Does the death postponement phenomenon really exist?

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Abstract. It is a common belief that people close to death from natural causes can postpone their imminent death if they see a strong reason to survive a bit longer. This is known as the Postponement hypothesis: that a meaningful occasion can act as a motivator to prolong life for a short amount of time. A few studies have already addressed this hypothesis but their conclusions are contradictory.

To check the postponement hypothesis, we analysed almost 249 thousand cases in the dataset for South African people who died in the year 2015. We took a person's birthday as the meaningful occasion and analyse the death rate around this date using statistical models offered by survival analysis. If the hypothesis is true, it can be expected that the mortality rate should be lower a period just before the birthday and, perhaps, higher shortly afterwards.

The results of our analysis show that no postponement of death can be seen for the examined dataset. In fact, to the contrary, the data suggest that the mortality rate is higher both before and after the birthday. Speculations as to why this is the case might be a higher risk associated with the stress of expectations for the birthday as well as an earlier start of celebrations with associated departure from the recommended regime.

Keywords: death rate, hazard function, postponement, longevity, survival.

1 Introduction

The Death Postponement theory has been with us for some time. It states that a person is able to postpone his/her death for a while if there is a strong reason for this. Such a reason could be personal events like the soon coming birthday or public events like important historical or religious dates close-by. The theory is popular because it is easy to believe that a person is, at least, in some control of one's own life even in critical circumstances. A number of studies has been carried out so far to see if it has any statistical grounds for the postponement to exist. Perhaps, the main proponent of the theory is David P. Philips who has published several articles with different co-authors studying the postponement phenomenon.

In the study [5], the authors investigated whether the postponement phenomenon can be detected using the Jewish holiday of Passover, Pesach, as a

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significant event. A dataset of 1919 adult humans, which died in California of natural causes during the years 1966–1984 was used as a basis for their analysis and was compared with a control group consisting of non-Jewish people. Application of regression analysis and binomial tests allowed the authors to detect a significant decrease (dip) in the number of deaths observed just before Pesach and their increase (peak) just after, while the control group did not show the same pattern. The results were later criticised by Gary Smith in [8] who noted that in the selection process, people were assumed to be Jewish only by their names. Another study by D.P. Philips examined the mortality of 1288 Chinese who died between the years 1960 and 1984 around the Moon Festival, a traditional celebration of Chinese culture [6]. Again, the authors claim to show a similar dip-peak pattern that was significant for Chinese and did not occur in a non-Chinese control group. The authors, however, noted that the sample size in both studies, of Pesach and the Moon party, were small in size, the statement which puts in doubts the very conclusion of these studies.

In a later work, entitled "The Birthday: Lifeline or Deadline?" [7], the authors analysed much larger samples of 1.3 and 1.4 million people aged 18+ who died of natural causes between 1969 and 1990 in California using birthday as a significant event. The analyses seem to demonstrate the postponement phenomenon for female population (so the birthday for females is a 'lifeline'), while for the male population the death rate is actually higher both before and after the birthday (a 'deadline').

The work of other authors mainly confirm this 'birthday deadline phenomenon' that the mortality actually increases before the birthday. The authors of [1] analyse Swiss mortality databases from years 1969-2008 containing over 2 million death records with the help of the ARIMA model. They show a 13.8% increase in death rate around birthdays with variations of between 11 to 18 per cent in men and women older than 60. In the group of natural causes deaths, the heart disease and cancer were the main causes of death. The conclusion is that birthdays increase the death rate mainly for the heart disease patients (infarction and stroke), certainly, due to extra stress. Another study [4] analyses more than 4 million death records in Germany during the period of 1992–2011. As the meaningful event, both Christmas and birthday were used. The conclusion is similar: there is no such phenomenon as an intentionally postponed death, at least for birthdays and on the scale of a few days.

A frequent source of error in data interpretation leading to belief in existence of the postponement phenomenon can be illustrated with the following example.

