Original Article

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Modelling the Frequency of Depression using Holt-Winters Exponential Smoothing Method

Psychiatry/Mental Health Section

PAYAM AMINI[1], ALI GHALEIHA[2], ELAHEH ZAREAN[3], MAJID SADEGHIFAR[4], MOHAMMAD EBRAHIM GHAFFARI[5], ZAHRA TASLIMI[6], SAEID YAZDI-RAVANDI[7]

ABSTRACT

Introduction: Depression is a worldwide concern causing lots of adverse social consequences.

Aim: To assess the stochastic processes of depression frequency through statistical modelling.

Materials and Methods: The data contained the processes of depression frequency in Hamadan from April 2008 to March 2016. A total of 3252 patients, according to psychiatrist diagnosed based on DSM-IV criteria, were accounted. To model and forecast the depression incidence frequency, the time series analysis method, Holt-Winter exponential smoothing, was applied.

Results: After a considerable decrease in the last months of 2010 which was followed by an increase in early 2011, a constant series of frequencies happened until 2015. The first months of 2015 are the beginning of the increase in the development of depression.

Conclusion: Present findings demonstrated an increase in the incidence of depression during 2016-2018. The Holt-winter exponential smoothing method can be used as an appropriate statistical tool to analyse and forecast such data.

Keywords: Depression, Incidence, Time series, Stochastic process

INTRODUCTION

Mood disturbances are among the most predominant forms of thought of mental illness [1]. Depression is a significant contributor to the global burden of disease. It affects about 17–22% of the populace [2-5]. Additionally, it is associated with a considerable functional impairment, diminished quality of life, increased burden, both for patients and caregivers, as well just like with a higher risk of mortality [6-9].

The major depressive disorder is predicted to rank as the eleventh largest global contributor to disability-adjusted lifetime years in 2010 [5], a significant proportion of the individuals suffering from a major depressive episode develop a chronic condition. Approximately about 30% of depressed individuals and 47% of the patients who present in mental health care services have problems with serious varieties of depression [10-13]. The higher prevalence of depression among women is one of the most widely recorded findings in psychiatric epidemiology [14]. This has been found throughout the world through variety of analysis schemes and interview methods [15] Seasonal variations in mood and behaviour have been recognised since Hippocrates. Hospital admission rates for mania and depressions have been shown to have annual rhythms. Depression tends to be higher in spring and in autumn [16-18].

Statistical methods include a variety of tools which deal with lots of medical and clinical problems. Modelling and forecasting methods such as time series [19-21], multivariate analysis [22,23] and also machine learning methods [24] are used frequently in studying special types of response variables.

A research characteristic such as incidence of an event might be of consequence and one can not determine the future state with precision. However, forecasting methods can reduce consequent risks and costs caused by the uncertainty of conditions in future [25]. Studying the development of a characteristic over the time can be carried out using stochastic processes methods. Time series methods, as well as Markov chain approaches, are classes of stochastic processes in which a future state of an experiment will depend on this current and previous status of the statement [26].

Several conditions such as stationary and seasonality of the time series observation require special attention in determining the forecasting and modelling method [26]. Among several time series methods, Holt-Winters exponential smoothing method is widely used based on its flexibility [27]. This popular method was first utilised to forecast seasonal time series [25].

The present study aimed to apply the Holt-Winters Exponential Smoothing method (HWES) approach to model and forecast monthly depression incidence frequency in Hamadan Province, from 2008 to 2016.

MATERIALS AND METHODS

The present historic cohort investigation was done on depression patients in Farshchian Psychiatric Hospital, from April 2008 to April 2016. Patients according to DSM-IV criteria were hospitalised. Also, data collection based on a checklist was developed by the investigators. All the explorations were done by R.3.2.3. Software using the packages “forecast” and “series”. The statistical considerable level was assumed as 0.05.

STATISTICAL ANALYSIS

Holt-Winters Exponential Smoothing (HWES); a time series model is a stochastic procedure of observations during the time [28,29]. Analysing such data requires a model which considers the conditions such as seasonality and stationary of the consequent observations. After the model is fitted, parameter estimation and evaluating the goodness of fit can be carried out. Using the model, one can find out the status and procedure of the time series observation during the time [30].

An HWES is of exponential smoothing methods which the forecasting procedure performs with a special type of weighting the previous observations. This method assigns exponentially increasing weights as the previous observation get closer to the current state and the older observations are given relatively less weight [25]. Special types of exponential smoothing methods such as single, double and triple smoothing approaches can be determined according to presence/

absence of the trend and seasonality. In contrast to single and double smoothing methods, the HWES is applied when the series presents trend in addition to seasonality. A multiplicative or additive approach can be applied based on the multiplicative or additive seasonality nature of the time series observations, respectively.

