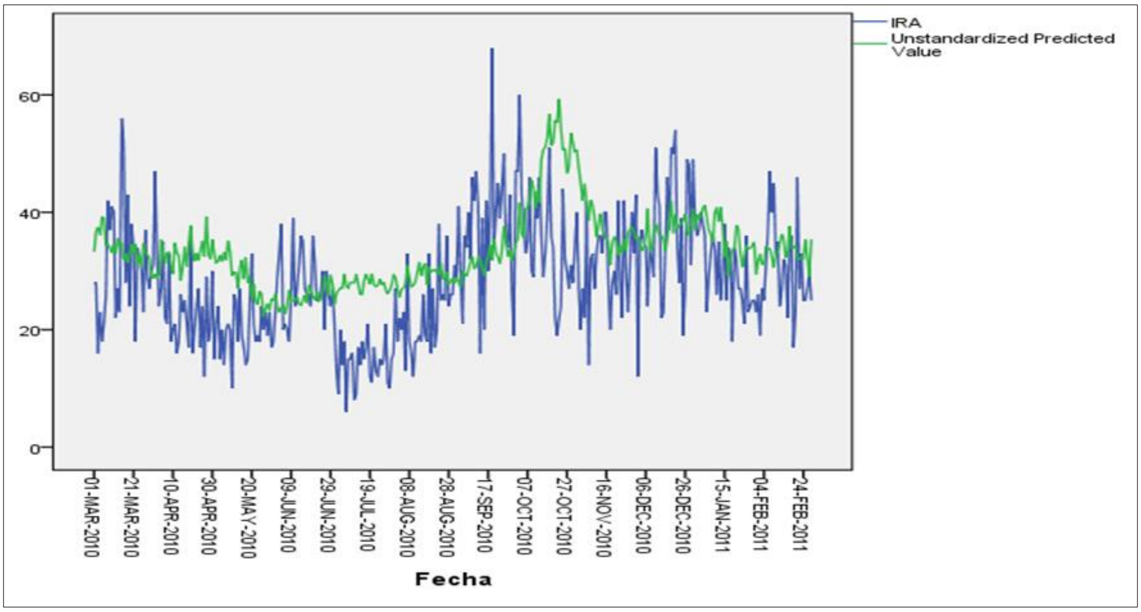

Figure 1 Actual and predicted long-term value for independent ARI sample

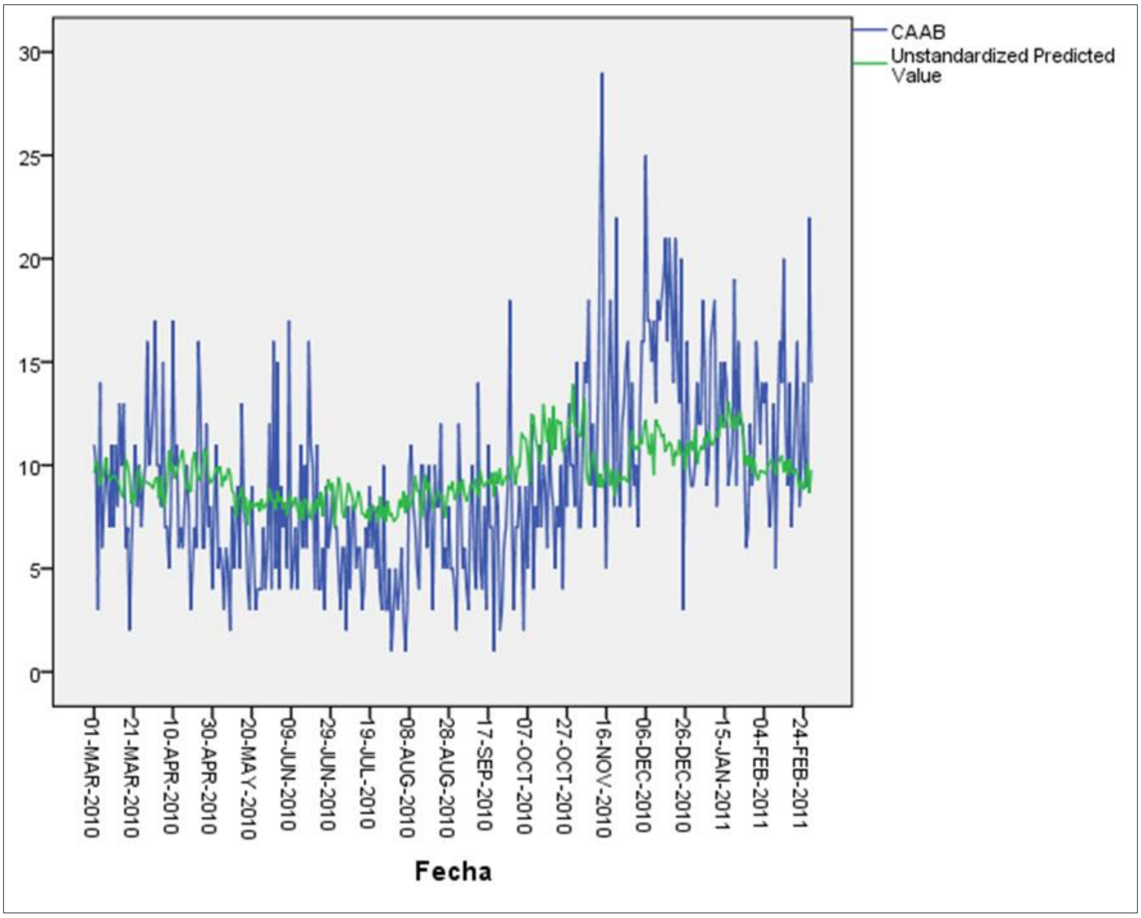

Figure 2 Actual and predicted long-term value for independent sample of AABC

The correlation between the actual and predicted value for long-term ARI was 0.335, significant at 99% (Table 1).

Table 1 Correlation between actual and predicted ARI in the 1-year independent sample

Correlations			
		IRA	**Unstandardized Predicted Value**
IRA	Pearson correlation	1	0.335**
	Sig. (bilateral)		0.000
	N	365	365
Unstandardized Predicted Value	Pearson correlation	0.335**	1
	Sig. (bilateral)	0.000	
	N	365	365
** The correlation is significant at the 0.01 level (bilateral).			

In the case of AABC, the plot of the actual value with the predicted value for the independent sample can be seen in figure 2.

The correlation between predicted value and independent sample for AABC was 0.384, significant at 99% (Table 2).

Table 2 Correlation between actual CAAB and predicted CAAB in the 1-year independent sample

Correlations			
		CAAB	**Unstandardized Predicted Value**
CAAB	Pearson correlation	1	0.384**
	Sig. (bilateral)		0.000
	N	365	365
Unstandardized Predicted Value	Pearson correlation	0.384**	1
	Sig. (bilateral)	0.000	
	N	365	365

** The correlation is significant at the 0.01 level (bilateral).

An analysis of the long-term errors (Table 3) shows that the minimum error for the AABC was 2.31, while for the ARI it was 37.3, the maximum error for the IRAs was 36.2, while for the AABC it was 58, the mean errors are small in the order of five cases for the IRAs and 18 cases for the AABC.

Table 3 Descriptive statistics of errors in independent sample

	N	**Minimum**	**Maximum**	**Media**	**Desv. típ.**
Error IRA	365	-37.29	36.18	-5.0994	9.99910
Error CAAB	365	-2.31	58.35	18.7086	9.73748
N valid (as listed)	365				

The errors for IRA are distributed as normal for a good model (Figure 3).

