ISSN 1808-057X
DOI: 10.1590/1808-057x20221556.en

ORIGINAL ARTICLE

Mortality differentials in beneficiaries of the National Institute of Social Security of Brazil in 2015*

Marcos Roberto Gonzaga[1]
https://orcid.org/0000-0002-6088-3453
Email: marcos.gonzaga@ufrn.br

Everton Emanuel Campos Lima[2]
https://orcid.org/0000-0001-6275-9854
Email: evertone@unicamp.br

Bernardo Lanza Queiroz[3]
https://orcid.org/0000-0002-2890-1025
Email: lanza@cedeplar.ufmg.br

Graziela Ansiliero[4]
https://orcid.org/0000-0003-0184-4232
Email: graziela.ansiliero@ipea.gov.br

Flávio Henrique Miranda de Araújo Freire[1]
https://orcid.org/0000-0002-7416-9947
Email: flavio.freire@ufrn.br

[1] Universidade Federal do Rio Grande do Norte, Centro de Ciências Exatas e da Terra, Departamento de Demografia e Ciências Atuariais, Natal, RN, Brazil
[2] Universidade Estadual de Campinas, Instituto de Filosofia e Ciências Humanas, Departamento de Demografia, Campinas, SP, Brazil
[3] Universidade Federal de Minas Gerais, Faculdade de Ciências Econômicas, Departamento de Demografia, Belo Horizonte, MG, Brazil
[4] Instituto de Pesquisa Econômica Aplicada, Departamento de Estudos e Políticas Sociais, Brasília, DF, Brazil

Received on 10.19.2021 – Desk acceptance on 10.29.2021 – 2nd version approved on 03.31.2022
Editor-in-Chief: Fábio Frezatti
Associate Editor: Luís Eduardo Afonso

ABSTRACT

This paper aims to estimate mortality and analyze its differentials by sex, age, and groups of beneficiaries of the Brazilian National Institute of Social Security (INSS) in 2015 and make comparisons with official estimates for the general population, assessing the distribution of deaths by age and of survival after 65 years old. The results reinforce the need for more studies on mortality differentials between beneficiary groups and for continuous investment to improve the quality of the data. Population aging, among other aspects, puts pressure on the Brazilian social security system, and there is real concern about its sustainability. Life tables by population subgroups are fundamental as a tool for analyzing the financial and actuarial equilibrium of the system. The results contribute to the debate on the mortality differentials between groups of beneficiaries of the general pension and social security system in Brazil. The death and population data derive from the administrative records of the INSS. We used Gompertz and Van de Maen models and Topals regression to estimate the mortality rates above the age of 65, according to the following beneficiary groups: retirees through age of the General Social Security Regime (*Regime Geral de Previdência Social* – RGPS) – disaggregated by urban and rural clienteles; retirees through period of contribution; and beneficiaries of welfare support for low income seniors. Among the main results, it was possible to minimize the crossover in the mortality rates of older ages, when the mortality of the less advantaged population becomes lower than the mortality of populations with better social indicators. Cross-checking the results with the official mortality estimates, it was observed that life expectancies for the 65 and 75 year old age groups of the target population of this study are higher than in the general population.

Keywords: mortality, life table, data quality, INSS, RGPS.

Correspondence address

Marcos Roberto Gonzaga
Universidade Federal do Rio Grande do Norte, Centro de Ciências Exatas e da Terra, Departamento de Demografia e Ciências Atuariais
Av. Senador Salgado Filho, s/n – Campus Universitário – 1º Andar, Sala 19 – CEP 59078-970
Lagoa Nova – Natal – RN – Brazil

*The authors thank the anonymous reviewers and guest editor for their useful comments and suggestions and help to improve the quality of the manuscript and analyses. In addition, the authors are grateful to the Economic Commission for Latin America and the Caribbean and the Institute of Applied Economic Research for the funding for this research project. Marcos R. Gonzaga, Everton E. C. de Lima, Bernardo L. Queiroz, and Flávio H. M. de A. Freire all receive productivity scholarships from CNPq (case numbers 307467/2018-0, 308219/2019-8, 312609/2018-3, and 303341/2028-1).

1. INTRODUCTION

Since the first half of the 20th century, mortality rates have fallen in the whole of Brazil, starting first with infant mortality and then being seen in adult and older ages. Together with this mortality transition, the country has also experienced a continuous decline in fertility rates, so that the proportion of the population aged under 15 has decreased with a proportional increase in the adult and elderly population.

As a consequence of that scenario, the old-age dependency ratio will increased substantially until reaching 42.6 in Brazil as a whole, according to a review of population projections for the country and federative units up to 2060 conducted by the Brazilian Institute of Geography and Statistics (IBGE). This means that for every 100 working age Brazilians (considering the interval between 15 and 64 years old), there will be 42.6 seniors aged 65 or more (IBGE, 2018).

In the General Social Security Regime (*Regime Geral de Previdência Social* – RGPS) in effect in Brazil, the simple distribution system is adopted, in which the active population (the taxpayers) contributes to the beneficiary population of the system. In this context, given population aging, with the increase in the old-age dependency ratio – considering that in the pension plans or regimes the beneficiary's death does not necessarily mean the benefit is closed, as it may mark the beginning of a dependents' pension – it is of fundamental importance that the life tables are estimated as accurately as possible, to help in achieving financial and actuarial equilibrium. However, robust estimates of mortality rates in Brazil are a challenge for demographers and actuaries for various reasons, especially at older ages. Even in populations with good death and population records, the data at older ages suffer disruptions due to the low number of events and/or some limitation in the information on age or the recording of death (Black et al., 2017; Feehan, 2018). In populations with worse quality data, there are also questions related to declared age, inconsistent birth records, digit preference, or overstatement when reporting age, both in death and in population data, most commonly at older ages, which produce various impacts on the observed rates (Gomes & Turra, 2009; Nepomuceno & Turra, 2020; Queiroz et al., 2020). Another problem is the lack of records or late recording of death, with greater occurrence of the latter in particular. Although there are demographic methods that enable an evaluation of death cover at young and adult ages, these methods are not indicated for evaluating death cover at older ages (Hill et al., 2009). In the records of the National Institute of Social Security (INSS), these inconsistencies in age are most probably related to delays in recording dates of birth, especially in the case of support benefits or age-based retirement in rural areas.

In addition to the problem of mortality data quality, there is a debate about hypotheses of selectivity and biological limits of mortality in human populations that in different ways would impact the behavior of mortality rates at older ages (Barbi et al., 2018; Beard, 1959; Feehan, 2018; Gavrilova & Gavrilov, 2014; Horiuchi & Wilmoth, 1998; Sacher, 1966; Weitz & Fraser, 2001). The selective mortality hypothesis, for example, bets on a deceleration of rates at older ages, related to a selective and resilient group of individuals (Horiuchi & Wilmoth, 1998). In that context of debates and hypotheses for the behavior of risk of death at older ages, the demographic and actuarial literature suggests different (parametric or non-parametric) models to explain that behavior (Pascarius & Canudas-Romo, 2017). In addition, the choice of an adequate model depends on the assumed hypotheses, whether in relation to the quality of the data or to the impacts produced by selectivity.

In light of that, this article estimated mortality rates by simple ages in different subgroups of INSS beneficiaries in 2015: retirees through age of the RGPS – disaggregated by urban and rural clienteles; retirees through period of contribution (RPC), also of the RGPS; and beneficiaries of welfare support for low income seniors [continuous provision benefit (CPB)], welfare benefits operationalized by the INSS. Various models were tested for estimating, grading, and extrapolating the mortality rates per insured group in the age interval from 65 to 110 years old. Initially, we employed some techniques for evaluating the quality of age declarations in death and population records. Next, we compared the results obtained through the different models with the mortality curve estimated by the IBGE for the total Brazilian population and extrapolated up to the age of 110 (Castro, 2018). Finally, we estimated some synthetic mortality measures to evaluate the results.

1.1 Data

The death and population data used were obtained from the administrative records of the INSS referring to 2015. The data are available for three categories of INSS beneficiaries: (i) retirees through age in the urban clientele

(RTA-URB); (ii) retirees through age in the rural clientele (RTA-RUR); (iii) RPC; and (iv) beneficiaries of welfare support for low income seniors (CPB).

In addition to that information, we used mortality tables from different countries, from the Human Mortality Database (HMD) (University of California & Max Planck Institute for Demographic Research, 2021), to define a standard for the shape of the mortality curve at older ages. This standard would be used in applying some of the proposed methods. Finally, we used the life tables estimated by the IBGE, organized by age and sex – referring to the Brazilian population – for a series of analyses comparing with the estimates produced in the study.

1.2 Evaluation of the Quality of the Ages in the Records

Two key questions for the mortality estimates are the quality of the death records (collection and correspondence between the date of the record and date of the event) and the quality of the birth records (accuracy of the date of birth). The administrative records of the INSS naturally tend to be more consistent than the census and sampling data, as they depend little (or not at all) on self-reported information and a lot on other frequently improved and monitored official records. Nonetheless, there are known to be persistent – though increasingly less important – problems in these official data sources.

With regard to deaths, an indication of this is the continuous effort of the INSS to improve recording, going beyond improving its interaction with civil registry offices. Over the decades it has implemented various administrative mechanisms and procedures focused on identifying signs of unreported deaths, such as carrying out social security censuses or aperiodic summonses, with the obligatory direct or indirect participation of the insured beneficiary; monitoring of inactive bank accounts, without signs of movements for established periods; and, more recently, annual proof of life, primarily carried out via the banking system, which may have contributed to improving death records in general.

Based on the analysis of ceased INSS benefits, in this study we chose to use the sum of official deaths (benefits ceased through death with the recording of a specific date) and suspected deaths (benefits suspended two years ago or more due to suspected death, using the date of suspension as an approximation for the date of death). The strategy tends to improve the quantification of deaths, but, as the date of suspension of the benefit due to suspected death tends not to coincide with the date on which the death possibly occurred, there is still some loss of precision in the estimate of the age at which the beneficiary effectively died, with an obvious risk of overestimation.

