NOWCASTING DAILY MORTALITY ON REAL-TIME FOR PUBLIC HEALTH SURVEILLANCE

Liliana Antunes[1,2,3], Marília Antunes[2], Baltazar Nunes[1,3]

[1]Department of Epidemiology, National Institute of Health Dr. Ricardo Jorge, Portugal
[2]Centre of Statistics and Applications of the University of Lisbon, Portugal
[3]FCT Research Unit of the Institute of Preventive Medicine of the University of Lisbon, Portugal

This work was financially supported by national funds from FCT: (2) projects PEst-OE/MAT/UI0006/2014 and PTDC/MAT/118335/2010

INTRODUCTION

Since the 2003 heat wave, the Department of Epidemiology of the National Institute of Health Dr. Ricardo Jorge (INSA) in Portugal has been developing a daily mortality monitoring system (VDM), which came fully operational in 2007. During health-related events, like influenza epidemics or occurrence of extreme weather events, such as heat waves or cold spells, the observed "all causes" mortality increases above the expected, presenting excess deaths of 20-40%. Previous studies have showed that 95% of the deaths that occurred in a specific day are registered up to 6 days after, with an average and median delay of 8 and 2 days respectively. Given that the detection of the impact of the events are dependent on these delays, it would be very important to have, on a daily basis, the estimate of the number of deaths occurred but not yet registered in the system.

OBJECTIVES

Development of a method to predict (nowcast) on a daily basis the number of deaths occured but not yet reported to the system;
Early detection of the impacts of health-related events using the proposed method.

METHODS

The VDM system receives electronically, on a daily basis, all deaths registered in the previous day at the Conservatories of the Civil Registry. The database comprised a total of 583,659 observations regarding data received between May 2007 and January 2014. The reporting delay was measured as time, in days, between occurrence of death and its notification to the VDM system.

The real number of deaths on day t using the registered number of deaths up to the current day $t+i$, $M_{t,i}$, is estimated by $\widehat{M}_{t,i} = \frac{n_{t,i}}{p_i}$, where $n_{t,i}$ is the number of deaths on day t registered up to day $t+i$ and p_i is the probability that a death occurred on day t is reported until day $t+i$, $i=1,\ldots$.

Logistic regression models, adjusted for overdispersion, were used to estimate each p_i using as covariates the binary variables indicating the weekday of death, the occurrence of public holiday on the day of death, on the day of nowcast and up to four days before death.

Performance of the developed method was evaluated in two phases:

Phase 1 adjusting the model to mortality using data from 2008 to 2011 and nowcasting mortality for 2012;

Phase 2 adjusting the model to mortality using data from 2008 to 2012 and nowcasting mortality for 2013;

using the measures: median percentual relative error of predictions, sensitivity, positive predictive value and timeliness in the detection of excess mortality, that was measured as time saved, in days, using the developed method.

RESULTS

DESCRIPTIVE MEASURES OF REPORTING DELAYS

The minimum delay is 1 day which corresponds to deaths that are registered on the day of death and reported to the VDM system the next day.

Table 1 - Descriptive measures of reporting delays

MININUM	MAXIMUM	MEAN	STD. DEVIATION
1	2543	6.14	55.48

PERCENTILES

50	75	80	90	95	99
2	3	4	5	6	40

It takes 2 days to get 50% of the mortality information of a certain day but, to get 90% of the deaths recorded, it takes 5 days (table 1). The mean delay is much greater than the median delay which indicates positive asymetry in reporting delay distribution.

MODELING REPORTING DELAYS

Dispersion parameters were much greater than 1, which may be due to variability of the reporting delay among regions, or other non observed factors.

The occurrence of a public holiday at day of death decreases the probability that a death is reported until 4 days. After 5 days this factor is no longer significant. The occurrence of a public holiday until 4 days before day of nowcast also decreases the probability that a death is reported within 1 to 5 days. The occurrence of a public holiday at nowcast day only explains the 1 day reporting delay, increasing the probability that a death is registered on the same day and reported the next day. On prediction day $t+1$, the effect of working days, is the most relevant effect, mainly at friday. From Monday to Saturday, having as reference Sunday, increases the probability that a death is reported within 1 day. For bigger reporting delays, the effect of these factors is attenuated, with exeception of Saturday and Friday, which decreases the probability that a death is reported within 2 and 3 days, respectively.