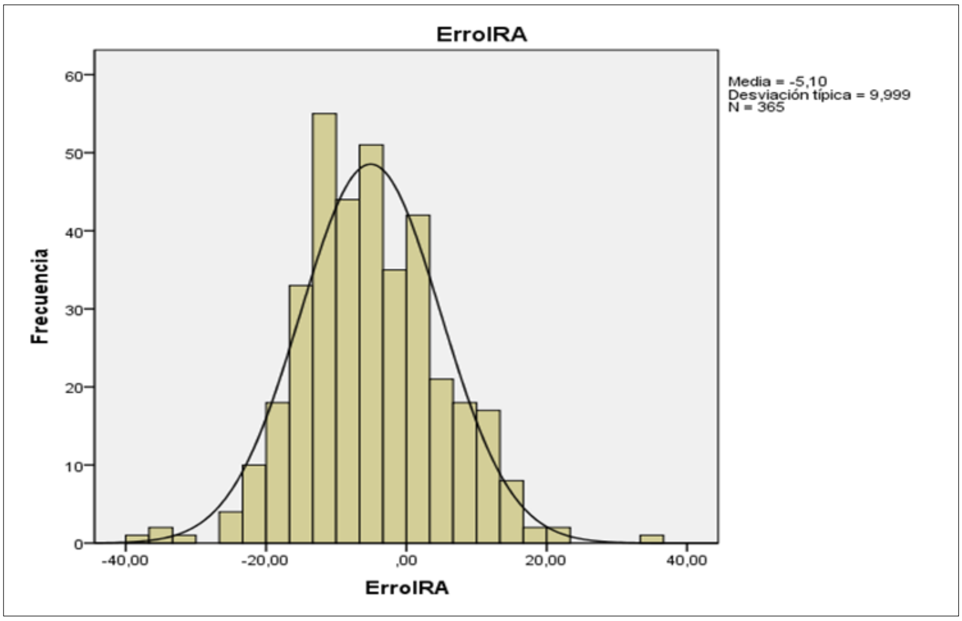

Figure 3 Histogram of errors in the independent ARI sample

The errors for AABC are also normally distributed as would be expected from a good model, although the mean is larger than the ARI (Figure 4).

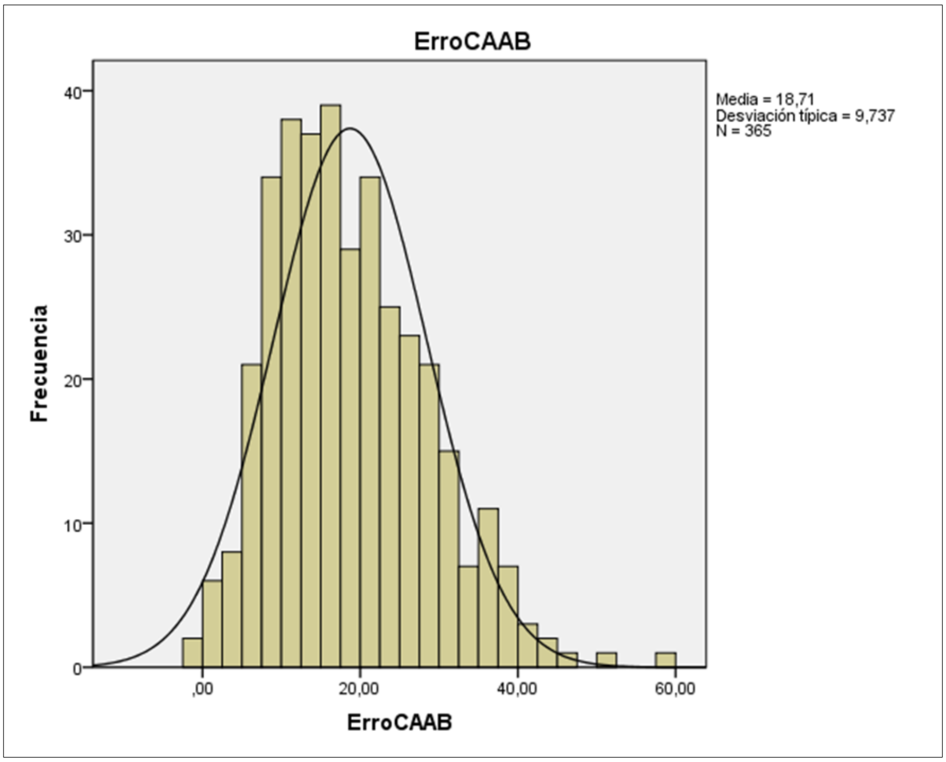

Figure 4 Histogram of the errors in the independent AABC sample

It should be noted that ARI has a higher mean value than AABC, as well as greater variability around the mean values, since its standard deviation is 14.6 and that of AABC, 5.7 (Table 4).