Given the current system of monitoring by the INSS, which tends to increasingly approximate the death of its official or inferred record, it is believed that the gain in capturing events exceeds possible imprecisions in the timeliness of their record. Another reason for this methodological choice, of a corrective nature, derives from the fact that, notwithstanding suspected deaths representing a reduced percentage of total official deaths (6% in 2015), these occurrences are not homogeneously distributed between the beneficiary groups considered in this study – the phenomenon is practically inexistent in RTA-URB and in RPC, being concentrated in RTA-RUR and CPB

With relation to declarations of death, the problems can result in lower mortality rates than the actual or expected ones for the population. Even in situations in which the population and death data derive from the same source, we can find inaccuracies in the age recorded. The ages of elderly people, as registered in the censuses or in the administrative records (and of the deaths of older people), are more subject to age misreporting, with even digit preference or age overstatement. The typical effect on the mortality rates calculated at older ages is lower rates than the actual ones (Preston et al., 1999).

Thus, before proceeding to estimate the mortality rates, it is important to analyze the quality of the declared age information. There is a vast body of literature indicating that age misreporting, especially at older ages, are common and affect the production of mortality curves, even when we apply different methods and models (Coale & Kisker, 1990; Condran et al., 1991; Gomes & Turra, 2009; Kannisto, 1988; Nepomuceno & Turra, 2020). To measure the quality of the sources of data relating to age, for the population and for deaths, we calculated indicators that refer to digit preference, as well as measures that indicate age overstatement.

To evaluate the error due to digit preference, we applied the index proposed by Coale and Li (1991). The metric is calculated based on a moving average of five ages, with one of two ages as a reference standard, and then the ratios between the two measures are compared. This is an index of the deviation in the observed number of the population, at each age, based on a smooth sequence (moving average), taking the proportion of the number of people at each age for the moving average of two ages. The mean index in ages divisible by 10, from 40 to

90, should be around 1, indicating the absence of digit preference; values closer to 5 indicate a high preference. The results of applying this method for evaluating the age declaration in each group of beneficiaries are presented in Table 1 of the Appendix.

To evaluate the error due to the age overstatement of deaths of older people, we applied the index proposed by Jdanov et al. (2008). The probability of overstatement becomes more pronounced with increased age, and this leads to implausible distributions of deaths and populations in specific ages (Kannisto, 1999). Jdanov et al. (2008) suggest, as a criterion for identifying possible overstatements in the age reported, the ratio between deaths at older ages. If there is a tendency for overstatement, the number of deaths at older ages (specific age group, numerator of the ratio) will be high in relation to the total deaths in the preceding age group (denominator).

The considerably higher proportions than those of an adopted gold standard are considered as evidence of overstatement and, based on previous discussion in the literature, we consider Sweden as a reference. The method was applied in the INSS data over time and the comparison is made using the ratio of the indicator of the population of beneficiaries with the data obtained in the standard population (Sweden), according to the criteria suggested by the authors (0.0-5.9: good quality; 6.0-9.9: acceptable quality; 10.0-14.9: conditionally acceptable quality; and 15.0 and more: weak quality). The results of applying this method in each beneficiary group are presented in Table 2 of the Appendix.

In general, the results indicate the good quality of the data for both sexes and each one of the beneficiary groups. The data on the CPB welfare support beneficiaries appear to have the worst quality in relation to the other groups, but it continues on a good quality scale. In the RGPS, the urban population – of the RTA-URB and, predominantly, of the RPC – appears to have better quality death records, even in the comparison with the group of rural retirees through age (RTA-RUR).

2. METHODS FOR ESTIMATING MORTALITY AT OLDER AGES

We chose some methods proposed by the demographic/actuarial literature developed with the aim of representing mortality behavior at older ages. As suggested by Grupo do Foz (2021), the mortality by sex and age methods or models can be divided into three major groups: purely mathematical models, relational models, and synthetic models. In the latter group, the models are more applicable for describing the variety of experiences at different historically observed mortality levels, which is not the case of this study.

The purely mathematical models are based on analytical curves that describe the risks of deaths over the life cycle or at least in some part of the age interval, such as in infancy or in old age. These models, also called "mortality laws," are based on expressions that describe mortality characteristics in terms of age and of a limited set of parameters to be estimated (Tabeau, 2001). These expressions provide the estimation of mortality curves smoothed by age, especially at older ages, and they enable extrapolations of these in cases in which the information is incomplete (Bravo, 2007). In this study, we chose the Gompertz (1825) and Van der Maen (1943) laws as they are more appropriate for describing mortality behavior at older ages.

Gompertz's mortality law has a long history in actuarial studies and is basically applied to describe adult mortality. According to this law, the mortality strength $\mu(x)$ of a human survival table at each age x follows the following mathematical expression:

$$\mu_x = Be^{cx} \quad \boxed{1}$$

in which x is the age and B and c are coefficients to be estimated.

The Gompertz curve does not capture infant and child mortality, as it was conceived with the aim of describing it beyond 30 or 40 years of age, for actuarial purposes. Its most common application is for "ending" a life table beyond the ages for which there are observed data or in cases in which the quality of these compromises its use. However, there are indications that it exaggerates mortality levels above 85 years of age.

From the old family of non-polynomial functions, Van der Maen's (1943) mortality law discusses the grading of mortality at adult and older ages through a linear composition of mortality rate values obtained from population data:

$$\mu_x = A + B_x + Cx^2 + {}^{I}\!/_{(N-x)} \quad \boxed{2}$$

in which x is the age and A, B, and C are coefficients to be estimated.

The first part of equation 2 is similar to the quadratic model of Coale and Kisker (1990), with the addition of the component $1/(N-x)$. The Mortality Law package developed by Pascariu and Canudas-Romo (2020) adjusts different mortality laws to the data, where the input is the mortality rates by simple ages. The package includes more than 27 parametric models (or mortality laws) and the law argument specifies the model to be used. Depending on the complexity of the model, various optimization strategies are available for implementation.

For both mortality laws, the parameters of the model are estimated based on the death and population data or on the observed mortality rates. Once the parameters are estimated, it is possible to extrapolate the mortality rates up to very older ages, notably above 100 years old. Thus, to estimate appropriate parameters, we suggest defining, a priori, the observed data interval that produces the best model fit. In this case, it is important not to use ages for which it is suspected that the data quality is causing some distortion in the behavior of the rates. To choose the age interval that produces the best fit, we used the root mean square error (RMSE):

$$RMSE = \sqrt{\frac{1}{n}\sum_{i-1}^{n}\left(y_i - \hat{y}_i\right)^2} \quad (3)$$

in which y_i and $\hat{y}_i$ are, respectively, the observed and estimated rates at age i and n is the number of ages used in the model.

The RMSE is widely used as a measure of the quality of fit of a model. The lower the RMSE is, the better the fit. Thus, the RMSE was calculated in an automated way for all the possible age intervals between 65 and 100, always maintaining the minimum number of 15 ages to adjust the model. The results of the selection of ages for each beneficiary group can be found in Table 3 in the Appendix. This measure was applied to the estimates of the mortality laws distinguished by model type and sex.

In the second group are the relational models that are based on an empirical life table, but transform one of its functions (Grupo de Foz, 2021). In this group of models we can include some recent ones that relate a typical mortality pattern, such as the logarithm of mortality rates or death probabilities observed in the population or population subgroup of interest, to estimate and smooth the entire mortality curve by sex and simple ages via the application of a statistical regression model (De Beer, 2012; Gonzaga & Schmertmann, 2016). In this article, we applied the relational model proposed by Gonzaga and Schmertmann (2016), which enables the estimation and smoothing of age-specific mortality rates for any population or population subgroup of interest, even in low exposure population subgroups.

The proposed method, called the Topals regression (Gonzaga & Schmertmann, 2016), boils down to a Poisson regression model based on Beer's (2012) original proposal for smoothing and projecting death probabilities by age. Gonzaga and Schmertmann (2016) proposed adopting the method, which estimates the logarithm of mortality rates by sex and age based on the following relational model:

$$\lambda(\alpha)_{101\times1} = \lambda^*_{101\times1} + B_{101\times7}\,\alpha_{101\times7} \quad (4)$$

in which λ is a vector of the logarithm of the mortality rates of a population of interest, λ* is a vector of the logarithm of the standard mortality rates, B is a matrix of constants in which each column is a B-spline linear function (de Boor, 2001; Eilers & Marx, 1996), and $\boldsymbol{\alpha}$ is a vector of parameters to be estimated, representing deviations of the mortality curve to be estimated in relation to the standard curve. The subscripts in this equation concern the number of lines and columns, in that order, of each vector/matrix.

In relational model 4, the B-spline linear function (B) is responsible for smoothing the logarithm of mortality rates between the nodal points, given the α parameters estimated based on the standard mortality function. Thus, for any set of mortality rates and risk-exposed population $\{D_x, N_x\}_{x=0,1,\ldots 99}$, it is assumed that the deaths are random variables that follow a Poisson distribution, so that the logarithm of its likelihood function is defined as:

$$logL(\alpha) = \sum_x\left[D_x\lambda_x(\alpha) - N_x e^{\lambda_x(\alpha)}\right] - \sum_{k=0}^{5}\left(\alpha_{k+1} - \alpha_x\right)^2 \quad (5)$$

in which D_x and N_x represent the number of deaths and exposed population at age x, respectively. The other terms were defined in equation 4.

The term given by the sum on the left of equation 5 aims to penalize very discrepant estimations of α, thus avoiding an implausible mortality pattern for the population of interest. Although the model needs a standard that describes the behavior of the rates by age, the proposed technique is not sensitive to the choice of that standard (Gonzaga & Schmertmann, 2016), making the model quite flexible for application in any low exposure population.