Consider a typical situation when the number of recorded deaths decreases with age, like on the left histogram in Figure 1. If we combine these data into the monthly death statistics, essentially by cutting the histogram on the left by the year start, we obtain the histogram on the right which would also demonstrate a decaying pattern. This may lead to a wrong interpretation as the postponement phenomenon that less people die before their birthday than after it. This, however, just reflects the fact that there are fewer people who survive to their next birthday. The same statement is true for any other cut-off day in the year rather than the birthday provided a decaying with age histogram pattern.

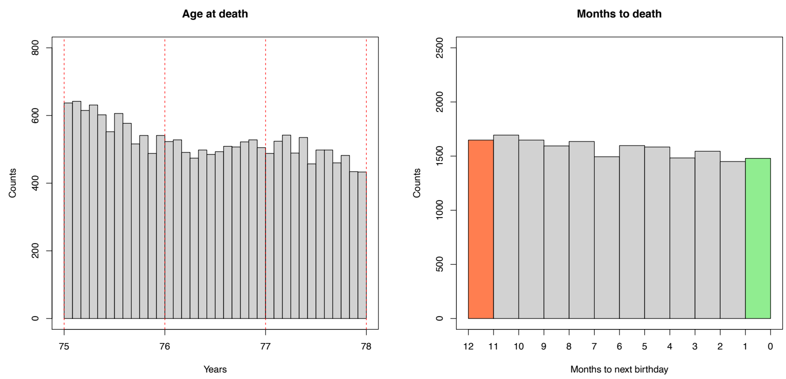

Fig. 1. Left plot: histogram of the number of deaths during a year for different ages. Right plot: histogram of the same data grouped into months. MCD-2015 dataset [2].

2 Data and pre-processing

We worked with the Mortality and Causes of Death in South Africa MCD-2015 dataset [2] which contains over 422 thousand records of death occurred in 2015 (or earlier, but reached Stats SA governmental agency in 2015) in South Africa. Just over 1700 records had missing birth dates and were excluded from the analysis. Also excluded were deaths caused by accidents since no death postponement could be expected for these. We also limited ourselves to people who died aged between 49 and 81 years. This left us with the total number of 204,367 natural death records to work with. We think that older people should be more concerned about their soon eminent death and express the postponement more clearly, if it exists. As for the people who died at age 82 or more (about 13% of all the deaths), the number of their deaths around birthday is too small to make any statistically credible statements about a subtle death rate changes assumed by the postponement phenomenon.

3 Theoretical model

We assume that each living person aged x is exposed to an instantaneous death rate $h(x)$ depending on the age and possibly on the absolute time, so that the probability that a person of age x survives to the age $x + \Delta x$ is $1 - h(x)\Delta x + o(\Delta x)$. Thus, if τ denotes the life duration of a randomly uniformly selected newborn, then the *Survival function* is given by

$$S(x) = \mathbf{P}\{\tau > x\} = \exp\{-\int_0^x h(y)\, dy\}. \quad (1)$$

Obviously, the p.d.f. $f_\tau(x)$ of τ and $S(x)$ are related through

$$h(x) = \frac{f_\tau(x)}{S(x)} \quad (2)$$

which is the definition of the *hazard function*. Assuming that new births happen in time as a Poisson point process with a rate ν, generally depending on time, the death records $\{(t_i, x_i)\}$, describing a person i to die at time t_i aged x_i, is a Poisson point process with the intensity function $\mu(t,x) = \nu f_\tau(x)$ in $\mathbb{R} \times \mathbb{R}_+$. Thus the number of deaths of people aged between x and $x + \Delta x$ years during a time interval of length s is Poisson distributed with parameter $s\nu\,(S(x) - S(x+\Delta x)) = s\nu\, S(x)h(x)\Delta x + o(\Delta x)$ and the death counts are independent for disjoint age ranges.

The birth rates are known to exhibit a seasonality. Assuming that people born in different time of the year have the same tendency towards the death postponement, when counted from an anniversary, the yearly pattern averages to a profile which would show the same susceptibility to the postponement. Thus, for its detection, we may assume that the parameters ν and h do not dependent on the absolute time t since, when related to an anniversary, they are averaged over the year.