Modeling was also performed by first calculating the long-term forecast, then the predicted value was used as a predictor for the short-term model, and the errors were calculated for the independent sample, followed by the results.

Figure 5 presents the long-term model for ARI, while figure 6 presents the long-term model for AABC in the independent sample.

Table 4 Variability around the mean values ARI has a higher mean value than AABC

Descriptive statistics					
	N	**Minimum**	**Maximum**	**Media**	**Desv. típ.**
ARI	1551	4	130	32.07	14.661
AABC	1551	0	38	10.64	5.747
N valid (as per list)	1551				

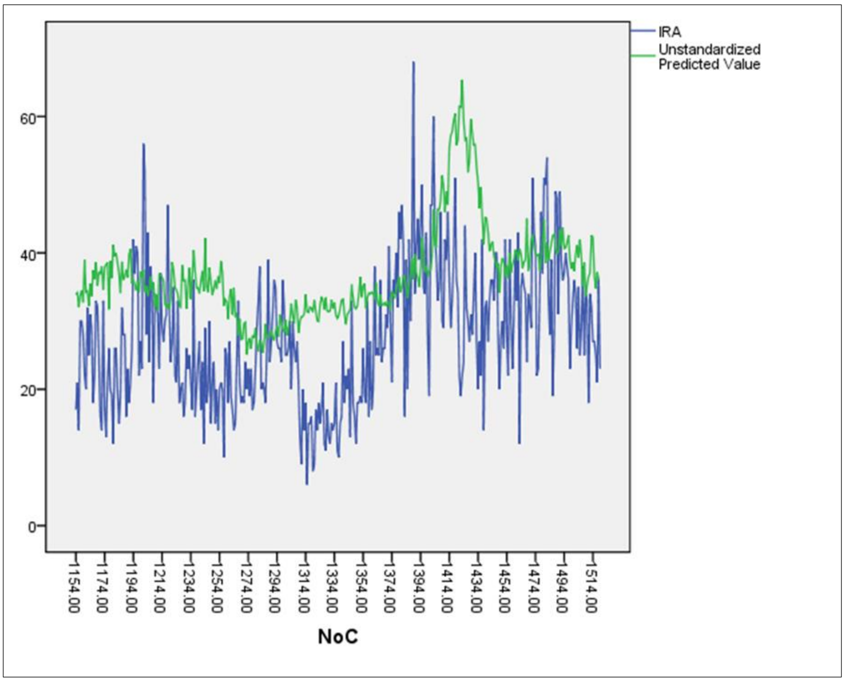

Figure 5 Actual and predicted long-term value for independent ARI sample

The correlation between the actual and predicted value for long-term ARI was 0.321, significant at 99% (Table 5).

Table 5 Correlation between the actual and predicted value of ARI in the 1-year independent sample

Correlations			
		IRA	**Unstandardized Predicted Value**
IRA	Pearson Correlation	1	0.321**
	Sig. (2-tailed)		0.000
	N	366	365
Unstandardized Predicted Value	Pearson Correlation	0.321**	1
	Sig. (2-tailed)	0.000	
	N	365	365
** Correlation is significant at the 0.01 level (2-tailed).			

In the case of the AABC, the plotting of the actual value with the predicted value for the independent sample can be seen (Figure 6).