2.1 Synthesis Measures of the Mortality Curve

Historically, one of the consequences of the decline in human mortality has been the significant reduction in the variability of age at death (Wilmoth & Horiuchi, 1999). This reduction has occurred, first of all, due to the significant decline in mortality at younger ages, especially infant mortality, as a result of the reduction in deaths from exogenous causes. Next, there has been a process of displacement of deaths toward adult and older ages, with a reduction in the dispersion of the distribution of deaths by age, basically due to structural changes and progress in the fight against non-infectious diseases.

In Brazil, the changes in the morbimortality profile beginning a little more than half a century ago can be considered a starting point for the progressive reduction in the variability of age at death, similarly to that verified in developed countries (Campos & Rodrigues, 2004; Gonzaga et al., 2009, 2018; Prata, 1992). This analysis consists of verifying how the evolution of mortality has affected the distribution of age at death, especially at older ages.

Two indicators were used to analyze the changes in the variability of age at death: the interquartile range (IQR) of age at the time of death and the smallest interval in which the 50% concentration (C50) of deaths occurs. The IQR has the functionality of measuring the size of the age interval (between the first and the third quartiles of the death distribution) in which 50% of deaths occur around the median age at the time of death (Wilmoth & Horiuchi, 1999). A simple way of calculating the IQR is to use a life table with an initial cohort of size 1, for which only the survival function (l_x) is used, which in this case varies from 0 to 1. The IQR can be calculated as follows:

$$IQR = l_{x,Q3} - l_{x,Q1} \quad (6)$$

in which l_x is the function of survivors of the life table and the subscripts $Q3$ and $Q1$ represent the ages so that $l_x = 0.75$ and 0.25, respectively.

The second measure of variability of age at death refers to the smallest age interval in which the C50 occurs (Kannisto, 2000). Even though various intervals can be obtained in which C50 of deaths occur, what is sought is the smallest of these (Gonzaga et al., 2009).

These two indicators were used in this study to evaluate the distribution of deaths by age above 65 years old based on the rates estimated by the methods chosen. In addition, we used the conditional life expectancy after the age of 65 for survival comparisons between subgroups of INSS beneficiaries and of the total beneficiaries with the official IBGE estimates up to 80 years-old.

2.2 Summary of the Operational Stages

The codes in R and the input data to reproduce the results of this article are available in GitHub via the link https://anonymous.4open.science/r/mortalidade-3F28/README.md. The Topals regression model was applied to the death and population data for the total INSS beneficiaries by beneficiary group, year, and sex. The human mortality standard used in this relational model was obtained through the death and population data from various countries available on the platform of the University of California and Max Planck Institute for Demographic Research (2021). The HMD data are considered to be of reasonable to quite good quality and the death data from Brazil in 2000 and 2010 were added to model the mortality pattern.

The Topals model depends on the arbitrary definition, or definition using some criterion, of the knots at ages of the spline function between specific ages or age intervals characteristic of the mortality pattern of the population. For the RPC and RTA-URB groups, the knots were defined at the ages of 65, 70, 75, 80, 85, and 95. For the RTA-RUR and CPB groups, in turn, the knots were defined at the ages of 65, 70, 75, and 80. There is likely to be greater consistency in the event and exposure data in the RPC and RTA-URB groups in relation to the other groups for the following reasons: (i) they are older benefits; (ii) greater exposure; and (iii) little indication of underreporting of deaths. Therefore, we chose to limit the nodal points to only four points, with an upper limit of 80 in the RTA-RUR and CPB groups. That means that, after the age of 80, the behavior of the estimated curve is adequately modeled by the pattern chosen without, however, deviating significantly from the behavior of the observed rates before and after that age.

The Gompertz and Van der Maen models were applied to all the age intervals possible between 65 and 100, always considering a minimum number of 15 ages in each interval. Finally, the best fitting age interval in each model was defined via the RMSE calculation.

3. RESULTS

3.1 Mortality Rates above the Age of 65 by INSS Subgroups

In general, the age intervals between 65 and 84 years old were the ones that produced the best model fit in each sex and benefits group (see Table 1 of the Appendix), presenting the lowest RMSE. The parameters estimated based on that lowest RMSE criterion were used in the models to estimate the mortality rates by beneficiary group and sex, as well as to extrapolate those rates up to the age of 110.

Figure 1 presents the comparisons between the estimates generated by the Topals, Van der Maen, and Gompertz models in relation to the rates observed for men and women, respectively, in each beneficiary group in 2015. In the RPC and RTA-URB groups, there is a notably good fit provided by the Topals model in the entire age interval for both sexes, despite the greater variability in the rates observed for women in these two beneficiary groups. Also for these two groups, the estimates produced by the Van der Maen model impose a greater pace of deceleration in the rates, starting a little earlier in relation to the observed estimates. The Gompertz model, in turn, imposes an approximately linear behavior on the rates after the age of 65 in all the groups for both sexes.

The good fit produced by the Topals model is even notable in the RTA-RUR and CPB groups. However, it warrants mentioning that the Topals model only smoothens the observed rates, without imposing any mathematical model on the behavior of the rates, nor does it incorporate any effect derived from the selectivity hypothesis. From this perspective, the results produced by the Van der Maen model in these two groups are quite robust and related to the discussion of the mortality trends at older ages in different countries around the world.

Given this comparison between the estimates for each model and beneficiary group, it remains for us to ask which model would be the most appropriate for defining the behavior of the rates between the ages of 65 and 110. The answer may be related to the hypotheses assumed both in relation to the behavior of the rates above the age of 85, and in relation to the expected differential regarding the quality of the data in each group. In addition, it is important to evaluate the results for Brazil in light of the evidence from other countries, both in Latin America and in other regions of the world.

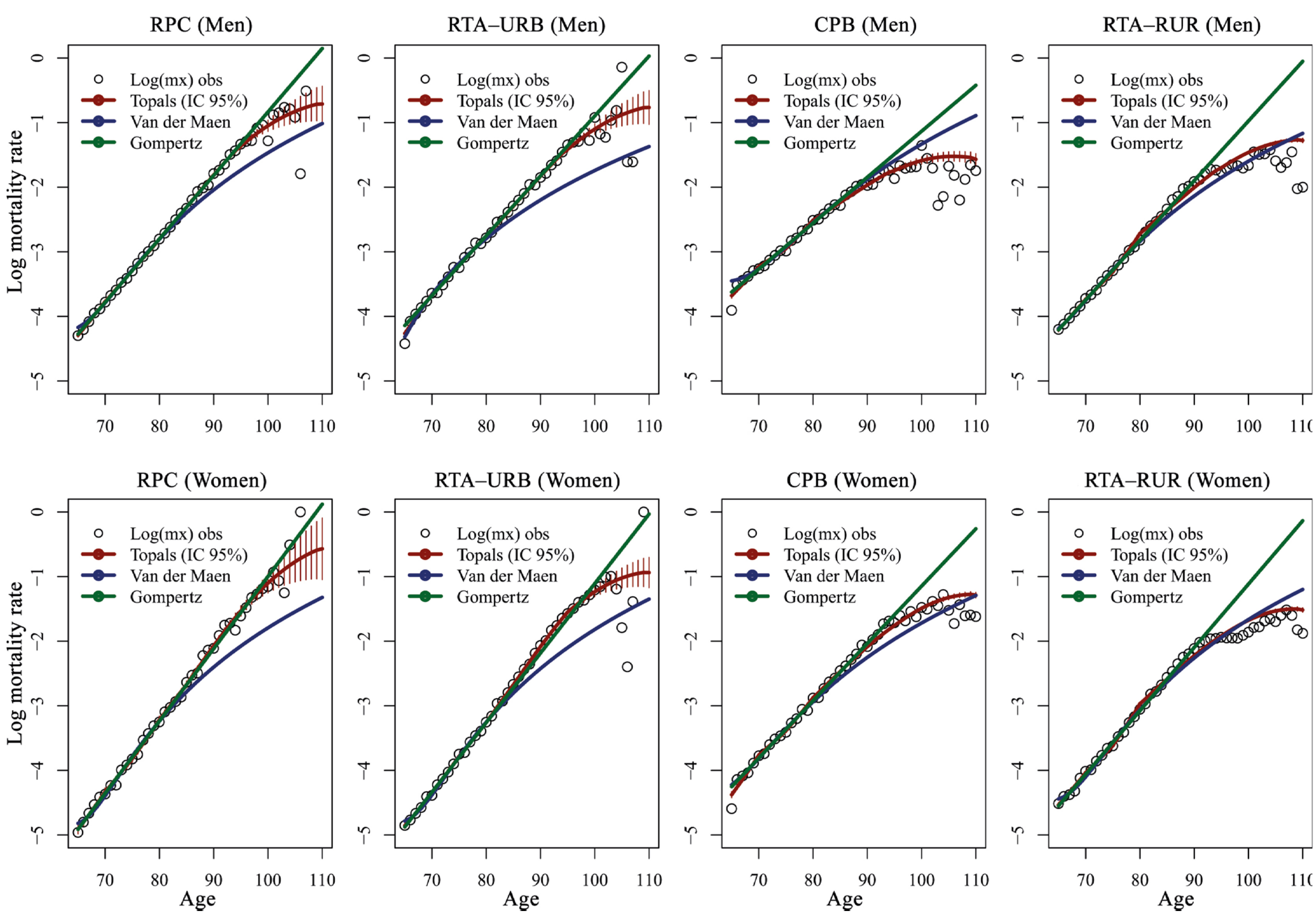

Figure 1 *Logarithm of observed morality rates and those estimated and extrapolated by sex, model, and INSS beneficiary group (2015)*

RTA-RUR = retirees through age in the rural clientele; RTA-URB = retirees through age in the urban clientele; RPC = retirees through period of contribution; CPB = continuous provision benefit; IC95% = 95% confidence interval.