IMPLEMETATION

Applying the calibrated method to the year of 2012 and 2013, various estimates were discrepant from the observed mortality. Those estimates corresponded to nowcasts made without information or with irregular data transmission. Excluding those estimates, nowcasts discrepant from observed mortality are rare (figure 1 and 2).

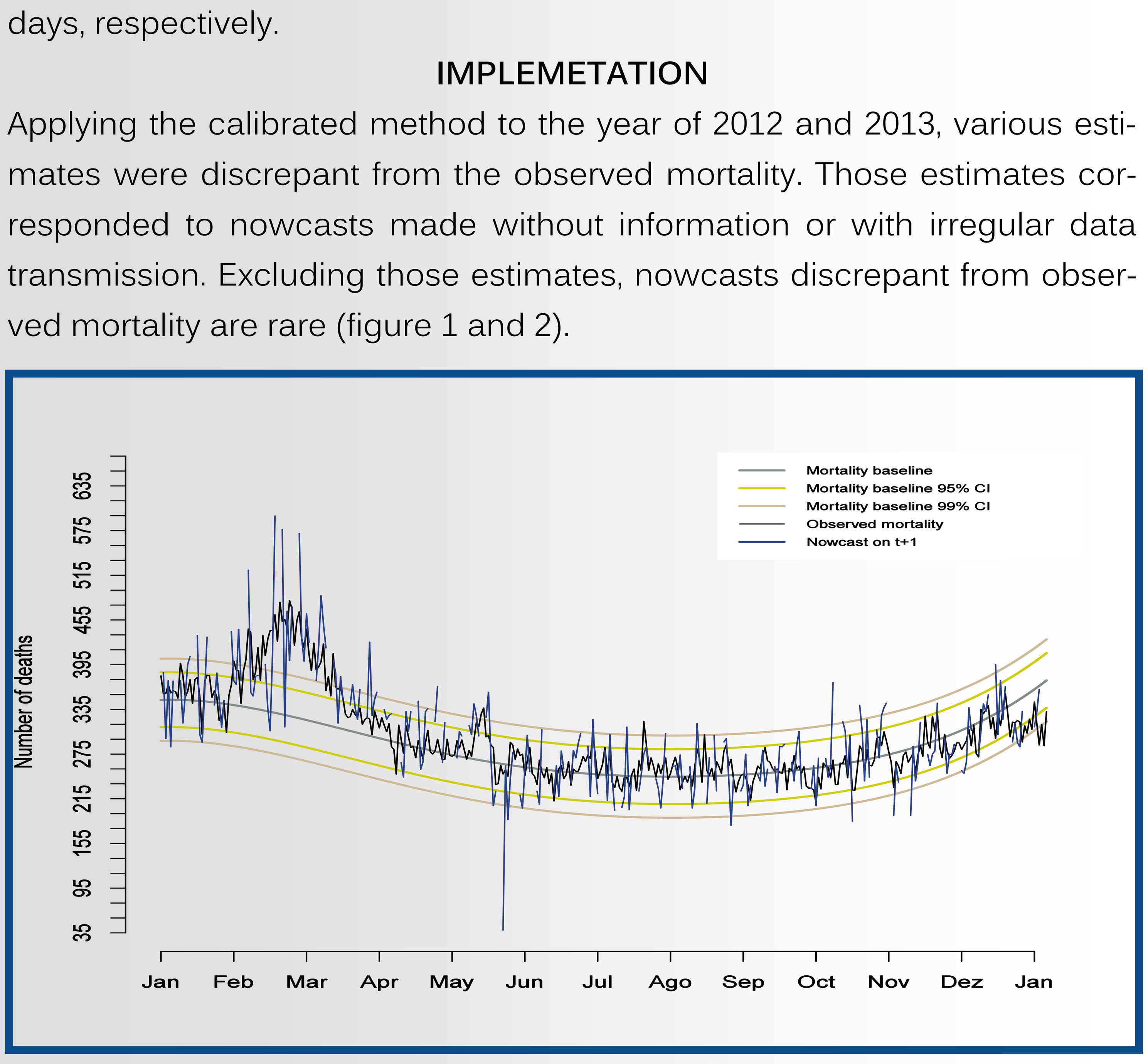

Figure 1 - Nowcasts for 2012 at moment $t+1$ (excluding predictions made without information)

