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Intimate Partner Violence in Madrid: A Time Series Analysis (2008-2016)

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Abstract

Purpose: This study analyzes whether there are time patterns in different intimate partner violence (IPV) indicators and aims to obtain models that can predict the behavior of these time series.

Methods: Univariate autoregressive moving average models (ARMA) were used to analyze the time series corresponding to the number of daily calls to the 016 telephone IPV help line and the number of daily police reports filed in the Community of Madrid during the period 2008-2015. Predictions were made for both dependent variables for 2016.

Results: The daily number of calls to the 016 telephone IPV help line decreased during January 2008-April 2012 and increased during April 2012–December 2015. No statistically significant change was observed in the trend of the number of daily IPV police reports. The number of IPV police reports filed increased on weekends and on Christmas holidays. The number of calls to the 016 IPV help line increased on Mondays. Using data from 2008-2015, the univariate ARMA models predicted 64.2% of calls to the 016 telephone IPV help line and 73.2% of police reports filed during 2016 in the Community of Madrid.

Conclusions: Our results suggest the need for an increase in police and judicial resources on non-work days. Also, the 016 telephone IPV help line should be especially active on work days.

Key words: Intimate partner violence, battered woman, spatial temporal analysis, Spain

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List of abbreviations

IPV: Intimate partner violence against women

ARMA: autoregressive moving average models

AR: auto-regressive

MA: moving average

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Introduction

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Intimate partner violence against women (IPV) is a public health problem that negatively affects quality of life for women, families and for society [1]. The European Institute for Gender Equality estimates the cost of IPV in the European Union at 109.1 billion Euros [2]. Studies have identified individual, relational, community and structural risk factors that can increase women's vulnerability to IPV [3,4]. The study of seasonal cycles that accompany IPV episodes could provide useful information to predict periods of change in women's risk. Preventive measures, such as intensifying surveillance of women at high risk of aggression or reducing women's contact with the aggressor during high risk periods could reduce the likelihood of aggression.

Studies [5,6] have identified an increase in assaults and rapes during the hottest times of the year (June–September); in contrast, homicides did not show any seasonal pattern [6]. Recent study describe a temporal pattern in violent crimes -homicides, rapes, aggravated assaults, and robberies-, showing that violence increases in the hottest months and with abnormally high temperatures, especially when these temperatures occur during the winter months. This association is significantly greater in lower income neighborhoods [7]. Changes in alcohol consumption patterns [8,9], and changes in times in which victim and aggressor coincide- *The Routine Activity Model Approach*- are possible hypotheses [10,11].

There are few studies that have identified possible temporal patterns in IPV. Results from Michel and Zumpe [6] showed increases in the number of crisis telephone calls, requests for shelter and number of women given shelter during the summer months. These increases were significantly related to temperature rhythms. According to the General Affective Aggression Model (GAAM), high temperatures cause human irritability, may trigger irritation and discomfort and thereby heighten aggression [12]. It is possible also that, since a Routine Activity Theory approach, high temperature increased cohabitation with a partner, and this may increase the probability of conflict and aggression [11]. Studies in New Jersey [13] found no space-time cluster in IPV homicides. In Spain Vives et. al found that a woman's risk of

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femicide increased 77% on Monday [14]. Different IPV indicators may show different dynamics.

In Spain, the Organic Law 1/2004 on Integral Protection Measures against Gender Violence [15] spurred police and judicial protection for women exposed to IPV, including the adoption of the 016 telephone IPV help line, which provides information, referral and legal advice related to IPV [16].

The daily frequency of IPV help line telephone calls, as a reflection of IPV exposure, and frequency of police reports filed, as a proxy for demand for help, are indicators that may permit identifying possible temporal patterns in IPV. Time series analysis using autoregressive integrated moving average models (ARIMA) [17] is useful in the study of the behavior of public health indicators, both from a predictive and a diagnostic perspective [18-21]. We hypothesized that IPV may show a temporal pattern. It is possible that IPV increases during hottest months, and when cohabitation is greater. Knowledge of the dynamics of different indicators of IPV could help support effective use of IPV resources.