Source: *AEPS (2021), University of California and Max Planck Institute for Demographic Research (2021).*

Assuming that above the age of 85 the behavior presented by the observed rates is unreliable and that the selectivity hypothesis is operating at different levels per group, the results produced by the Van der Maen model are quite reasonable. To help in this discussion, Figure 2 shows the logarithm of the estimated/extrapolated mortality rates per model, sex, and INSS beneficiary group in 2015. The aim of this figure is to assess the adjustments produced by each model, based on the differentials in the curves between the beneficiary groups.

The smoothing/estimates produced by the Topals and Gompertz models reveal the crossover in the risk of death between groups. The RTA-RUR and CPB groups start from higher mortality levels after the age of 65, but present a greater pace of deceleration in the rates throughout the ages, to the point of reverting the trends of these two groups in relation to the RPC and RTA-URB groups between the ages of 85 and 95. For women, the crossover of trends occurs later in relation to men. This crossover in the trend of the rates between groups may be related to the problems with the data or could simply be a selection effect.

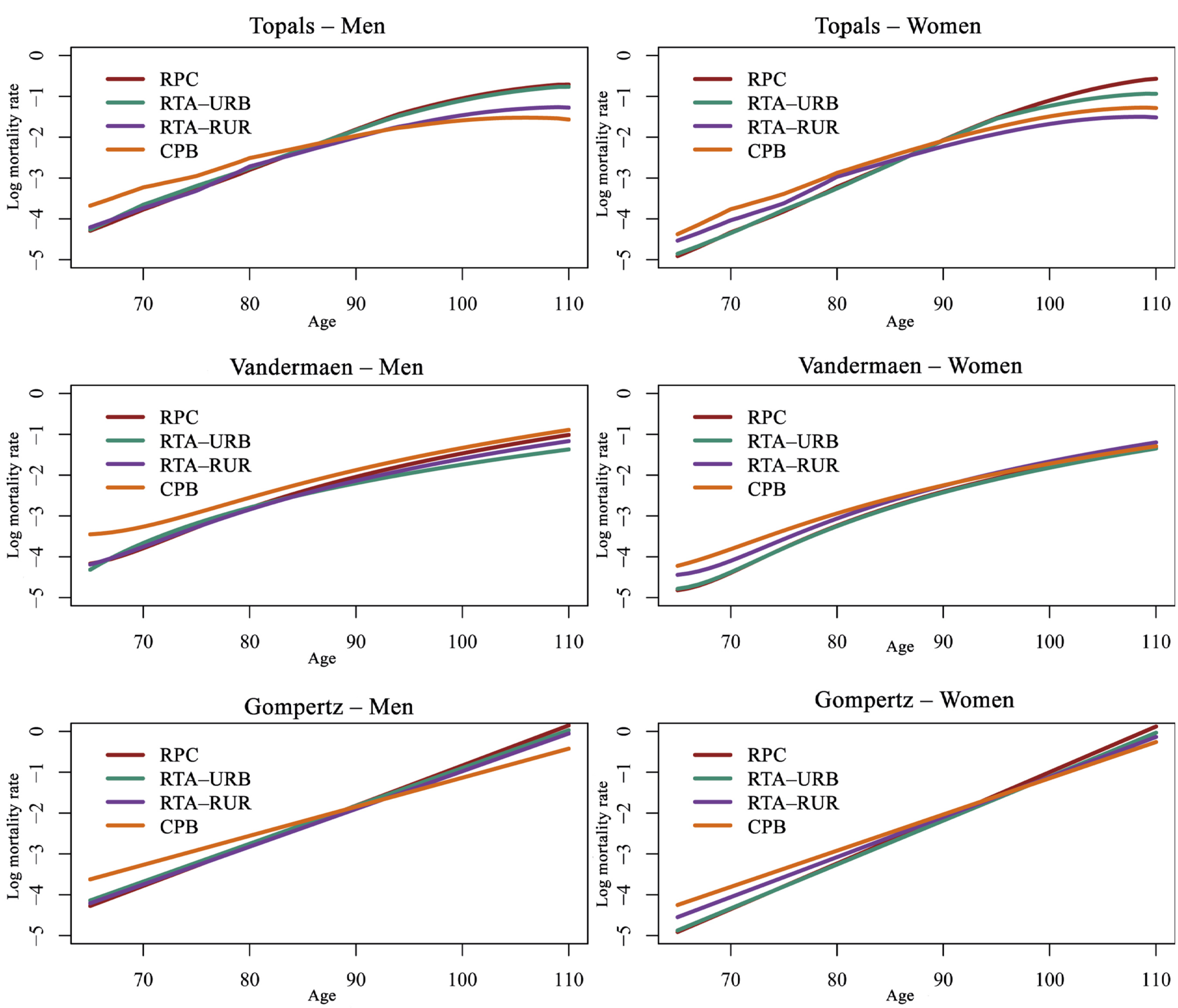

Figure 2 *Logarithm of estimated and extrapolated morality rates by sex, model, and INSS beneficiary group (2015)*
RTA-RUR = retirees through age in the rural clientele; RTA-URB = retirees through age in the urban clientele; RPC = retirees through period of contribution; CPB = continuous provision benefit.
Source: *AEPS (2021), University of California and Max Planck Institute for Demographic Research (2021).*

Assuming that selectivity is impacting the deceleration of the rates at the most oldest ages, but that this impact would not be enough to impose a crossover in the trends between the RTA-RUR and CPB groups in relation to the RPC and RTA-URB groups, that is, that the mortality level in the RTA-RUR and CPB groups must be higher in the entire age interval, the results produced by the Van der Maen model would be the most reasonable to explain the behavior of the mortality rates in all the INSS beneficiary groups, from the ages of 65 to 110. However, as observed in Figure 1, the curves estimated by the Van der Maen model underestimate the risk of death above the age of 85 precisely in the RTA-URB and RPC groups, in which it is supposed that data are of better quality. In the RTA-RUR and CPB groups, in turn, the results presented in Figure 1 also show that the Van der Maen model mitigates the excessive deceleration of the mortality rate a little, especially for men. It is thus suggested that for the RTA-URB and RPC groups, we should use the smoothing produced by the Topals model and, for the RTA-RUR and CPB groups, we should use the estimates/extrapolations produced by the Van der Maen model.

The adjustments presented are reasonable, despite maintaining the deceleration effects on the curves at the most oldest ages which, as we already highlighted, involves an effect that occurs in many populations, even some with data that is recognized to be of good quality (Barbi et al., 2018; Gavrilov & Gavrilova, 2019; Steinsaltz & Wachter, 2006; Wachter, 2018). With relation to the differentials by beneficiary group in the adjusted curves, the trend crossovers in the mortality rates of the RTA-URB and RPC groups in relation to the RTA-RUR and CPB groups are maintained, but mitigated in relation to what occurs in the observed rates.

3.2 Comparisons with the IBGE Rates Extrapolated to the Age of 105

Although the official life tables produced by the IBGE are limited to the open age interval of 80 years older, an extrapolation of the death probabilities up to the age of 105, frequently used in the special social security policies, was produced by Castro (2018).

In this study, we made a comparison between the estimates produced by each model for the total INSS beneficiaries with the estimates produced by the IBGE and also extrapolated by Castro (2018). No substantial differences would be expected in the estimates for the total INSS beneficiaries and total for the population of Brazil, due to the fact that the difference, in terms of exposed population, would only be the absence of public servants – who tend to present lower mortality rates than the general population (Beltrão & Sugahara, 2017; Silva, 2011), but are not included in the group of INSS beneficiaries – and of the population not covered by any of the social security regimes, public or private, whose percentage in relation to the general population decreases after the age of 65. Therefore, discrepancies tend to indicate some problem in the official extrapolated estimated, in the data that generated the estimates produced by the models considered here, or in the consistency of the hypothesis of high and stable cover among the elderly.

Figure 3 presents the logarithm of the death probabilities for the general population (IBGE, official and extrapolated) and for the INSS beneficiary groups, observed and adjusted by model type in 2015, for men and women, respectively. For comparison purposes, we also present the death probabilities of the HMD pattern used in the Topals relational model.

The results presented in Figure 3 indicate higher mortality in the official and extrapolated IBGE estimates for both sexes, in comparison with the estimates by INSS beneficiary group by the three models used, especially for women, with the exception of the beneficiaries of welfare support for low income seniors (CPB), for which the death probabilities are higher than the general population, according to the official IBGE estimate and the IBGE curve extrapolated by Castro (2018), at least up to around the age of 90. For the RPC, RTA-URB, and RTA-RUR groups, up to the age of 80, the trends among the death probabilities estimated by this study and according to the official IBGE estimates are similar and approximately linear, with a slightly smaller inclination (greater pace of increase in the rates by age) in the death probabilities of the IBGE life tables, whatever the model used. Unlike the extrapolated IBGE curve, some similarity is noted in the behavior of the death probabilities by age of the INSS beneficiary groups with that presented in the HMD pattern. That is, to the detriment of a lower level, the curves estimated by INSS beneficiary group follow a deceleration pattern observed in the set of countries of the HDM pattern. The highest mortality level for the set of countries from the HMD is due to the fact that we used, in building the standard curve, historical data from many countries, including from the start of the previous century, when mortality levels were high in those countries.

Another result that Figure 3 highlights is the exponential increase in the death probabilities in the extrapolations made based on the official IBGE estimates. The death probabilities extrapolated by Castro (2018) appear to represent an upper limit for mortality levels older ages. Nonetheless, it can be concluded that the exponential increase behavior appears to be unlikely, if compared with the HMD pattern, which, as already highlighted, incorporates high mortality regimes.