A multiplicative HWES approach was used to consider multiplicative change in a seasonal development of time series. Seasonal trend is defined as the propensity of time-series data to display behaviour that reiterates itself every L periods. The multiplicative term refers to an amount that multiplies at beginning of next period. The following model includes "y_{t+h}" as the frequency of depression at "t+h" (the time of processes), "p" as period length, (a_t, b_t) as the permanent and trend of time series, as "*S*" the multiplicative seasonal factor and E_t as the random error component.

Forecasting the estimated response at any future time point can be carried out using the estimated coefficients from the model.

Formula 1

$$y_{t+h} = (a_t + hb_t)S_{t-p+1} + \epsilon_t$$

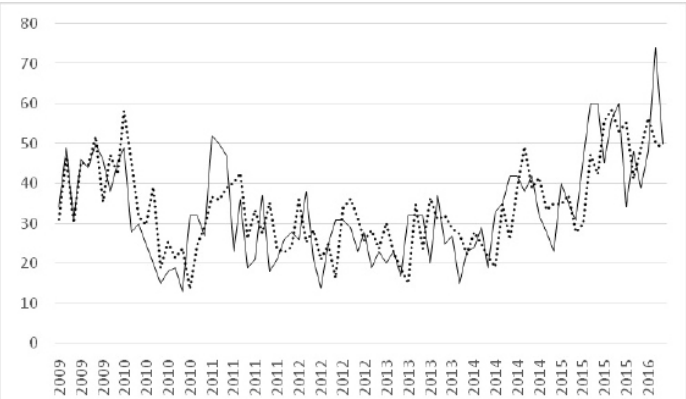
$$a_t = \alpha\left(\frac{y_t}{S_{t-p}}\right) + (1-\alpha)\,(a_{t-1} + b_{t-1})$$

$$b_t = \beta(a_t - a_{t-1}) + (1-\beta)b_{t-1}$$

$$S_t = \gamma\left(\frac{y_t}{a_t}\right) + (1-\gamma)\,S_{t-p}$$

RESULTS

The data contains the processes of depression frequency in Hamadan from April 2008 to March 2016. The [Table/Fig-1] shows the development of depression as well as fitted numbers estimated by the HWES method. Based on the observations, after a considerable decrease in the last months of 2010 which was followed by an increase in early 2011, a constant series of frequencies happened until 2015. The initial months of 2015 were the beginning of an increase in the development of depression which continued untill March 2016.



[Table/Fig-1]: The development of depression (Dashed line=estimated frequencies resulted by the HWES, line=Observed frequency of depression).

Holt-Winters exponential smoothing method with a multiplicative approach was applied. The model resulted is as follows:

Formula 2

The level, trend and seasonal components were estimated and shown in [Table/Fig-2] in which the period is 12 month (p=12). Thus, according to the nature of HWES modeling, forecasting the future status of depression is possible.

Hence, a 24 month prediction of depression was carried out using the estimated model. The frequencies as well as a 95% confidence interval are exposed in [Table/Fig-3].

$$y_{t+h} = (a_t + hb_t)S_{t-p+1} + \epsilon_t$$

$$a_t = 0.48\left(\frac{y_t}{S_{t-p}}\right) + 0.52\,(a_{t-1} + b_{t-1})$$

$$b_t = b_{t-1}$$

$$S_t = 0.27\left(\frac{y_t}{a_t}\right) + 0.73\,S_{t-p}$$

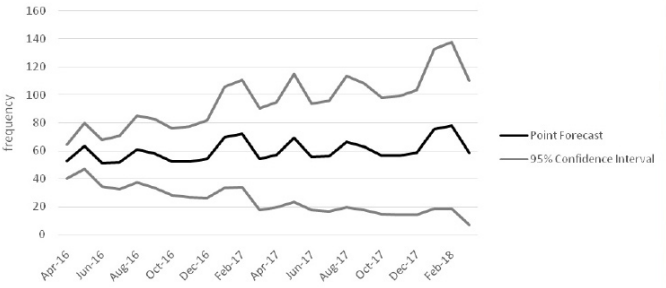
Moreover, [Table/Fig-4] demonstrates the development of depression in the next 24 months with 95% confidence interval.

Coefficients	Estimates
a	57.81
b	0.43
s1	0.89
s2	1.08
s3	0.86
s4	0.87
s5	1.02
s6	0.96
s7	0.85
s8	0.84
s9	0.87
s10	1.12
s11	1.15
s12	0.85

[Table/Fig-2]: The estimation of level, trend and seasonal components of time series HWES model.