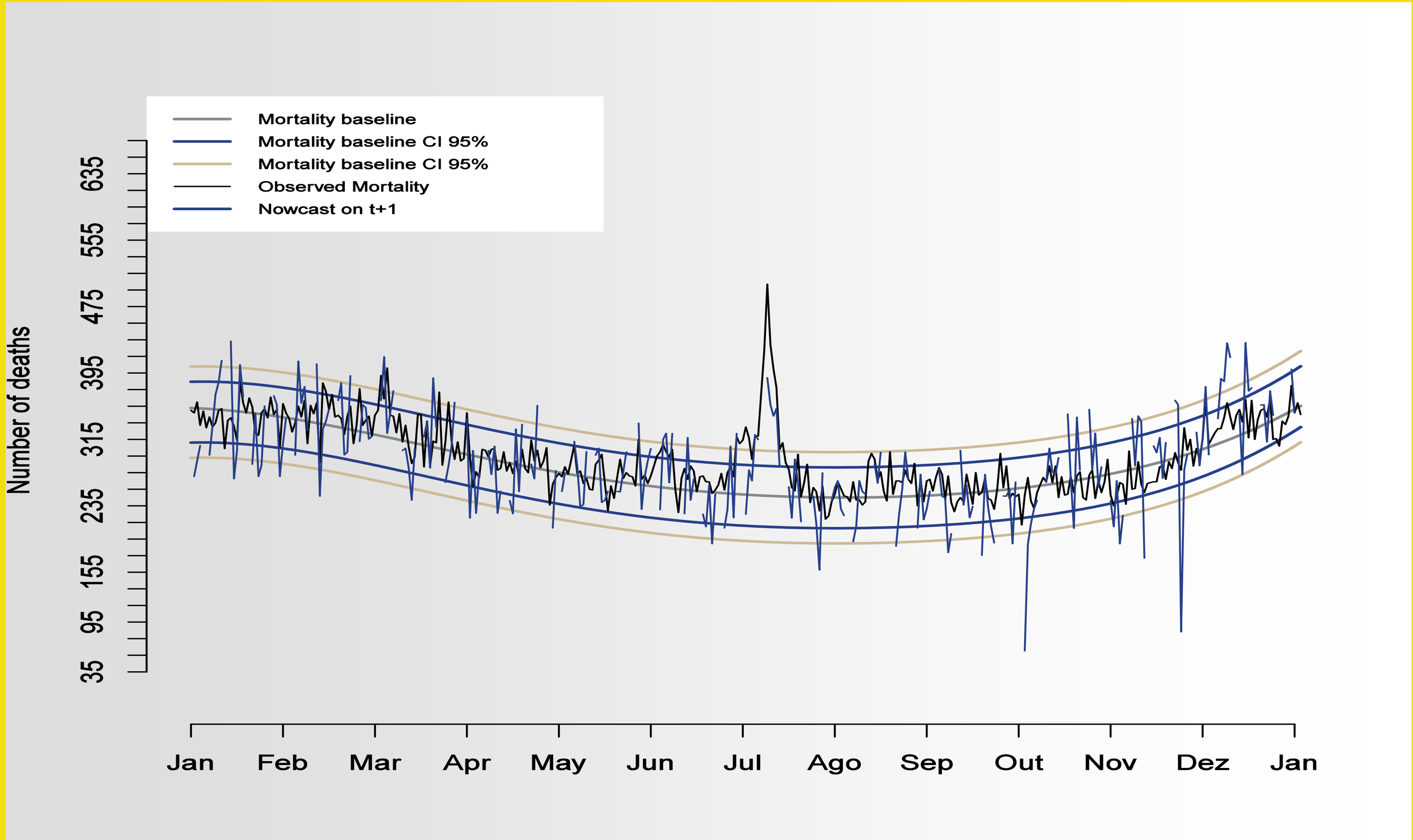

Figure 1 - Nowcasts for 2013 at moment $t+1$ (excluding predictions made without information)