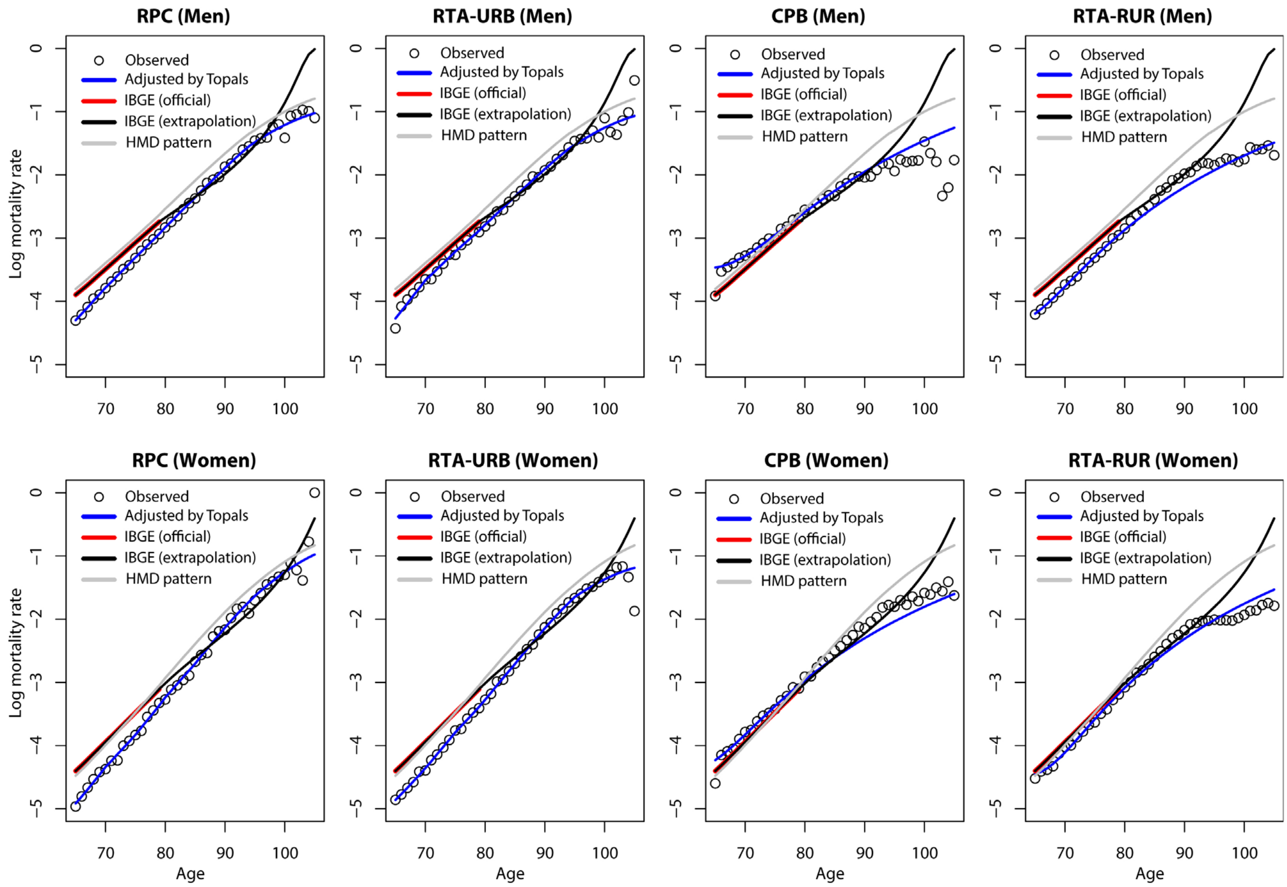

Figure 3 *Logarithm of death probabilities for the Brazilian population [official and extrapolated, Brazilian Institute of Geography and Statistics (IBGE)] for the set of countries of the Human Mortality Database (HMD pattern) (University of California and Max Planck Institute for Demographic Research, 2021) in various years and for the INSS beneficiary groups (2015) (observed and estimated by the Topals and Van der Maen models)*

RTA-RUR = retirees through age in the rural clientele; RTA-URB = retirees through age in the urban clientele; RPC = retirees through period of contribution; CPB = continuous provision benefit.

Source: *AEPS (2021), Castro (2018), IBGE (2021), University of California and Max Planck Institute for Demographic Research (2021).*

3.3 Comparison of Conditional Life Expectancies by Model/Group

Figure 4 presents the differences between the conditional life expectancies (estimated – observed) by sex, age, model type, and beneficiary group. As expected, we see that the differences between the observed and estimated mortality levels increase with age in the three models and in both sexes. This occurs due to the major variability of the rates observed at older ages. To the detriment of the quality of fit per model, the variability in the estimated rates is always lower.

Another point highlighted by the results shown in Figure 4 relates not only to the magnitude, but also to the direction of the difference between conditional life expectancies based on the estimated or observed rates. According to the results of the Topals model, the differences between the estimated and observed conditional life expectancies are practically null up to the age of 85. This means that the smoothing provided by the model has little or no effect on the ages at which exposure is high, implying a greater number of events and less variability in the observed rates.

The results according to the Van der Maen model indicate greater discrepancies between the estimated and observed conditional life expectancies at all ages, especially for males. The differences are almost always positive in the RTA-RUR and RPC groups at all ages and in both sexes.

In Figure 5, we compare the conditional life expectancies at the ages of 65 and 75, by sex and model type for the total INSS beneficiaries in 2015, with the conditional life expectancies of the IBGE at the same ages. According to both the observed life tables and the estimated tables for the total INSS beneficiaries, through any model, the conditional life expectancies at the ages of 65 and 75 for the INSS beneficiaries are always higher than those estimated by the IBGE for the general population. That is, the implicit mortality levels in the IBGE life tables are higher than the mortality levels of the INSS beneficiaries, especially for women.

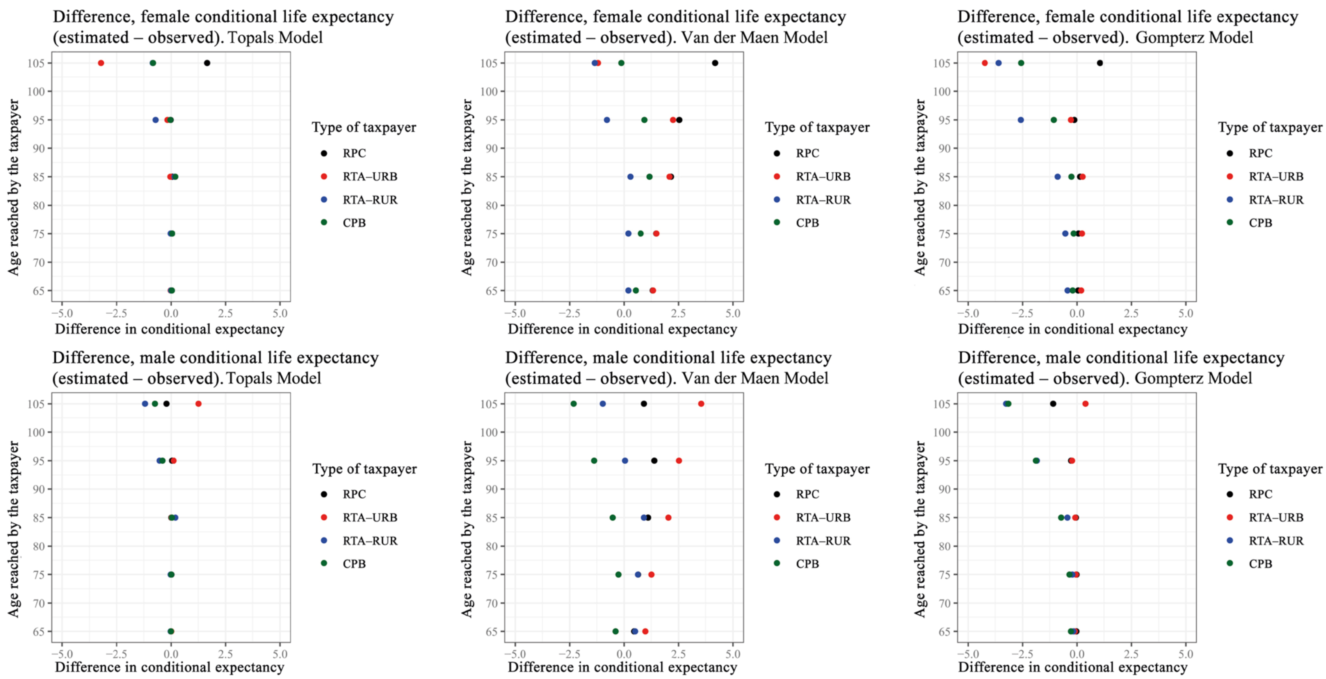

Figure 4 *Differences between conditional life expectancies (estimated – observed) by age, model type, and INSS beneficiaries group (2015)*

RTA-RUR = retirees through age in the rural clientele; RTA-URB = retirees through age in the urban clientele; RPC = retirees through period of contribution; CPB = continuous provision benefit.