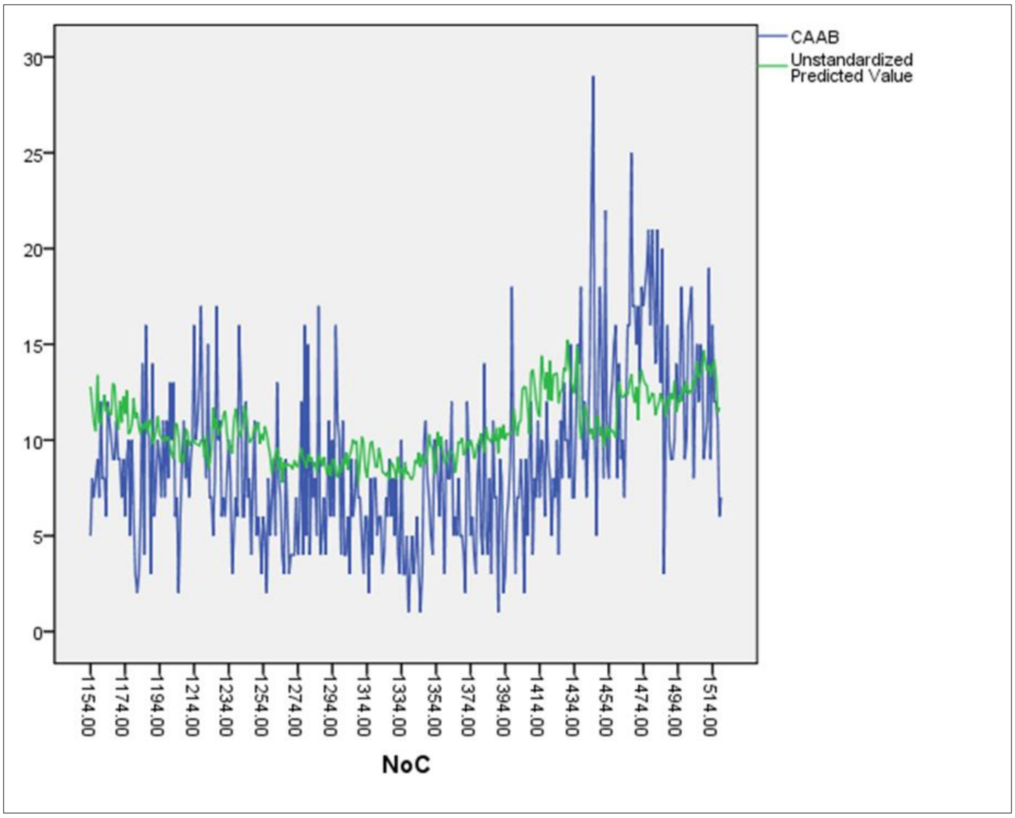

Figure 6 Long-term actual and predicted value for independent sample of AABC

The correlation between predicted value and independent sample for AABC was 0.388 significant at 99% (Table 6).

Table 6 Correlation between actual CAAB and predicted CAAB in the 1-year independent sample

Correlations			
		AABC	**Unstandardized Predicted Value**
AABC	Pearson Correlation	1	0.388**
	Sig. (2-tailed)		0.000
	N	366	365
Unstandardized Predicted Value	Pearson Correlation	0.388**	1
	Sig. (2-tailed)	0.000	
	N	365	365
** Correlation is significant at the 0.01 level (2-tailed).			

Figure 7 shows the value of the errors for the IRA, while figure 8 shows the histogram of the errors in an independent sample for the AABC.