Date	Point forecast	95% Confidence interval
April-2016	52.25	40.35 - 64.16
May-2016	63.38	47.07 -79.70
June-2016	51.01	34.40 - 67.62
July-2016	51.50	32.46 - 70.54
August-2016	61.04	37.24 - 84.84
September-2016	57.92	33.53 - 82.31
October-2016	51.91	28.07 - 75.76
November-2016	51.97	26.51 - 77.44
December-2016	53.98	26.20 - 81.76
January-2017	69.68	33.38 - 105.99
February-2017	72.07	33.69 - 110.45
March-2017	53.91	17.35 - 90.47
April-2017	56.91	19.14 - 94.68
May-2017	68.99	23.12 - 114.86
June-2017	55.49	17.16 - 93.82
July-2017	55.99	16.48 - 95.50
August-2017	66.33	19.38 - 113.28
September-2017	62.90	17.57 - 108.22
October-2017	56.34	14.67 - 98.01
November-2017	56.38	13.92 - 98.84
December-2017	58.52	13.84 - 103.21
January-2018	75.51	18.11 - 132.90
February-2018	78.05	18.42 - 137.67
March-2018	58.35	6.64 - 110.06

[Table/Fig-3]: A 24 months forecasting of depression using the HWES model.



[Table/Fig-4]: Forecasting 24 next months of depression frequency.

DISCUSSION

Current research aimed to apply the HWES approach to model and forecast monthly depression incidence frequency in Hamadan Province, from 2008 to 2016. The present findings illustrated that after a considerable decrease in the last months of 2010 which was followed by an increase in early 2011, a constant series of frequencies happened until 2015. The first months of 2015 are the beginning of an increase in the development of depression. Epidemiological researches on mood disorders in the overall population most frequently explain depressed feelings during winter, affecting women harder than men [31,32] and young women severer than older women [19]. Kraines SH, also illustrated an increase in the occurrence of depression [33]. On the other hand, Magnusson A et al., did not find any seasonal consequence on the occurrence of depression, though some contradictory effects reported for seasonal differences in frequency of admittances to hospital for effective incidents and for other forms of human behaviour could be due to methodological difference [34]. The psychobiological foundation underlying a connection between seasonality and depression is unclear.

Moore PJ et al., used exponential smoothing and Gaussian process regression to forecast depression among patients with bipolar disorder resulting in the same performance of the methods [35]. Dorea FC et al., performed three types of time series model including HWES to examine syndromic surveillance using veterinary laboratory information. They mentioned HWES as a recursive estimating method which can adapt the forecasts in reply to recent behaviour of the time series. However, they concluded that using several models caused more accurate and complete results [36]. However, a study demonstrated the out performance of other methods comparing to HWES. Zhang L et al., predicted the incidence of Hepatitis B in China and showed more accurate results by Nash nonlinear grey Bernoulli model in comparison to traditional methods such as HWES [37].

LIMITATION

The main limitation of the current research was the lack of access to the data before 2008.

CONCLUSION

The current study forecasted an increase in depression incidence during the next two years and health policy makers must apply proper tools to reduce its costs and negative consequences.

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PARTICULARS OF CONTRIBUTORS:
1. PhD Student of Biostatistics, Department of Epidemiology and Reproductive Health, Reproductive Epidemiology Research Center, Royan Institute for Reproductive Biomedicine, ACECR, Tehran, Iran.
2. Professor of Psychiatry, Behavioral Disorders and Substance Abuse Research Center, Hamadan University of Medical Sciences, Hamadan, Iran.
3. MSc. of Biostatistics, Modeling in Health Research Center, Department of Epidemiology and Biostatistics, School of Public Health, Shahrekord University of Medical Sciences, Shahrekord, Iran.
4. Assistant Professor of Statistics, Department of Statistics, Bu-Ali Sina University, Hamadan, Iran.
5. PhD Student of Biostatistics, Dental Sciences Research Center, Department of Biostatistics, School of Dentistry, Guilan University of Medical Sciences, Rasht, Iran.
6. PhD Student of Neuroscience, Neurophysiology Research Center and Students Research Center, Hamadan University of Medical Sciences, Hamadan, Iran.
7. PhD Student of Behavioral Sciences, Behavioral Disorders and Substance Abuse Research Center, Hamadan University of Medical Sciences, Hamadan, Iran; PhD Student of Behavioral Sciences, Young Researchers and Elite club, Rudehen Branch, Islamic Azad University, Rudehen, Iran.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Saeid Yazdi-Ravandi,
PhD Student of Behavioral Sciences, Behavioral Disorders and Substance Abuse Research Center, Hamadan University of Medical Sciences, Hamadan, Iran;
PhD Student of Behavioral Sciences, Young Researchers and Elite club, Rudehen Branch, Islamic Azad University, Rudehen, Iran.
E-mail: Saeid_Yazdiravandi@yahoo.com

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