Source: *AEPS (2021).*

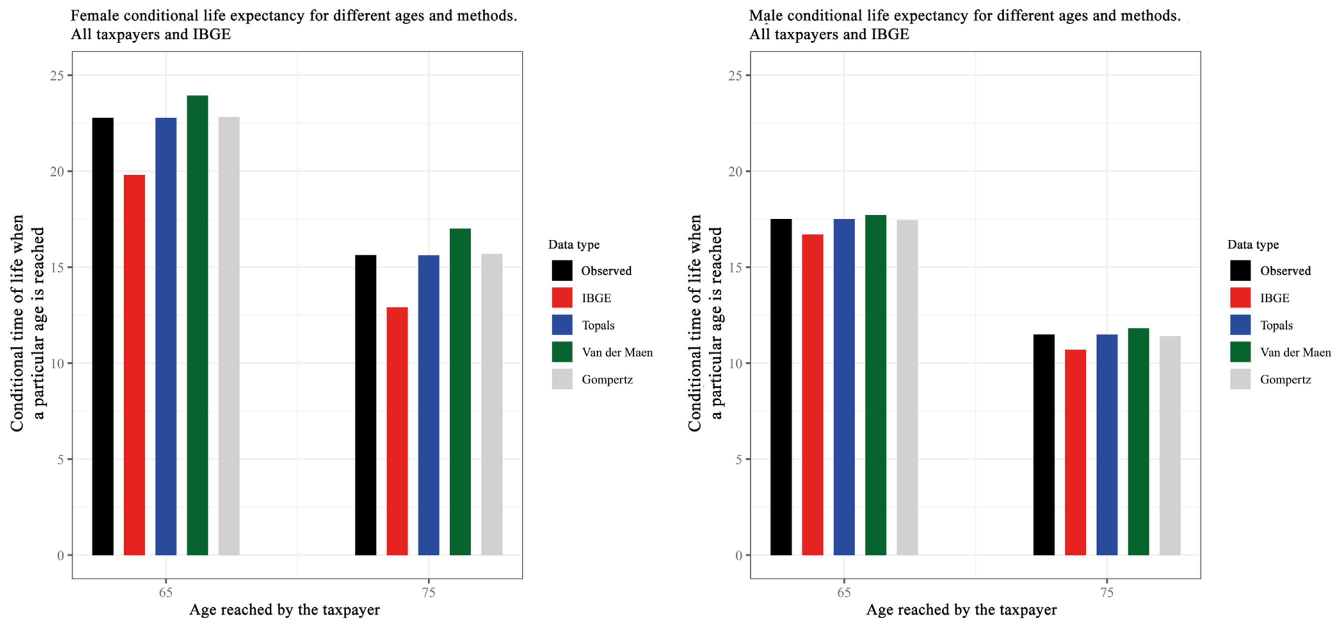

Figure 5 *Official conditional life expectancies by sex [Brazilian Institute of Geography and Statistics (IBGE)] and by model type for the total INSS beneficiaries (2015)*

Source: *AEPS (2021) and IBGE (2021).*

3.4 Comparison of Variability Measures in the Distribution of Deaths by Model/Group

Figure 6 presents the results related to the dispersion of deaths over the 65 to 105 year old age interval, as measured by the IQR and by the smallest C50 interval of deaths by model type and beneficiary group. In general, we do not perceive any major differences in terms of core trend or dispersion in the distribution of deaths between the estimates by different models in each beneficiary group or sex. Nonetheless, it is observed that the IQR indicates a greater dispersion and higher median age at the time of death in the results produced by the Van der Maen model in all the beneficiary groups, especially for women. For the other models, or considering the observed data, the differences in terms of position or dispersion in the distribution of deaths are very small. As expected, the C50 results accompany those shown by the IQR, indicating greater dispersion in the results according to the Van der Maen model in each beneficiary group.

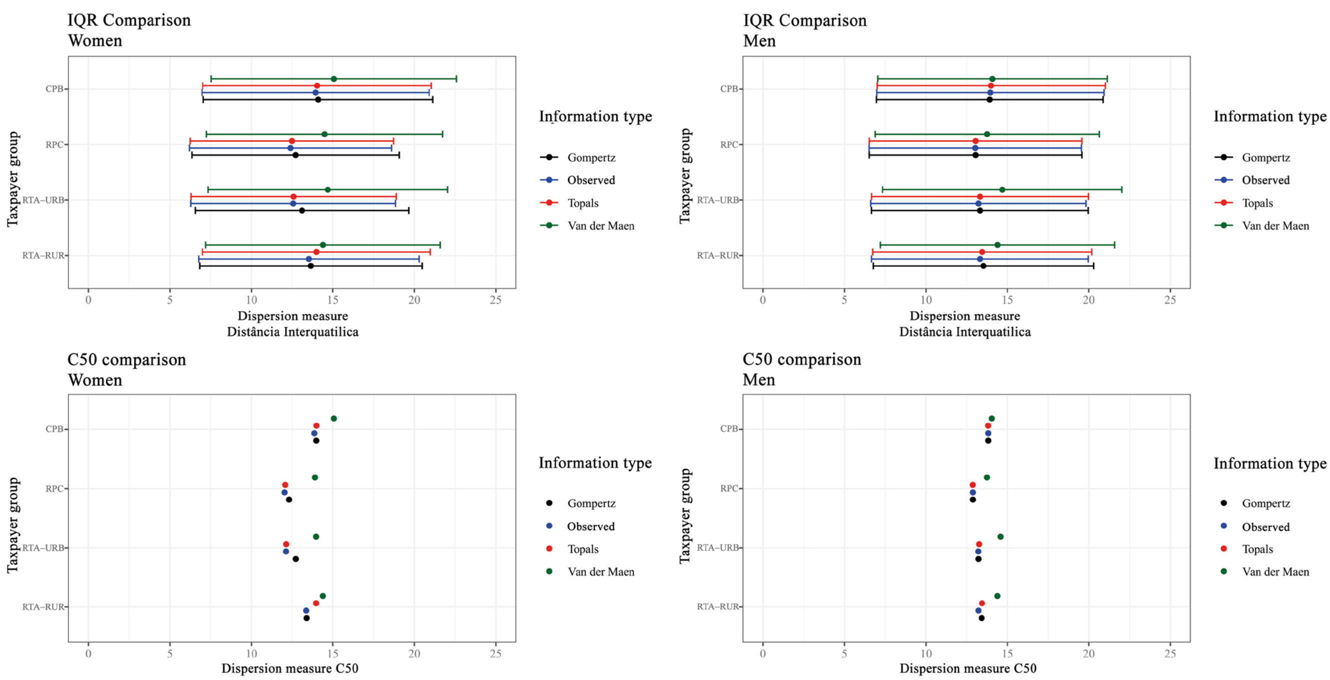

Figure 6 *Interquartile range (IQR) and smallest 50% concentration (C50) of deaths by model type and INSS beneficiary group (2015)*

Comparativo IQR = IQR Comparison; Comparativo C50 = C50 comparison; Grupo de contribuinte = Taxpayer group; Homens = Men; Medida de dispersão = Dispersion measure; Modelo de dispersão = Dispersion model; Mulheres = Women; Tipo de informação = Information type.

Source: *AEPS (2021).*

4. DISCUSSION AND CONCLUSION

In general, the evidence presented in the study indicates that the death and population data for INSS beneficiaries has good quality in relation to age misreporting, especially for the most recent study period, but it also suggests that there are differences in quality in the data between the beneficiary groups considered. The urban beneficiaries, voluntarily retired through the RGPS via RTA-URB and RPC, appear to have more consistent death records than the rural pension beneficiaries (RTA-RUR) and the beneficiaries of welfare support for seniors (CPB). In these last two groups, there was an expressive improvement in the collection and timeliness of the information, but there are still indications of underreporting, with some risk that the date of death captured or, in the case of suspected death, estimated, has been displaced in time and generates some distortion in the calculation of the age at which the event actually occurred.

The use of different methods for estimating, smoothing, and extrapolating the rates for older ages enabled comparative analyses regarding the mortality pattern at older ages by beneficiary group. In general, the results indicate that the Gompertz model did not present a good fit for the mortality curves of INSS beneficiaries. The estimates produced by the Topals method and the Van der Maen mortality law adjusted better to the observed data and presented more consistent results.

According to the comparative analysis using synthetic mortality measures (conditional life expectancy at different ages) and dispersion measures (IQR and C50) for different models and beneficiary groups, it was noted that conditional life expectancies at the ages of 65 and 75 for the total INSS beneficiaries are always higher than those estimated by the IBGE for the general population. That is, the implicit mortality levels in the IBGE life tables are higher than the mortality levels of the INSS beneficiaries, especially for women.

Among the still scarce studies published that compare the mortality of INSS beneficiaries with that of the general population, it warrants highlighting the master's dissertation of Castro (1997), which consists of one of the first efforts in this sense. Using administrative records from the INSS, whose weaknesses at the time were duly highlighted, the author confirmed, when the opening was possible, the differentials by sex, with systematically lower mortality among women beneficiaries, and she reached intriguing results in the comparison between urban and rural beneficiaries, with overmortality of the former. In this regard, the explanation was closely related with the major deficiency at the time in capturing deaths, which was even worse in the rural beneficiary groups. In the comparison with the indicators estimated for the total population, also calculated by the author, the results indicate high mortality differentials that grow with age, favoring the INSS beneficiaries.

Based on administrative records of the INSS covering 1998 to 2002, Souza (2009) also elaborated mortality and survival indicators for the elderly population retired through the RGPS, considering all the beneficiary groups (retirees through invalidity, age, period of contribution, welfare support, accident benefits, and death pensions) and the ages within the 65 to 90 year old range. The author also estimates greater survival for the RGPS beneficiaries, compared to the indicators produced by the IBGE for the total population in 2008. This result draws attention due to the time distance between the data used in each estimate (1998-2002 *versus* 2008)

Other studies, elaborated based on different data sources and temporal cuts, also confirm the differentials between men and women and indicate a certain level of convergence between urban and rural individuals, whether based on the area of residence or clientele criterion (nature of economic activity, a reference adopted by the RGPS). Based on more recent (1997-2016) and more consistent administrative microdata, Paiva et al. (2018) equally indicated the convergence of the survival curves of urban and rural retirees through age, including with some positive differential in favor of the latter, and they find differentials by sex comparable with those obtained in this study. Using the IBGE 2010 Demographic Census data, Albuquerque (2019) estimated that the life expectancy of residents in rural areas exceeds that obtained for the urban area. More recently, again based on administrative records of the INSS (1999-2018), Santos et al. (2020) analyzed the mean ages of termination through death and the mean duration of the retirements through age terminated through death to reach similar conclusions.