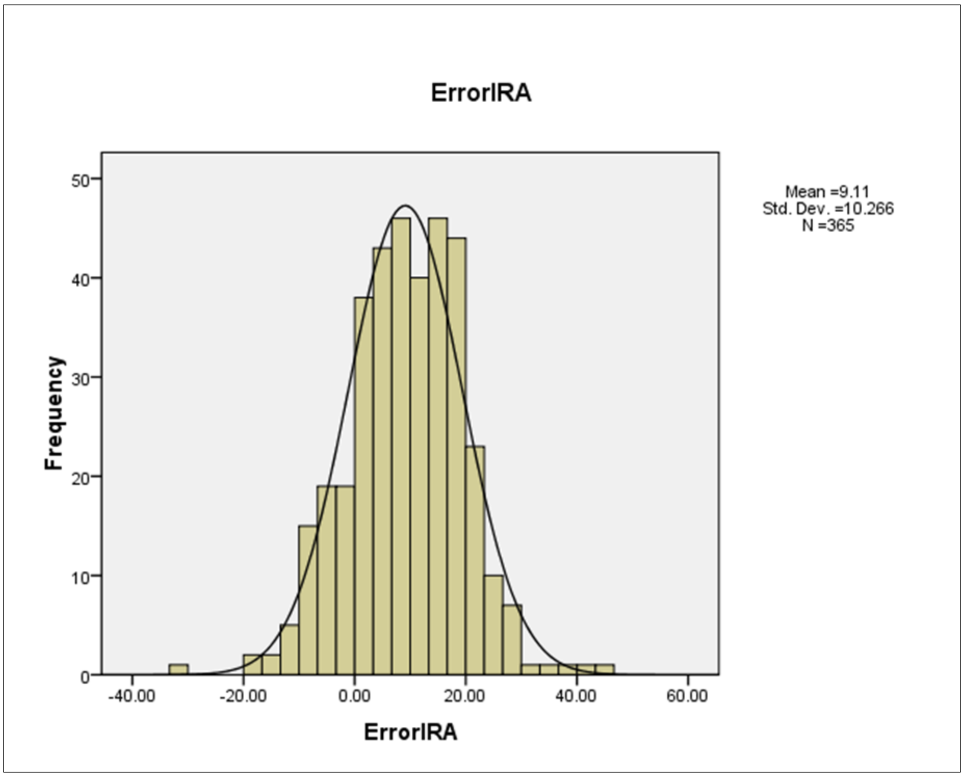

Figure 7 Value of the errors for the ARI

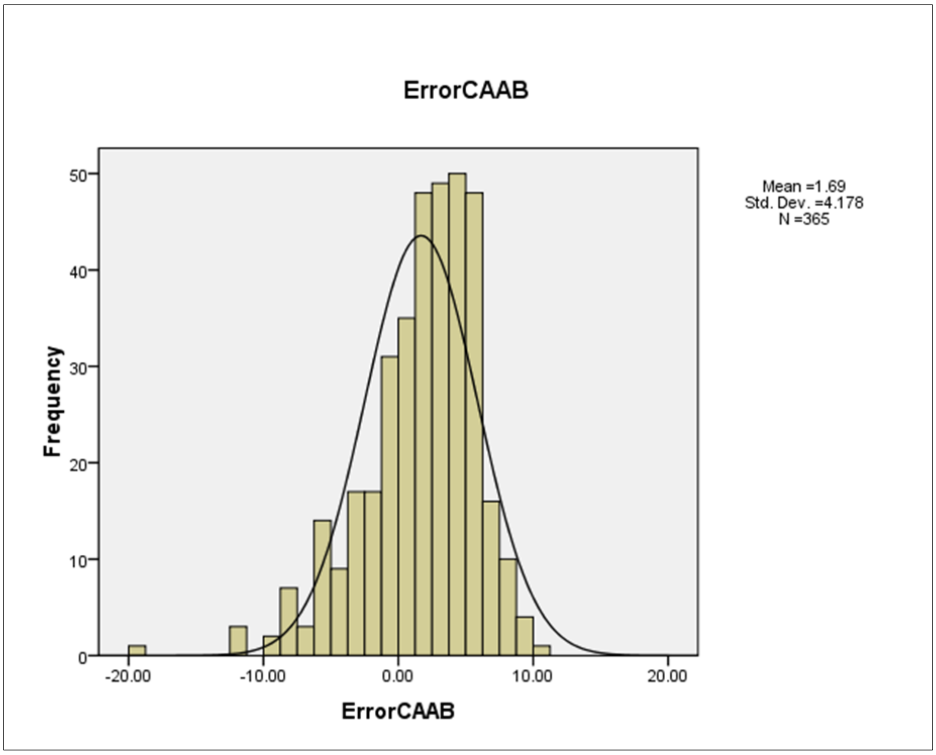

Figure 8 Histogram of errors in the independent sample of AABC

It should be noted that the ARI errors have a higher mean value than the AABC, as well as greater variability around the mean values, since their standard deviation is 10.26, while that of the AABC was 4.17 (Table 7).