A popular distribution to describe the remaining lifetime after attaining a certain age a is the *generalised Pareto* $\mathsf{GP}(\xi, a, \sigma)$-distribution, for which

$$S(x) = \Big(1 + \frac{\xi(x-a)}{\sigma}\Big)^{1/\xi};$$
$$\frac{1}{h(x)} = \sigma + \xi(x-a). \tag{3}$$

When $\xi = 0$, the hazard is constant and $S(x) = \exp\{-(x-a)/\sigma\}$ so that $\tau - a$ is Exponentially $\mathsf{Exp}(1/\sigma)$-distributed. As we will see in Section 4.2 below, the linear form of the inverse hazard $1/h$ agrees with our data suggesting a GP-distribution for the remaining lifetime after a person turns 50 years old.

4 Methods and analysis

We employ two methods to detect possible postponement phenomenon: Poisson regression to estimate the Poisson process intensity $\mu(t,x)$ above and fitting the hazard function suggested by the GP-distribution.

4.1 Modeling the counts

The counts of deaths for each day lived after the 49th anniversary is shown at the upper plot on Figure 2.

Our approach consists in fitting a linear model to

$$\log \mu(t,x) = \log \nu + \log f_\tau(x)$$

not counting the people who died within 7 days before, at and within 7 days after the birthday. We then analyse the residuals produced by the fitted model for these days around the birthday to see if their mean is significantly different from the residuals of the other days. The death postponement would mean that the residuals for the days prior to birthdays are on average smaller and within

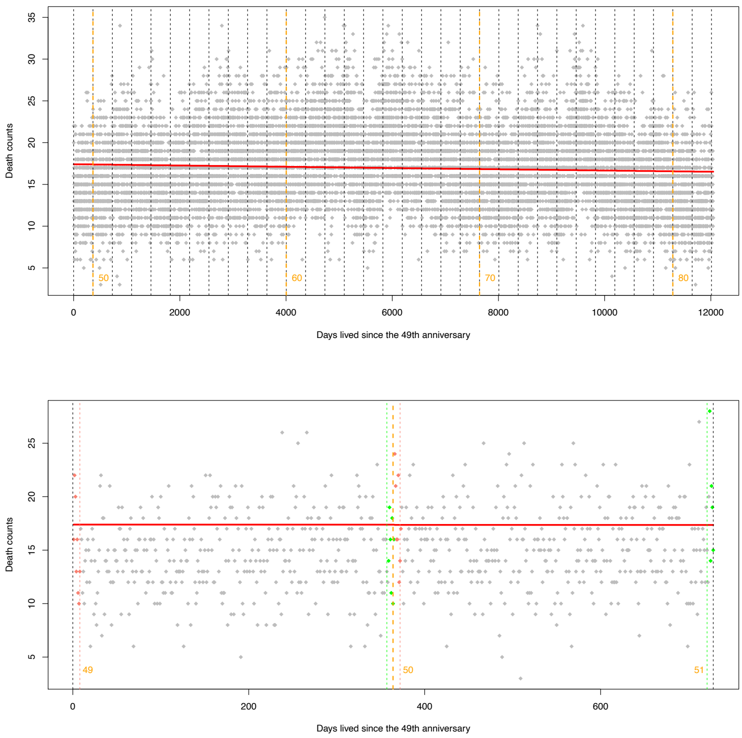

Fig. 2. Top: the death counts for each day between the ages from 49 to 81 years old. Bottom: similar, but from 49 to 51 years old only.

the week after, perhaps, larger than the residuals for the other days. That would indicate a dip in the number of deaths prior to the birthdays possibly followed by a peak just after it.

The estimated exponential curve for μ using generalised linear model fitting with Poisson distribution is shown in red on the top plot on Figure 2. The two-sample t-test was used for assessment of the presence of dips or peaks. We found that there is no significant peak after the birthday (p-value $= 0.13$), but contrarily to the postponement hypothesis, we found a significant *peak before* the birthday (p-value $= 0.05$). The residual deviance was 13529 on 11547 degrees of freedom which indicates over-dispersion in the Poisson regression. Therefore the quasi-Poisson family as well as the negative binomial regression were also tried which, however, did not vary much from the Poisson model and gave the same result. We may argue that the age only partly explains the mortality: a significant part of the variation is due to other factors, in particular, the mentioned seasonality of the true birth rate.