In general, therefore, the results found in the literature are consistent with the findings obtained in this study, given that the survival estimates were higher among beneficiaries in general and rural and urban retirees of the RGPS, these being lower than those of the IBGE only in the group of non-pension benefits. With the CPB being a welfare support-type benefit, meant to protect low income seniors without the taxpaying conditions to achieve pension benefits, its higher mortality rates are supported by studies such as that of Beltrão et al. (2010), who estimate full mortality tables by sex for family members with an income per capita of up to one, two, or three monthly minimum wages. The tables, built based on the worsening of the tables estimated by the IBGE for the total Brazilian population, indicate the inverse relationship between income level and mortality. This inverse relationship, possibly mediated by factors such as local basic sanitation infrastructure, access to health services, and information level, would determine important regional differences in survival, even when this is controlled by family income per capita.

It warrants mentioning, however, that the results of Beltrão et al. (2010), although they help to explain the worse CPB indicators, make it difficult to understand the estimates obtained for RTA-RUR, given that the rural beneficiaries are given a prevalently weak socioeconomic profile and that this type of voluntary retirement is concentrated in the less developed regions of the country – in 2015 (AEPS, 2021), 60% of the stock of active benefits were concentrated in the North and Northeast. Besides the aforementioned worse quality of the death records, the explanation may involve, for example, differences in food security (fulfillment of basic calorie needs) between urban and rural beneficiaries, but it is clear that this topic warrants a more in-depth evaluation.

Considering that the separately treated benefit groups are predominant among the elderly and that their indicators are shown to be apparently more coherent in the comparison with the IBGE estimates, the explanation for this result must involve the behavior of death pensions and their peculiarities in terms of rules of concession, maintenance, and cover by sex. Besides any hypothesis that sustains substantially lower mortality among women pensioners, we should more cautiously analyze the data from this type of pension provision, since it is possible that the explanation is due to peculiarities in its treatment in the INSS records and/or to the fact that a considerable portion of women are only beneficiaries in the condition of pensioner and that, in opposition to the original hypothesis of stable cover among the elderly, the proportion of protected women is lower and the cover by death pensions rises with age (Institute of Applied Economic Research [IPEA], 2018) – that is, there are continuous increases in the risk-exposed population at higher ages, requiring the use of techniques that capture that dynamic and avoid distortions in mortality rates.

Assuming that the RTA-URB and RPC data are better quality, we suggest, for these groups and both sexes, only the smoothing of mortality rates produced by the Topals method. For the CPB and RTA-RUR groups, in which it is supposed that the data for ages above 80 are unreliable, we suggest the estimates produced by the Van der Maen method. In all the estimates, some mortality selectivity effect at older ages is assumed, contributing to a deceleration in the rates at these ages, as envisioned by the demographic/actuarial literature.

The comparison of the results of this research with the IBGE table, extrapolated by Castro (2018) up to the age of 110 and over, revealed an overestimation of the death probabilities produced by the author at older ages, which would have important implications for the mathematical provisions in the use of that extrapolated table, with a lower life expectancy, and in the sustainability of pension plans, by indicating the solvency of the plan when the adjustments are smaller or almost equal to the obligations (Ayuso et al., 2021; Gosmann & Avozani, 2014). It is important to consider that the impacts of a lower life expectancy occur over time and will require important adjustments for the system to work. Thus, the results presented here indicate the need for more studies for evaluating and correcting the quality of the data and the improvement of methods for producing more reliable and robust estimates, especially at older ages (Nepomuceno & Turra, 2020; Turra, 2012), which could be applied by pension entities.

It warrants mentioning that this study was based on the search for mortality models or laws that produced a better fit of the parameters and, consequently, smoothing/extrapolation of the rates at older ages for each INSS beneficiary group. Therefore, the choice of model by group was based on the quality of the data (supposing better quality RTA-URB and RPC), on the quality of the fit of each model/group, and on the suppositions related to the behavior of the curves at older ages.

In light of the above, we believe that the results obtained in this study contribute to the debate on the mortality differentials by sex and age between RGPS and INSS beneficiary groups. Conversely, they reinforce the need for more studies that seek to identify and explore these mortality differentials between beneficiary groups and of these with the general population, as estimated by the IBGE.

REFERENCES

Albuquerque, F. R. P. C. (2019). Tábuas de mortalidade segundo a situação do domicílio utilizando-se o Censo Demográfico de 2010. *Informe de Previdência Social*, *31*(5), 3-20.

Anuário Estatístico da Previdência Social. (2021). *Infologo – Base de dados do Anuário Estatístico da Previdência Social.* Dataprev.gov. http://www3.dataprev.gov.br/infologo/inicio.htm

Ayuso, M., Bravo, J. M., & Holzmann, R. (2021). Getting life expectancy estimates right for pension policy: Period versus cohort approach. *Journal of Pension Economics & Finance*, *20*(2), 212-231. https://doi.org/10.1017/S1474747220000050

Barbi, E., Lagona, F., Marsili, M., Vaupel, J. W., & Wachter, K. W. (2018). The plateau of human mortality: Demography of longevity pioneers. *Science*, *360*(6396), 1459-1461.

Beard, R. E. (1959). Note on some mathematical mortality models. In G. E. W., et al. (Eds.), *The lifespan of animals* (pp. 302-311). Wiley Online Library. https://doi.org/10.1002/9780470715253

Beltrão, K. I., Sugahara, S., & Silva, L. (2010). Estimate of mortality for individuals from low-income families. In C. Contador (Org.), *Microinsurance in Brazil: Research series* (pp. 171-218). Escola Nacional de Seguros.

Beltrão, K., & Sugahara, S. (2017). Mortalidade dos funcionários públicos civis do Executivo por sexo e escolaridade – 1993/2014. *Revista Contabilidade & Finanças*, *28*(75), 445-464. https://doi.org/10.1590/1808-057x201704320

Black, D. A., Hsu, Y. C., Sanders, S. G., Schofield, L. S., & Taylor, L. J. (2017). The Methuselah effect: The pernicious impact of unreported deaths on old-age mortality estimates. *Demography*, *54*(6), 2001-2024.

Bravo, J. M. V. (2007). *Tábuas de mortalidade contemporâneas e prospectivas: modelos estocásticos, aplicações actuariais* *e cobertura do risco de longevidade* [Doctoral Thesis]. Universidade de Évora. http://dspace.uevora.pt/rdpc/handle/10174/11148

Campos N. O. B., & Rodrigues, R. N. (2004). O ritmo de declínio da mortalidade dos idosos nos estados do Sudeste, 1980/2000. *Revista Brasileira de Estudos de População*, *21*(2), 323-342.

Castro, L. G. (2018). *Nota técnica sobre a metodologia adotada pelo Ministério da Previdência Social na extrapolação das Tábuas de Mortalidade IBGE para as idades acima de 80 anos, de autoria do atuário Luciano Gonçalves de Castro, MIBA nº 1.116, doutorando em demografia, mestre em estudos populacionais e pesquisas sociais, pesquisador – demógrafo da COPIS/DPE/IBGE.* http://sa.previdencia.gov.br/site/2015/06/NOTA-TECNICA-ATUARIAL-EXTRAPOLACAO-DA-TABUA-IBGE-MPS.pdf

Castro, M. C. (1997). *Entradas e saídas no sistema previdenciário brasileiro: uma aplicação de tábuas de mortalidade* [Master's Dissertation]. Universidade Federal de Minas Gerais. https://repositorio.ufmg.br/handle/1843/MCCR-7S8LV4

Coale, A. J., & Kisker, E. E. (1990). Defects in data on old-age mortality in the United States: New procedures for calculating mortality schedules and life tables at the highest ages. *Asian and Pacific Population Forum*, *4*(1), 1-31.

Coale, A. J., & Li, S. (1991). The effect of age misreporting in China on the calculation of mortality rates at very high ages. *Demography*, *28*(2), 293-301. https://doi.org/10.2307/2061281

Condran, G. A, Himes, C. L. E, & Preston, S. H. (1991). Old-age mortality patterns in low-mortality countries: An evaluation of population and death data at advanced ages, 1950 to the present. *Population Bulletin of the United Nations*, (30), 23-60.

De Beer, J. (2012). Smoothing and projecting age-specific probabilities of death by TOPALS. *Demographic Research*, *27*(20), 543-592. https://doi.org/10.4054/DemRes.2012.27.20

De Boor, C. (2001). *Applied mathematical sciences: A practical guide to splines*. Springer-Verlag. (Original paper published in 1978).

Eilers, P. H. C., & Marx, B. D. (1996). Flexible smoothing with B-splines and penalties. *Statistical Science*, *11*(2), 89-121.

Feehan, D. M. (2018). Separating the signal from the noise: Evidence for deceleration in old-age death rates. *Demography*, *55*(6), 2025-2044.

Gavrilov, L. A., & Gavrilova, N. S. (2019). Late-life mortality is underestimated because of data errors. *PLoS biology*, *17*(2), Artigo e3000148. https://doi.org/10.1371/journal.pbio.3000148

Gavrilova, N. S., & Gavrilov, L. A. (2014). *Mortality trajectories at extreme old ages: a comparative study of different data sources on U.S. Old-age mortality. Living to 100 monograph.* https://www.soa.org/globalassets/assets/files/resources/essays-monographs/2014-living-to-100/mono-li14-3a-gavrilova.pdf

Gomes, M. M., & Turra, C. M. (2009). The number of centenarians in Brazil: Indirect estimates based on death certificates. *Demographic Research*, *20*(20), 495-502.

Gompertz, B. (1825). On the nature of the function expressive of the law of human mortality, and on a new mode of determining the value of life contingencies. *Philosophical Transactions of the Royal Society of London*, *115*, 513-583.