The relative median error of nowcasts were always ≤ 10% for all moments of prediction (e.g. $t+i$, i=1,...,5). The first detection of excess mortality is more likely (sensitivity>75%) at $t+2$ with 2 or 1 day of information. The more reliable nowcasts of excess mortality (positive predictive value>80%) are at $t+2$ with 2 days with information and at $t+3$ with 3 and 2 days of information.

During influenza epidemics in 2012, the first day of excess mortality was observed for February 4th, with 386 deaths. The VDM system detected excess mortality for this day 10 days later, with 377 deaths reported. Applying the developed method, the first day of excess mortality was detected 3 days later, with 410 deaths estimated (r.e.%=5.85). During the heat wave in 2013, the first day of excess mortality was observed for June 28th with 318 deaths. The VDM system detected excess mortatlity for this day 5 days later, with 288 deaths reported. Applying the developed method, the first day of excess mortality was detected the next day, with 322 deaths estimated (r.e.%=1.26).

The developed method allowed the early detection of the impact of the two health-related events in study, reducing the timeliness of the system (saving 2 and 5 days until the impact detection).

DISCUSSION

The main limitation of this estimator is not allowing predictions to be made without information (e.g. $n_{t,i}$=0) or when data transmission is irregular which does not allow daily estimates. The developed method was able to produce nowcasts with a median relative error ≤ 10% when it had access to at least one day of information. The most frequent scenario during a year is the production of estimates with at least one day with information for all moments of prediction. This method also allowed the early detection of excess mortality during the two health-related events in study.

FUTURE DEVELOPMENTS

Development of an alternative method for the days without information using the observed and estimated mortality (auto-regressive models). Nowcast mortality per region, age group and sex in order to reduce the heterogeneity in data. Implementation of the developed method to the VDM system.

BIBLIOGRAPHY

Hosmer D, Lemeshow S, Sturdivant R. Applied Logistic Regression, Third Edition, Wiley, 2013.
Turkman M, Silva G. Modelos lineares Generalizados - da teoria à prática, Lisboa, 2000.
Lombardo J S, Buckeridge D L. Disease Surveillance: APublic Health Informatics Approach, Wiley, 2007.
R Development Core Team. R: A language and enviroment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, 2009. ISBN 3-900051-07-0. Available from: http://www.R-project.org
Centers for Disease Control and Prevention. Updated guidelines for evaluating public health surveillance systems: recommendations from the guidelines working group. MMWR,2001; 18(15):pii=20451. Available from: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=20451
Nogueira P J, Machado A, Rodrigues E, Nunes B, Sousa L, Jacinto M, Ferreira A, Falcão J M, Ferrinho P. The new automated daily mortality surveillance system in Portugal. Available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=19529
EuroMOMO. European monitoring excess mortality for public health action [Internet]. Copenhagen: EuroMOMO; [14 JAN 2014]. Available from: http://www.euromomo.eu/index.html.
Nunes B, Natario I, Carvalho L. flubase}: Baseline of mortality free of influenza epidemics. 2009: R package version 1.0.
Wagner A P, McKenzie E, Robertson C, McMenamin J, Reynolds A, Murdoch H. Automated mortality monitoring in Scotland from 2009. Euro Surveill. 2013; 18(15):pii=20451. Available from: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=20451
Donker T, Boven M, Ballegooijen M W, Klooster M T, Wielders C C, Wallinga J.Nowcasting pandemic influenza A/H1N1 2009 hospitalizations in the Netherlands},J Epidemiol Community Health 2012;66:866e868. doi:10.1136/jech-2011-200962.