The objective of this study was twofold: 1) to analyze whether there are temporal patterns in the number of daily complaints of IPV and in the daily number of 016 telephone calls and 2) to obtain prognostic models to predict the behavior of these series for a relatively lengthy time period, such as an entire year.

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Methods

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Data sources and dependent variables

- Number of daily calls to the 016 telephone IPV help line carried out in the Community of Madrid during the 2008-2016 period. Data was provided by the Government Office for Gender Violence (Ministry of Health, Social Services and Equality).
- Number of daily police reports filed with the state police force (FCSE; National Police Force and Civil Guard) in the Community of Madrid during the 2008-2016 period, provided by the Criminal Statistics System (Secretary of Security of the Ministry of the Interior).

Statistical analysis

The number of daily calls to the 016 telephone IPV help line and the number of daily IPV police reports filed were analyzed using univariate auto-regressive (AR) integrated (I) moving average (MA) ARIMA models. The models are based solely on the history of the series; they do not include external variables not inherent in the series structure (trends, cycle, and seasonal variables).

The ARIMA forecasting equation for time series is a linear equation in which the predictors consist of lags of the dependent variable and/or lags of the forecast errors. Thus:

Predicted value of Y = a constant (μ) and/or a weighted sum of one or more recent values of Y (Y t-1…Y t-p) and/or a weighted sum of one or more recent values of the errors (e t-1…e t-q).

A nonseasonal ARIMA model is classified as an "ARIMA (p,d,q)" model, where:

- p is the number of autoregressive terms,
- d is the number of nonseasonal differences needed for stationarity, and
- q is the number of lagged forecast errors in the prediction equation.

In terms of y, the general forecasting equation is:

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$$\hat{y}t = \mu + \varphi 1\, yt\text{-}1 + \ldots + \varphi p\, yt\text{-}p - \theta 1 et\text{-}1 - \theta q et\text{-}q.$$

In the case of a model with seasonality S of the form (P,D,Q) the equation would be similar to the above mentioned equation, but taking into account that the lags P and Q refer to seasonal periods. This work uses a seasonal period of 7 days, therefore the terms P and Q would refer to the values of "Y" and "e" that have occurred 7*P and 7*Q days later, respectively.

To control the differencing component (I) has been introduced a trend component (counter named n1). The trend is included through a counter n1 which would be equal to 1 for the first day of the series, 2 for the second, and successively. By this procedure ARIMA models change to ARMA models during the following steps.

To control for annual (365 days), semestral (180 days), trimestral (90 days), and bi-semestral (60 days) seasonality, the functions sine (sin) and cosine (cos) were included in these periodicities in the following way: Sin365= sin (2*3.1416*n1/365) and Cos365= cos (2*3.1416*n1/365).

Vacation periods and days of the week are included as *dummy* variables. The corresponding vacation periods were: Christmas Holidays from December 24th through January 6th, Summer Holidays from July 1st through August 31st, and the Easter Holiday which varies each year.

Modelling is a step by step process with the elimination of those variables with an insignificant estimator at $p<0.05$. The model's goodness of fit was obtained by analysis of residuals, by obtaining the Akaike Information Criterion (AIC), Bayesian information criterion, autocorrelation function, partial autocorrelation function and Ljung-Box text. We use $p<0.05$ as the criteria to select the final statically significant variables, and during the process it is possible to obtain different final models (or versions), that can include different variables, due to the high correlation between similar variables, for example, variables to control seasonalities. The Autocorrelation Function (ACF) and Partial autocorrelation function (PAF)

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are supposed to have *white noise* in the final models considered. To select the best model between the possible final models, we used the AIC.

The modelling process of dependent series variables was carried out for the 2008-2015 period. The resulting model was applied to the prediction of the values of the dependent variables for the year 2016. The fit of prediction between the adjusted and real values was carried out using Pearson's correlation. The sensitivity of the coefficients was found using the Jack-Kniffe method. The statistical software package used was SPSS v15.