Gonzaga, M. R., & Schmertmann, C. P. (2016). Estimating age- and sex-specific mortality rates for small areas with TOPALS regression. *Revista Brasileira de Estudos de População*, *33*(3), 629-652. https://doi.org/10.20947/S0102-30982016c0009

Gonzaga, M. R., Queiroz, B. L., & Lima, E. E. C. (2018). Compression of mortality. *Revista Latinoamericana de Población*, *12*(23), 9-35.

Gonzaga, M. R., Queiroz, B. L., & Machado, C. J. (2009). Compressão da mortalidade: um estudo da variabilidade da idade à morte na população do estado de São Paulo, Brasil, 1980-2005. *Cadernos de Saúde Pública*, *25*(7), 1475-1485.

Gosmann, M. C., & Avozan, C. L. (2014). Risco de longevidade na previdência dos servidores públicos federais no Brasil. In C. S. Calvete, & M. C. Gosmann (Org.). *Políticas de emprego, trabalho e previdência* (pp.116-140). Universidade Federal do Rio Grande do Sul. https://lume.ufrgs.br/bitstream/handle/10183/198720/001100762.pdf?sequence=1&isAllowed=y

Grupo de Foz. (2021). *Métodos demográficos: uma visão desde os países de língua portuguesa*. Blucher. https://doi.org/10.5151/9786555500837

Hill, K., You, D., & Choi, Y. (2009). Death distribution methods for estimating adult mortality: Sensitivity analysis with simulated data errors. *Demographic Research*, *21*(9), 235-254. https://doi.org/10.4054/DemRes.2009.21.9

Horiuchi, S., & Wilmoth, J. R. (1998). Deceleration in the age pattern of mortality at older ages. *Demography*, *35*(4), 391-412. https://doi.org/10.2307/3004009

Instituto Brasileiro de Geografia e Estatística. (2018). Projeções da população: Brasil e Unidades da Federação. Revisão 2018. Série Relatórios Metodológicos (40). IBGE.

Instituto de Pesquisa Econômica Aplicada. (2018). Políticas sociais – acompanhamento e análise. *Boletim de políticas sociais*, (27), 1-45. http://repositorio.ipea.gov.br/bitstream/11058/10278/1/BPS_n27_previdencia_social.pdf

Jdanov, D. A., Jasilionis, D., Soroko, E. L., Rau, R., & Vaupel, J. W. (2008). *Beyond the Kannisto-Thatcher Database on old age mortality: An assessment of data quality at advanced ages* [Working Paper]. Max Planck Institute for Demographic Research.

Kannisto V. (2000). Measuring the compression of mortality. *Demographic Research*, *3*. https://doi.org/10.4054/DemRes.2000.3.6

Kannisto, V. (1988). On the survival of centenarians and the span of life. *Population Studies*, *42*(3), 389-406. https://doi.org/10.1080/0032472031000143546

Kannisto, V. (1999). Assessing the information on age at death of old persons in national vital statistics. In B. Jeune, & J. W. Vaupel (Eds.), *Validation of exceptional longevity (Odense Monographs on Population Aging, Vol. 6)* (pp. 235-249). Odense University Press.

Nepomuceno, M. R., & Turra, C. M. (2020). The population of centenarians in Brazil: Historical estimates from 1900 to 2000. *Population and Development Review*, *46*(4), 813-833.

Paiva, L. H., Stivali, M., & Rangel, L. A. (2018). *Devemos unificar as idades de elegibilidade das previdências urbana e rural?* [Discussion Text]. Instituto de Pesquisa Econômica Aplicada.

Pascariu, M. D., & Vladimir C.-R. (2017). A history of mortality modelling from Gompertz to Lee-Carter everything in a single R package: MortalityLaws. In *Anais do International Population Conference*. https://iussp.confex.com/iussp/ipc2017/meetingapp.cgi/Paper/4572

Pascariu, M. D., & Vladimir C.-R. (2020). *MortalityLaws: Parametric mortality models, life tables and HMD.* https://CRAN.R-project.org/package=MortalityLaws

Prata P. R. (1992). A transição epidemiológica no Brasil. *Cadernos de Saúde Pública*, *8*(2),168-175.

Preston, S. H., Elo, I. T., & Stewart, Q. (1999). Effects of age misreporting on mortality estimates at older ages. *Population Studies*, *53*(2), 165-177.

Queiroz, B. L., Gonzaga, M. R., Vasconcelos, A. M. N., Lopes, B. T., & Abreu, D. M. X. (2020). Comparative analysis of completeness of death registration, adult mortality and life expectancy at birth in Brazil at the subnational level. *Population Health Metrics*, *18*(11). https://doi.org/10.1186/s12963-020-00213-4

Sacher, G. A. (1966). The Gompertz transformation in the study of the injury-mortality relationship: Application to late radiation effects and ageing. In P. J. Lindop, & G. A. Sacher (Eds.), *Radiation and aging* (pp. 411-441). Taylor & Francis.

Santos, C. F., Costanzi, R. N., Silva, V. S., Fernandes, A. Z., & Maximino, S. L. (2020). Longevidade dos aposentados e duração das aposentadorias por idade. *Informe de Previdência Social*, *32*(1), 5-20.

Silva, L. G. C. E. (2011). Estudo da mortalidade dos servidores públicos civis do estado de São Paulo: tábua de mortalidade destinada aos regimes próprios de previdência social. In *Anais do XX Encontro Nacional de Estudos Populacionais*.

Souza, M. C. M. (2009). *Um estudo sobre a mortalidade dos aposentados idosos do Regime Geral de Previdência Social do Brasil no período de 1998 a 2002* [Master's Dissertation]. Universidade Federal de Minas Gerais. https://repositorio.ufmg.br/handle/1843/AMSA-8AMNS9

Steinsaltz, D. R., & Wachter, K. W. (2006). Understanding mortality rate deceleration and heterogeneity. *Mathematical Population Studies*, *13*(1), 19-37.

Tabeau, E. (2001). A review of demographic forecasting models for mortality. In E. Tabeau, et al. (Eds.). *Forecasting mortality in developed countries. European studies of population* (*Vol. 9*). Springer. https://doi.org/10.1007/0-306-47562-6_1

Turra, C. M. (2012). Os limites do corpo: a longevidade em uma perspectiva demográfica. *Revista da Universidade Federal de Minas Gerais*, *19*(1), 156-181.

University of California & Max Planck Institute for Demographic Research. (2021). *Human Mortality Database.* https://www.mortality.org/

Van der Maen, W. J. (1943). Het berekenen van stertfekansen. *Verzekerings Archief*, *44*(4), 281-300.

Wachter, K. W. (2018). Hypothetical errors and plateaus: A response to Newman. *PLoS biology*, *16*(12), Artigo e3000076. https://doi.org/10.1371/journal.pbio.3000076

Weitz, J. S., & Fraser, H. B. (2001). Explaining mortality rate plateaus. *Proceedings of the National Academy of Sciences*, *98*(26), 15383-15386. https://doi.org/10.1073/pnas.261228098

Wilmoth J. R., & Horiuchi, S. E. (1999). Rectangularization revisited: Variability of age at death within human populations. *Demography*, *36*(4), 475-495. https://doi.org/10.2307/2648085

APPENDIX

Table 1
Evaluation of the quality of age declarations, Coale and Li (1991), RGPS, and CPB method (AEPS, 2015)

Population/deaths	Total	RPC	RTA-URB	RTA-RUR	CPB
Male					
Population	0.992	0.943	0.954	1.017	1.012
Deaths	1.008	0.990	0.990	1.028	0.999
Female					
Population	1.005	0.963	0.975	1.012	1.027
Deaths	1.035	0.993	1.013	1.034	1.046

API-RUR = RTA-RUR = retirees through age in the rural clientele; API-URB = RTA-URB = retirees through age in the urban clientele; ATC = RPC = retirees through period of contribution; BPC = CPB = continuous provision benefit; RGPS = General Social Security Regime.
Source: *RGPS/AEPS (2021).*

Table 2
Indicators of digit preference for deaths (Jdanov, 2008; AEPS, 2015)

Deaths	Total	RPC	RTA-URB	RTA-RUR	CPB	Sweden
Male	96.7	85.5	95.9	98.7	106.8	94.7
Female	102.3	93.0	94.8	103.6	103.8	97.4

API-RUR = RTA-RUR = retirees through age in the rural clientele; API-URB = RTA-URB = retirees through age in the urban clientele; ATC = RPC = retirees through period of contribution; BPC = CPB = continuous provision benefit.
Source: *General Social Security Regime (RGPS)/AEPS (2021).*

Table 3
RMSE estimated by age interval, sex, and INSS beneficiary group (AEPS, 2015) for the Gompertz (1825) and Van der Maen (1943) laws

Van der Maen				Gompertz	
Age interval	Group	RMSE	Age interval	Group	RMSE
Men					
65-80	RTA-RUR	0.000669	65-80	RTA-RUR	0.000533
65-80	RTA-URB	0.001626	66-81	RTA-URB	0.001707
67-82	RPC	0.000528	66-81	RPC	0.000470
68-83	CPB	0.001451	69-84	CPB	0.001588
Women					
65-81	RTA-RUR	0.001451	66-81	RTA-RUR	0.000719
65-81	RTA-URB	0.001626	65-81	RTA-URB	0.000494
65-80	RPC	0.000528	65-80	RPC	0.000846
66-81	CPB	0.000669	66-84	CPB	0.001344

API-RUR = RTA-RUR = retirees through age in the rural clientele; API-URB = RTA-URB = retirees through age in the urban clientele; ATC = RPC = retirees through period of contribution; BPC = CPB = continuous provision benefit; INSS = National Institute of Social Security; RMSE = root mean square error.
Source: *General Social Security Regime (RGPS)/AEPS (2021).*