The shape of the data on the upper plot on Figure 2 suggests that there may be some extra curvature not explained by the Poisson model on the whole data range and hence its conclusions may not be accurate. Therefore we proceed with analysis of each year individually: for y ranging from 50 to 81, we fit a Poisson model to the number of deaths at the ages from anniversary $y-1$ plus one week to anniversary $y+1$ minus one week *excluding* deaths at the age of one week around anniversary y. Only one anniversary showed a significant dip before birthday (p-value less than 0.05). Also one anniversary showed a peak before birthday and 4 had p-value below 10%. Four anniversaries showed a peak after birthday (and 7 had p-value less than 10%). For 32 years considered, 4 peaks or dips is not a significant figure: the probability for the binomially distributed random variable with $n = 32$ and $p = 0.05$ to take values 4 or more is 0.074, this is the Binomial test. On the other hand, it is a 90%-significant figure, since the probability for the binomially distributed random variable with $n = 32$ and $p = 0.1$ to take values 7 or more is 0.036. Strictly speaking, the binomial test is not applicable since the consecutive years $y, y+1$ use the same data between y and $y+1$ to estimate the regression. However, taking just the even years still gives the same number of peaks after the birthday.

We also noted that excluding two weeks before and after the birthday when constructing the model or excluding 3 days before and after instead of one week marks as significant exactly the same years as one week before-after analysis does.

To conclude, the counts modelling using Poisson and negative binomial regression around each anniversary indicates that more people are dying in the week after the birthday and the all years range model indicates that more people than could be expected are dying within one week before birthday.There is no postponement phenomenon exhibited by the data.

4.2 Modelling the hazard function

Another method to verify the postponement phenomenon is to detect if the hazard function h, which is the death rate at each age, has a dip prior to birthdays. It is common to use the Kaplan–Meier estimator [3] of the hazard function, but in the absence of censoring (all the people in the dataset have died in 2015), it is equivalent to the following estimators:

$$\hat{h}(k) = \frac{d_k}{\hat{S}(k)}, \; k = 0, 1, \dots \quad \text{with}$$
$$\hat{S}(k) = \frac{1}{n} \sum_{i=k+1} d_i,$$

where d_i is the number of deaths at the age of $i = 0, 1, \dots$ days and $n = \sum_{i=0} d_i$.

The estimated hazard $\hat{h}$ and its inverse $1/\hat{h}$ for the people who died at the age of 50 to 80 years are presented in Figure 3. The observed parabola-like curves correspond to the same number of deaths recorded during one day: if, say, $d_k = d_{k+1} = d$, then $\hat{h}_k = d/(d + \hat{S}_{k+2})$ and $\hat{h}_{k+1} = d/\hat{S}_{k+2}$ are lying on a parabola and $|\hat{h}_k - \hat{h}_{k+1}| = O(1/\hat{S}_{k+2}^2)$. It would be approximately a parabola if the days with the same number of counts are not consecutive. If $d_k = k$ and $d_{k+1} = d+1$, then $|\hat{h}_{k+1} - \hat{h}_k|$ is of order $1/\hat{S}_{k+2}$ and $\hat{h}_{k+1}$ is lying on the next curve above corresponding to $d+1$ deaths during a day.