Results

Time series evolution and modelling of the variable "daily IPV police reports filed"

During the 2008-2016 period, there were 84,652 IPV police reports in the Community of Madrid, an average of 25.7 per day (standard error 8.7). **Figure 1** shows the temporal evolution of the variable "IPV police reports filed" during the 2008-2015 period. The significant variables found in the univariate modeling process are shown in **Table 1**. During 2008-2015 there was no statistically significant change in the trend of the daily number of IPV reports. Police reports that occur on a day "t" are associated with reports filed the prior day with a coefficient (AR1:0.99), and with reports filed the prior week as shown by the coefficient for the seasonal period of 7 days introduced in the model (seasonal AR1:0.62). During Christmas Holidays the number of daily IPV police reports filed increased significantly (Christmas Holidays: 4.84), as it did on the weekend- and Friday and Monday-, with the greatest number of reports filed on Sunday (Sunday: 12.40). Therefore, IPV reports filed produced on day "t" respond to the following equation given by the model:

n_t = (Police reports $_t$ - (0.62* Reports $_{t-7}$ + 0.55*error $_{t-7}$ – 2.46*cos365 + 0.56*cos60 + 2.87*Monday – 0.92*Wednesday +1.04*Friday + 6.99*Saturday + 12.40* Sunday + 4.84 *Christmas Holidays + 22.3))

nt = 0.99*n $_{t-1}$ + 0.92*error $_{t-1}$ + 0.07* error $_{t-2}$ + 0.62* n $_{t-7}$ +0.55*error $_{t-7}$

The day of the week will include in the equation if day of t=name of the day of the week.

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Figure 1a shows the sequence graph of the predicted and real values of the variable "daily IPV police reports filed". The Pearson's correlation coefficient between both series is 0.575, significant at $p<0.001$ for the 2,922 data points of the time series from 2008 to 2015.

The model's goodness of fit, obtained by the simple autocorrelation function of the error, shows that the error structure in the different lags is random, indicating a good fit of the model.

Figure 2a shows the comparison between the prediction of the number of daily police reports in 2016, based on the model identified with the analysis of the data from 2008 to 2015, with the number of real reports registered in 2016. The Pearson correlation among the predicted and real values is 0.642, which is significant at $p<0.001$ for the 366 data points of the fit.

Temporal evolution and modeling of the variable "daily calls to 016 telephone IPV help line".

During 2008-2016 there were 143,863 calls to the 016 telephone IPV help line in the Autonomous Community of Madrid. **Figure 1b and 1c** show the temporal evolution of the variable "daily calls to 016 telephone IPV help line" during the 2008-2015 period. The time series of this variable behaves in a "V" fashion, indicating a change in the behavior trend of the time series. After adjusting to a quadratic function, it is significant at $p<0.001$ with a Snedecor F of 257.92 and an equation: "daily calls to 016 telephone IPV help line"$=7.6*10^{6}n_1^2-0.024n_1+55.7$. The determination of the minimum point of the parabola according to the previous equation indicates that this trend change occurs for n1=1564, which corresponds to April 12, 2012. This different temporal behavior justifies the analysis of the series in two periods.

During period 1, which includes the time between January 1st, 2008 and April 12th, 2012 ($n<1564$), there is a statistically significant decreasing trend in the number of daily calls to the

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016 telephone IPV help line. The average number of calls during this period was 44.5 calls per day. During period 2, which includes the time period from April 13th, 2012 to December 31st, 2015, the trend becomes increasing, with statistical significance. In this period, the average number of calls to 016 is 40.8 calls per day.

The coefficients of the significant variables after the univariate modeling of the variable "number of daily calls to 016 telephone IPV help line" in period 1 and period 2 are shown in **Table 2**. In both periods, calls that occur on day "t" are associated with the calls of the three prior days, in both period 1 (AR1: -0.88; AR2: 0.44; AR3:0.32) and period 2 (AR1: 1.62; AR2:-1.28; AR3:0.61) and with the calls from the prior week (P1: seasonal AR1: 0.94; P2: seasonal AR1: 0.93) (P1: seasonal AR1: 0.94; P2: seasonal AR1: 0.93). The number of 016 telephone IPV calls decreases during the days of the weekend and the day prior day, which is Friday. Saturday is a day with low telephone IPV demand in both periods (P1 Saturday:-7.56; P2 Saturday: -8.31), and Monday is the day that accounts for the greatest number of calls (P1 Monday: 9.55; P2 Monday: 7.64). The prediction equation for day "t" based on these coefficients is expressed for period 1 in the following way:

n_t= (Telephone 016 IPV $Calls_t$ – (- 0.94* $Calls_{t-7}$- 0.95* $error_{t-7}$ –0.01n1 + 9.55 * Monday + 2.97 *Tuesday+ +3.02*Friday –7.56* Saturday –5.57* Sunday – 3.90 *Easter Holidays + 51.06)

n_t= -0.88*n_{t-1} +0.44*n_{t-2}+0.32*n_{t-3}-0.99*$error_{t-1}$ + 0.08*$error_{t-3}$- 0.94*$n1_{t-7}$- 0,95*$error_{t-7}$