Table 7 Long-term ARI and CAAB errors using the predicted value to improve the short term

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Desviation**
Error IRA	365	-31.79	43.38	9.1122	10.26607
Error CAAB	365	-18.96	10.79	1.6873	4.17753
Valid N (listwise)	365				

Comparing table 3 with table 8, an improvement in the AABC forecast can be seen, since the error decreases from 18.7 to 1.68, while the IRA worsen, going from -5.09 to 9.11 respectively, it seems that the ARI respond better to the long term, while the AABC need a short-term readjustment, that is, their cause is more immediate corresponding to short-term factors, or the previous day.

Up to this point, only statistical values had been calculated without using climatic values; once the maximum temperature (Tx) regressed on 365 days was included (Table 8), an improvement was obtained for AABC and an improvement for ARI, but it does not exceed that of table 3; in the case of IRA, the Partial Oxygen Density (DOA) regressed on 369 days was used.

Table 8 With climatic variable including Tx for CAAB and DOA for IRA

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Error ARI	365	-32.46	43.74	9.3947	10.32866
Error AABC	365	-17.79	10.72	0.6269	4.17262
Valid N (listwise)	365				

Figure 9 shows the AABC and the predicted value using DOA regressed on 369 days. The correlation between these parameters is 0.388, significant at 99%.

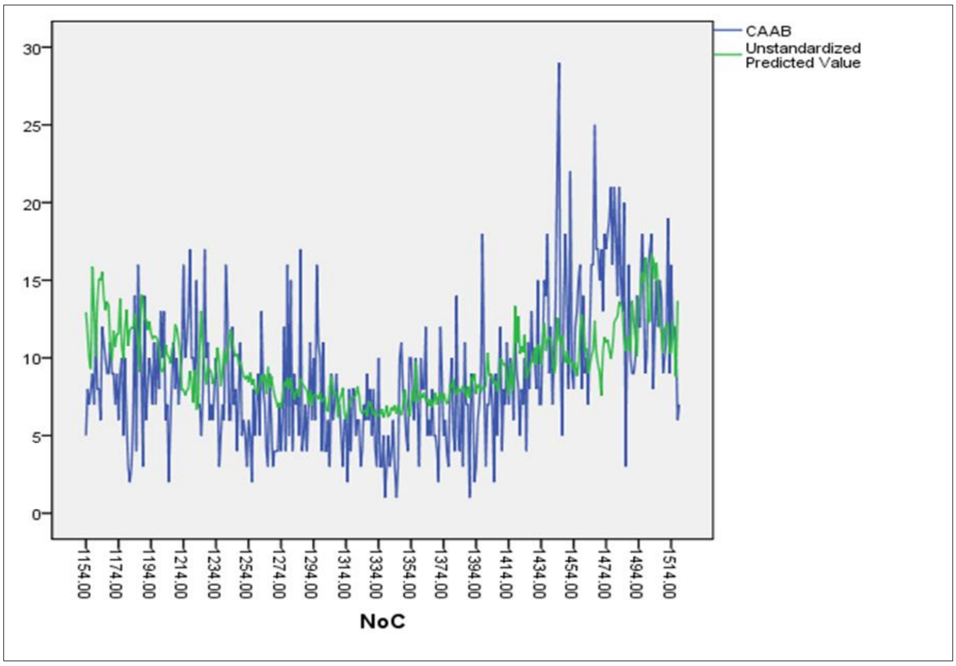

Figure 9 Actual and predicted long term value for independent sample of AABC with climate variable (DOA) lagged by 369 days

4. Discussion

In the case of modeling and prognosis of ARF, the most commonly used mathematical statistical techniques are correlation analysis and multiple linear regression (Ortiz, 2006), which are undoubtedly influenced by their relative simplicity and availability in any statistical software package.

There are other approaches to the problem, much less frequent, through the possibilities offered by the analysis of time series (Osés *et al*., 2021a) applied it in their studies of bronchial asthma in two U.S. cities, and the same author in 2003 used it to address mortality in Chile, both with novel and very interesting results. In this regard, Colwell & Patz (2005) criticize the scarce dissemination of the new epidemiological research methodologies, in vogue worldwide, in the field of climate and health, within which one of the fundamental factors is the knowledge of the temporal variation of diseases (daily, periodic or seasonal). Its importance lies in the fact that this approach could reveal etiopathogenies that were not known until then, which could constitute an essential element for taking effective measures for their prevention (Coronel, 2007; Soler *et al*., 2013; Gutiérrez *et al*., 2023).