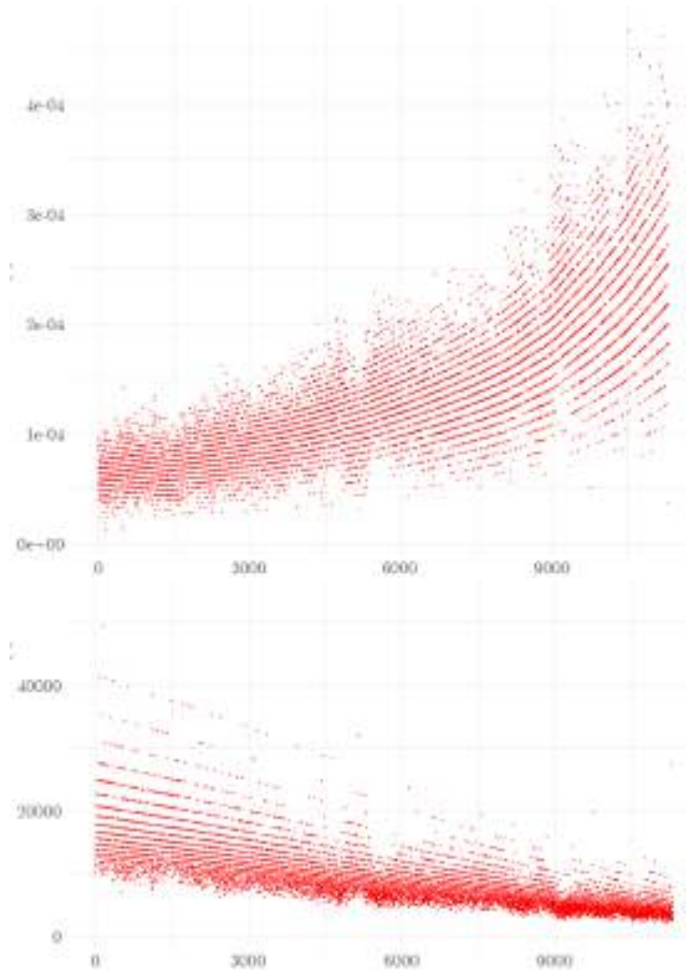

Fig. 3. Estimated hazard function h and $1/h$ for the days after the 50th anniversary.

The shape of the lower graph suggests that $1/h$ is linear, i.e. the lifetime remaining after attaining 50th anniversary conforms to a Generalised Pareto distribution (3). To make it more certain, we smoothed $1/\hat{h}$ over one week intervals and computed 95% confidence intervals using bootstrap method. The resulting graph, shown on Figure 4, prompts to use a linear model to fit $1/\hat{h}$.

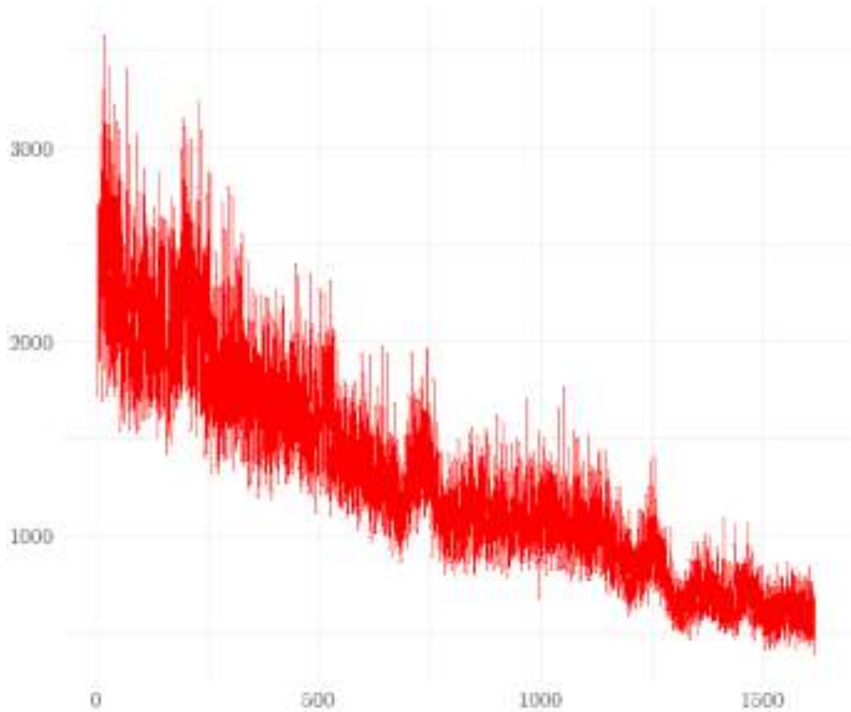

Fig. 4. Graph of $1/h$ smoothed over one week interval with vertically drawn 95% bootstrap estimated confidence intervals. The timescale – weeks.