And for period 2:

n_t= (Telephone 016 IPV $Calls_t$ – (0.93* $Calls_{t-7}$+ 0.91* $error_{t-7}$ + 0.01n1 + 7.64* Monday + 1.98*Tuesday+ –8.31* Saturday –6.54* Sunday –5.21 *Easter Holidays + 4.39)

n_t= 1.62*n_{t-1} -1.28*n_{t-2} + 0.61*n_{t-3} +1.38*$error_{t-1}$ - 1.07*$error_{t-2}$ + 0.47*$error_{t-3}$ + 0.93*n_{t-7} + 0.91* $error_{t-7}$

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Figure 1b and 1c show the real and predicted values of the temporal evolution of the series of daily calls during the 2008-2015. The coefficient of Pearson's bivariate correlation among both series for period 1 is 0.601 ($p<0.001$) for the 1564 data points of the time series and 0.717 ($p<0.001$) for the 1358 data points of the series for period 2.

The simple autocorrelation function of the error shows that the error structure in the different lags is random, indicating a good fit of the model.

Finally, if the ARMA model obtained for the variable telephone 016 IPV calls during period 2 is used to predict behavior during the year 2016, the result shown in **Figure 2b** is obtained. Pearson's bivariate correlation coefficient for both series is 0.732 ($p<0.001$) for the total of 365 predicted days.

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Discussion

Main results

During the 2008-2016 period there were nearly 26 IPV police reports filed per day, and an average of 44 daily calls made to the 016 telephone IPV help line in the Community of Madrid. During the 2008-2015 period, there was no statistically significant change in the trend of the number of daily IPV police reports. The probability of filing an IPV report increased during the Christmas Holiday period. Sundays were the day with the greatest number of reports filed, followed by Saturday and Friday.

The daily number of calls to the 016 telephone IPV help line decreased significantly in a first period (January 2008/April 2012) to continue with an increasing trend in a second period (April 2012/December 2015). In both periods, during the Easter Holiday period the probability of making a call to 016 decreased. Saturday was the day with the lowest number of calls to the 016 telephone IPV help line, followed by Sunday and Friday.

The equations identified through ARMA models using data from 2008-2015, the univariate ARMA models predicted 64.2% of calls to the 016 telephone IPV help line and 73.2% of police reports filed during 2016 in the Community of Madrid.

Possible explanations

The absence of a significant trend in daily police reports during the period studied could be due to the stable prevalence of IPV over time and/or to the stability of factors related to greater probability of filing a report. According to the Macrosurvey on Gender Violence, the prevalence of women who have ever suffered IPV in Spain presents little variation during the 2011-2015 period (10.9% vs 13%) [22,23]. Recent studies show that fear and lack of confidence in the police processes is one of the reasons that women give for not filing a report [24]. Our

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results suggest the need to identify actions that avoid the recidivism of aggressors and increase women´s confidence in the police process.

The greatest number of calls to the 016 IPV telephone help line was registered in 2008, possibly associated with an increase in awareness raising activities for 016 in 2007. The decrease in the number of calls during the 2008-2012 period, followed by an increase in the following period, is also observed in other indicators related to IPV. During the 2008-2015 period, the number of femicides, and divorces- which pose risk for IPV [25]- reached their lowest levels in 2012 and in 2013, respectively [26]. Also, Spain's economic crisis, which began in 2008, could have made separations and divorces of couples more difficult, resulting in a decrease in the demand for 016 [27,28]. The implementation, during the second period, of awareness raising campaigns related to telephone 016 help line calls directed at vulnerable groups [29, 30] could be associated with the increase in the number of calls.