At present, the clarification of the relationships between different diseases and weather-climate, and especially the feasibility and effectiveness of issuing predictions with a biological-meteorological character, are highly controversial issues and can be considered as problems not yet solved by the international scientific community (Molina *et al*., 2001; Álvarez & Álvarez, 2007; Fimia *et al*., 2023).

Despite all the drawbacks mentioned above, bioclimatic forecasts are making their way in one way or another in today's world (Ortiz, 2006). Their use in the dosage and management of climatotherapeutic procedures is increasingly widespread (Mc Michael, 2004; Ortiz, 2006; Castillo *et al*., 2023).

On the other hand, in Cuba, the tradition of medical-climatological studies is long, especially through the medical community (Lecha, 1989; Lecha, 1994; Ortiz, 2003), with research topics that address the study of the relationship between climate and diseases such as cardiovascular and respiratory diseases, mainly through the use of linear correlation and regression analysis (Osés *et al*., 2021b; Alonso *et al*., 2022; Osés *et al*., 2022; Fimia *et al*., 2023).

The breadth of studies in terms of biological-meteorological forecasting in Cuba has reached such a magnitude that it extends to other non-conventional approaches in relation to the links between weather, climate and infectious entities (Osés *et al*., 2018b; Fimia *et al*., 2019; Fimia *et al*., 2020; Fimia *et al*., 2023). By modeling these processes, using time series analysis, expressions have been obtained that allow the prognosis of the attendance to emergency services in hospitals in Havana City and in the rest of the country, to patients suffering from acute bronchial asthma attacks (CAAB) and acute respiratory infections (ARI) (Molina *et al*., 2001; Ortiz, 2003; Ortiz, 2006; Soler *et al*., 2013). The issuance of these forecasts, unlike other currents in vogue, requires constant updating of the epidemiological and climatic series (Ortiz, 2003; Alonso *et al*., 2022; Gutiérrez *et al*., 2023). Another methodology used in the statistical forecasting of data series is the Objective Regressive Regression Methodology (Osés, 2004; Osés & Grau, 2011; Osés *et al*., 2022).

This prediction method for daily CAABs one year in advance exceeds by six months that obtained by Osés *et al*. (2015), which was six months in the case of municipal CAAB, which logically presented less variability and used Dummy variables (dummy), this methodology also surpasses other previous works (Omar, 2008), where municipal data were also used six months in advance, even further back in time models had been obtained that predicted four months in advance, but these referred to monthly CAAB values (Osés, 2004), here they are also surpassed by these results; Moreover, it is our belief that CAAB and IRA can be estimated on the daily scale 11 years in advance, as well as the three-hourly atmospheric pressure (Osés *et al*., 2017; Osés *et al*., 2018a,b; Osés *et al*., 2022).

Some authors use the ROR methodology due to its simplicity and easy application (Osés & Grau, 2011). This methodology has also been used in the prognosis of infectious entities, such as Angiostrongylosis, Fasciolosis and avian infections (Osés *et al*., 2015; Fimia *et al*., 2016a, b), and for the prognosis of high intensity earthquakes in Cuba, as well as hurricanes (Osés *et al*., 2018c; Osés *et al*., 2024); in addition, it was implemented in surveillance, monitoring and control of culicidae (Fimia *et al*., 2019; Fimia *et al*., 2020; Fimia *et al*., 2023); it has also been implemented in studies related to the incidence in natural disasters and human health (Osés *et al*., 2021a; Osés *et al*., 2022; Osés *et al*., 2024).

5. Conclusion

In conclusion, good results were obtained in the long-term prognosis of AKI and CAAB, since the correlations between actual and predicted values were highly significant, as were the errors. This form of long-term modeling is a powerful tool to prevent these diseases in advance. Thus, both ARI and CAAB can be mathematically modeled using the ROR methodology, and not only in the long term, but also in the short and medium term.

Compliance with ethical standards

Acknowledgement

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Disclosure of conflict of interest

No conflict of interest exists among the Authors.

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