Another approach consists in using the generalised Gamma-family linear model to fit h directly since the inverse tranformation is its natural link. Once the linear model is accepted, it would mean the generalised Pareto distribution for the residual lifetime over 50 years of age.

Arguing as in the Poisson model fitting above, even if the linear model for $1/h$ might be a too strong assumption for the whole range of deaths at 50-80 years age, it should be a good approximation for shorter periods. So we analyse separately deaths at the ages $y-1, y+1$, where y ranges from 50 to 80. We fit both a linear model to $1/h$ and a generalised gamma-family linear model to h *excluding* the deaths 2 weeks before and 2 weeks after the anniversaries. We decided that 2 weeks is more appropriate here than 1 week in the Poisson model analysis above to account for dependence of $\hat{h}_i$'s: close days i have a similar denominators $\hat{S}_i$'s.

As for the Poisson regression in the precious section, we proceed with examining the residuals produced by the predicted values of these models for omitted data before and after birthday and compare their means to the rest of the residuals. We obtained the following results presented in Figure 5. As we see that according to linear modeling of $1/h$, there are 13 significant peaks before birthday and 12 after birthday that is, according to the binomial test

	Before BD		After BD			Before BD		After BD	
Age	LM	GLM	LM	GLM	Age	LM	GLM	LM	GLM
50	Peak	-	-	-	65	-	-	Peak	-
51	Peak	-	Peak	-	66	Peak	-	-	-
52	Peak	Peak	Peak	Peak	67	-	-	-	-
53	Peak	-	-	-	68	-	-	Peak	Peak
54	-	-	-	-	69	Peak	Peak	-	-
55	-	-	Peak	-	70	-	-	-	-
56	Peak	-	-	-	71	-	-	Peak	Peak
57	-	-	-	Dip	72	Peak	Peak	-	Dip
58	-	Dip	-	-	73	Dip	Dip	Peak	-
59	-	-	-	-	74	Peak	-	-	Dip
60	-	-	Peak	-	75	-	-	Peak	Peak
61	Peak	Peak	-	-	76	Peak	-	-	-
62	-	-	-	Dip	77	-	Dip	Peak	Peak
63	-	Dip	Peak	Peak	78	Peak	Peak	-	-
64	Peak	Peak	-	-	79	-	-	Peak	-

Fig. 5. 95%-significant periods before and after birthday according to a linear model (LM) fitting $1/h$ and according to a generalised linear model (GLM) fitting h for people died from 49 to 80 years old.

with p-value of 5%, a highly significant figure for 31 anniversaries considered. Notably, the same years which were identified by the Poisson regression in the previous section are also appearing here. The generalised linear model is more conservative, but still gives 6 significant peaks before and 6 after birthday. The observed 4 dips is not a significant number when working with 95% confidence level.

5 Conclusion and critique

We verified validity of the death postponement theory on a dataset consisting of over 204 thousand records of deaths from natural causes in South Africa in 2015. We took person's birthday as an important event a person tries to survive to, and studied the death rates just before and after the birthday. If a death postponement phenomenon exists, it would manifest itself in a lower than expected death rate just before birthday (a dip), perhaps, followed by a higher rate (peak) at the birthday and just after it. We employed a Poisson model to estimate the number of deaths at each day to verify this hypothesis and also analysed the hazard function by linear and generalised linear models. We found *no confirmation* of the postponement phenomenon for this dataset, for the birthday as an important event and for the timescale of a few days. On the contrary, the death rate is found to be higher both before and soon after the birthday. This might be explained by the stress of expectations for the birthday and/or an earlier start of celebrations with associated departure from the recommended regime.

As a byproduct of our analysis, we found that the models of mortality based only on the age explained at most 60% of the variation in the death counts. Thus the age is an important, but not the only determining factor of the death hazard.

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