Our results could be explained using the Routine Activity Theory [11] framework. The likelihood of filing an IPV police report relates to periods characterized by a greater opportunity for conflict, which include non-work periods, with Sunday being the day of the week with the greatest probability of filing a police report, and the Christmas vacation period. That police reports are filed mostly in non-work periods could indicate that filing a police complaint is not a planned behavior, rather it occurs when violence surpasses a certain level of severity, at which point a woman looks for external protection [30-32]. Police resources and surveillance measures for women at high risk should increase on non-work days, and women should be provided opportunities to spend time outside the home during high risk periods, reducing opportunities for aggression.

Calls to the 016 IPV telephone help line behave inversely and diminish during non-work periods, weekends, and the Easter Holiday period, and increase on the days after these periods. This gives us important information about the use of resources. It could indicate that in cases of IPV the demand for information and telephone IPV assistance is a planned act that

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permits being delayed until a woman can find a space to call without the presence of the aggressor.

This study has some limitations. The observational longitudinal time series design uses aggregated data, which prevents individual level conclusions. Second, only one in three women exposed to IPV filed a police report [23], therefore women that file a police report are not representative of all women exposed to IPV. And finally, the analysis of the number of daily calls to the 016 telephone IPV help line could include repeat calls from a single woman.

Despite these limitations, the models identified in this study have a high predictive value for the behavior of reports and calls during the year 2016. Including time variables in protocols that estimate the risk of women under surveillance for experiencing IPV could increase their efficiency. Our results suggest the need for an increase in police resources on non-work days, given that the probability of reports on these days is greater. In the same way, the 016 telephone IPV help line should be especially active on work days. The ARIMA method is useful from the diagnostic and predictive points of view, however, including other external variables could increase the fit of the predictions and support the effort to address IPV.

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Conflicts of interest

None declared

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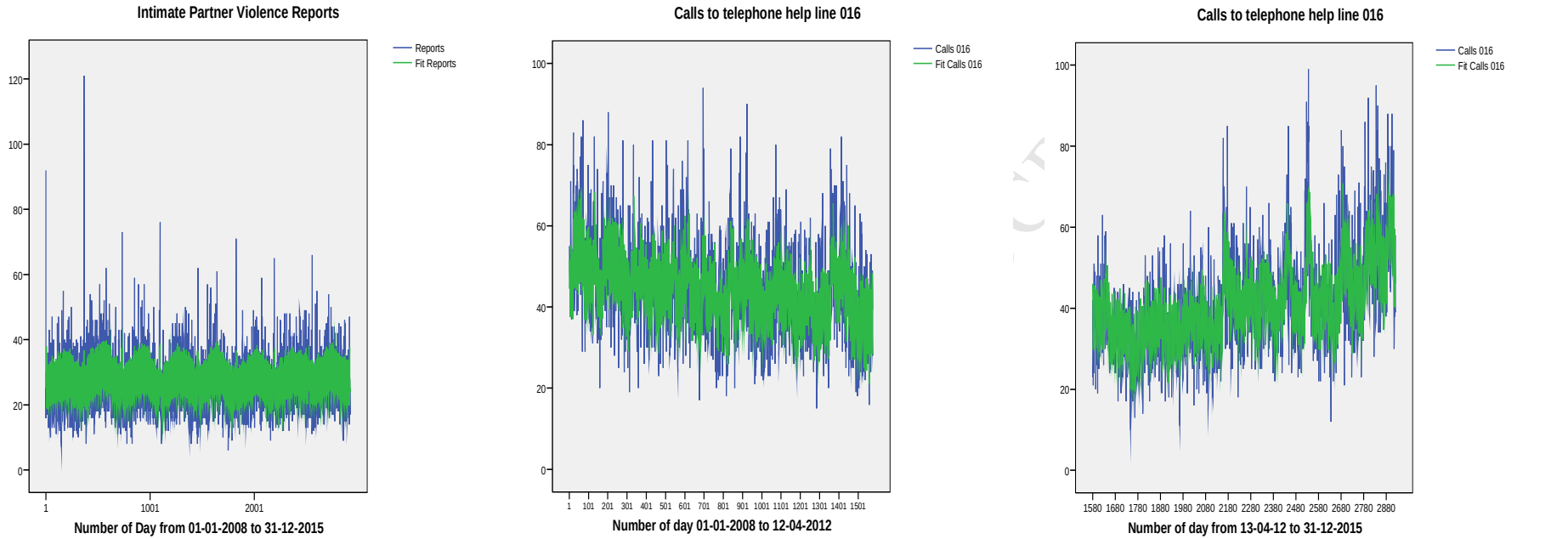

Figure 1.

a) Real values and estimated values of the number of daily police IPV reports from January 1st, 2008 to December 31st, 2015.
b) Real values and estimated values of the number of daily calls to the 016 telephone IPV help line from January 1st, 2008 to April 12th, 2012
c) Real values and estimated values of the number of daily calls to the 016 telephone IPV help line from April 13th, 2012 to December 31st, 2015. Autonomous Community of Madrid.

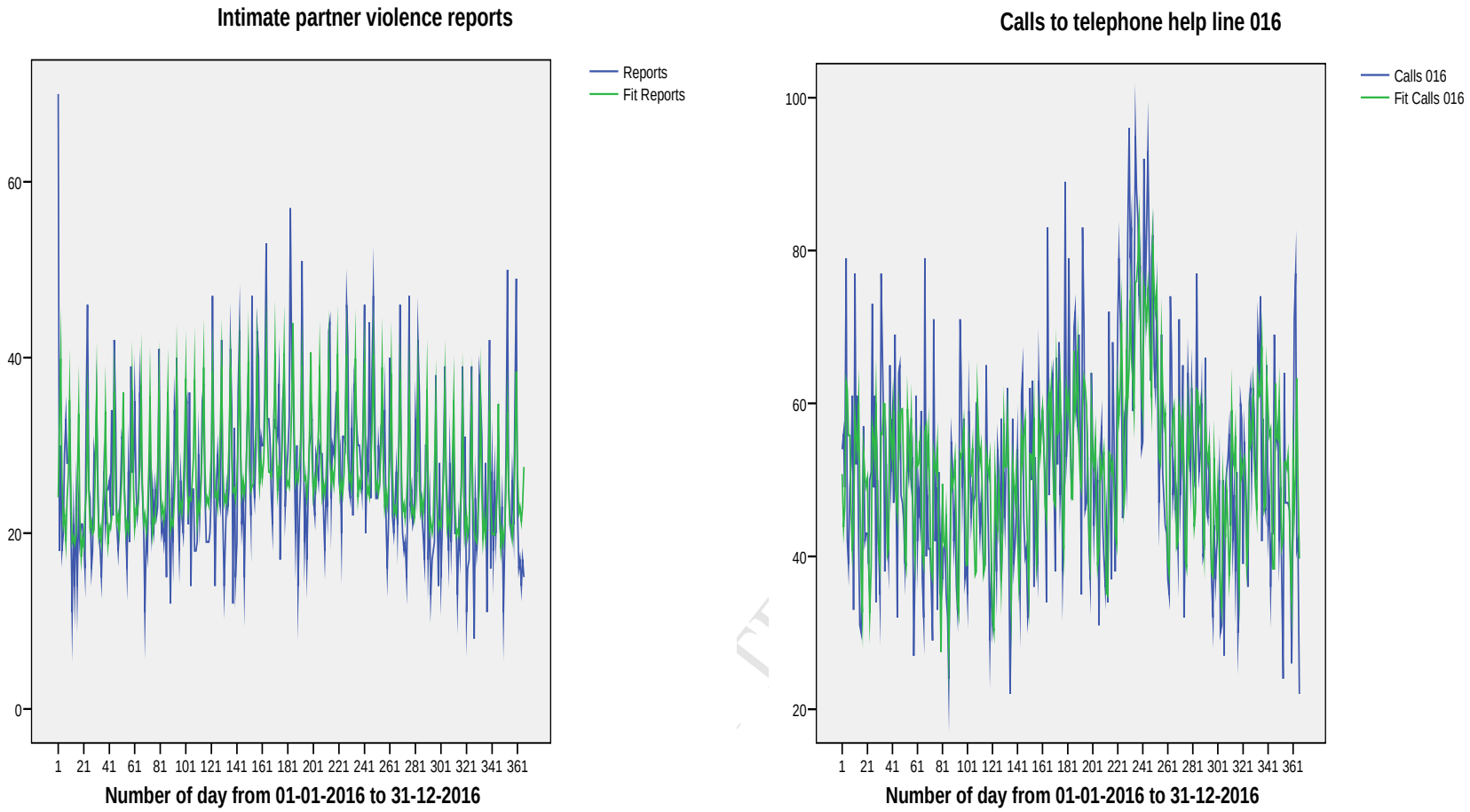

Figure 2:

a) Real value and prediction of the number of daily police reports of IPV
b) Real value and prediction of the number of daily calls to the 016 telephone IPV help line. Period from January 1st, 2016 to December 31st, 2016. Autonomous Community of Madrid.

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Variables	Estimates	Standard error	p
Nonseasonal lags			
AR1	0.993	0.007	<0.001
MA1	0.918	0.02	<0.001
MA2	0.065	0.019	0.001
Seasonal lags			
Seasonal AR1	0.623	0.135	<0.001
Seasonal MA1	0.551	0.143	<0.001
Regression coefficients			
sine 365	-2.457	0.294	<0.001
cosine 60	0.561	0.208	0.007
Monday	2.871	0.493	<0.001
Wednesday	-0.92	0.482	0.056
Friday	1.044	0.493	0.035
Saturday	6.994	0.505	<0.001
Sunday	12.395	0.505	<0.001
Christmas holidays	4.836	0.795	<0.001
Constant	22.3	0.42	<0.001

AR: autoregressive term; MA: moving average terms

Table 1. Univariate models of the variable "daily police reports of IPV filed in the Community of Madrid.2008-2015 Period.

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	Period 1: n1≤ 1564			Period 2: n1>1564		
Variables	Estimates	Standard error	p	Estimates	Standard error	p
Nonseasonal lags						
AR1	-0.880	0.077	<0.001	1.615	0.265	<0.001
AR2	0.441	0.077	<0.001	-1.284	0.351	<0.001
AR3	0.322	0	<0.001	0.610	0.157	<0.001
MA1	-0.999	0.083	<0.001	1.377	0.267	<0.001
MA2	0.080	0.087	0.355	-1.066	0.302	<0.001
MA3	0.080	0.013	<0.001	0.470	0.131	<0.001
Seasonal lags						
Seasonal AR1	-0.940	0.147	<0.001	0.931	0.081	<0.001
Seasonal MA1	-0.947	0.138	<0.001	0.909	0.093	<0.001
Regression coefficients						
n1	-0.008	0.001	<0.001	0.017	0.003	<0.001
Monday	9.549	0.726	<0.001	7.641	1.074	<0.001
Tuesday	2.966	0.718	<0.001	1.984	1.005	0.049
Friday	-3.017	0.719	<0.001	-1.587	1.007	0.115
Saturday	-7.557	0.726	<0.001	-8.308	1.074	<0.001
Sunday	-5.560	0.768	<0.001	-6.553	1.105	<0.001
Easter holidays	-3.903	2.202	0.076	-5.208	2.705	0.054
Constant	51.060	0.880	<0.001	4.391	6.939	0.527

AR: autoregressive term; MA: moving average terms

Table 2. Significant variables in the univariate models of the variable daily calls to the 016 telephone IPV help line in the Community of Madrid during Period 1 (January 1st, 2008 through April 12th, 2012) and during Period 2 (April 13th, 2012 through December 31st, 2015)

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Highlights

- It is unknown whether IPV responds to cycles that permit prediction of periods in which a woman could be at increased risk of suffering aggression.
- The time series analysis of the number of daily calls to the 016 help line, as well as the daily number of reports filed, could help to predict possible periods of risk.
- The findings of this work show that IPV reports increase during the Christmas Holidays and on weekends. Calls to the 016 help line decrease during the Easter Holidays and on non-work days and increase on Mondays.
- Our results suggest the need to increase police and judicial resources on non-work days. 016 help line assistance should be especially active on work days.
- Univariate ARIMA modeling used in this model could be useful regarding IPV from both a diagnostic and a prognostic point of view.

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