Does seasonal mortality have an impact on life expectancy trends? The case of Italian regions

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Extended Abstract

Introduction

Short-term events, such as intra-annual fluctuations including seasonal mortality, may affect mid and long-term longevity trends (Ballester et al. 2019, Rau 2004). However, the majority of mortality studies focus on annual estimates, masking seasonal mortality changes. As a result, the impact of different short-term factors on mortality trends remains largely unclear (Ballester et al. 2019). Particularly, heightened attention to this topic emerged during the recent COVID-19 pandemic, highlighting the significance of understanding the intricate dynamics of mortality variations beyond annual metrics.

The role of seasonal mortality in shaping long-term mortality trends is still mostly unclear, especially during the last decades. Its influence extends beyond meteorological factors and encompasses a range of determinants, such as socio-economic status, educational attainment, urbanization, and economic growth (Burkart 2011). The investigation of this topic is especially important for ageing populations, where the growing older population also increases the number of people at higher risk of dying during extreme temperature events, like flu epidemics during winter time and heatwaves during summer months (Ballester et al. 2011, Gardener et al. 2016, Ledberg 2020).

Furthermore, climate change is likely to increase the frequency and intensity of heat waves (Kovats and Hajat 2008). Although the spatial pattern of extreme weather-attributable mortality is similar at the beginning and at the end of the 21st century, the magnitude of the changes between European regions is substantially different (Martínez-Solanas et al. 2021). Moreover, the inequality in a person's vulnerability to climate change is linked to their exposure, sensitivity, and adaptive capability (SwissRe Institute 2023), potentially resulting in a heterogeneous pattern of the impact of extreme temperatures on mortality.

Most of the existing studies emphasize temperature-attributable mortality, modelling the seasonal variation and quantifying the seasonal excess mortality at the national level (Martinez-Solanas et al. 2021, Quijal-Zamorano et al. 2021, Madaniyazi et al. 2022). Literature on subnational entities is lacking, except for state-level analyses of the United States (Rau 2004) and mortality projection scenarios for European regions (Ballester 2011).

Regarding Italy, the country in the last decades underwent several fluctuations in life expectancy at birth due to short-term events, such as the economic crisis (Salinari et al. 2023), heatwaves (Conti et al. 2005, Kosatsky 2005) and extreme winter temperatures (Rosano et al. 2019). Furthermore, a mortality divergent pattern within the country was observed in the last

20 years. The pace of the increase in life expectancy in the north-eastern and central Italian territories had been more rapid than the one in the north-western and southern regions. A study by Rizzo and colleagues (2007) analysed age-specific patterns of death from influenza (pandemic or epidemic) between 1969 and 2001 in Italy. The research found that the elderly population was more affected in all epidemic influenza seasons, while there was a shift to younger people during the 1969-70 pandemic. However, when they compared northern, central, and southern Italy, the amplitude of peaks of influenza-related deaths were very similar.

Our objective is to estimate whether there was a change in the impact of seasonal mortality on mortality at the subnational level. Specifically, we analysed how winter and summer mortality are interrelated with the annual life expectancy trends. The results will help in understanding whether changes in seasonal mortality have contributed to shaping the current life expectancy trends and identifying territories most affected by seasonal fluctuation of mortality.

Data and Methods

The data used in the analysis were retrieved from the Italian National Statistical Office (ISTAT). Specifically, we used monthly death counts by region and 5-year age group, from 2003 to 2019 and yearly subnational population estimates on the 1st of January.

To study the contribution of each season to the change in life expectancy at the subnational level, we used the stepwise decomposition method (Andreev et al. 2002) applied to groups of months, referring to the meteorological division of the year (Winter: Dec-Jan-Feb, Spring: Mar-May, Summer: Jun-Aug, Autumn: Sept-Nov).

The baseline mortality schedule adopted was based on the three months with the lowest mortality rates of the year for the specific region, hence we obtained an "ideal" level of mortality for each year and region. In this way, we have an insight into the contribution of seasonal mortality variations on life expectancy at birth with respect to the baseline "best" mortality schedule, the one we would observe in the absence of seasonal risk factors.

Moreover, standardized death rates (SDR) were calculated using the 2003 European Standard Population. We computed the winter and summer ratios as:

$$R^{i}_{r,t} = \frac{SDR^{i}_{r,t}}{SDR_{r,t}},$$

where $SDR^{i}_{r,t}$ are the SDR in season $i = winter\ (R^{w}_{r,t}), summer\ (R^{s}_{r,t})$ in region r, and year t; $SDR_{r,t}$ are the annual standardized death ratios in year t region r.

The winter/summer ratio is computed as:

$$R^{\frac{w}{s}}_{r,t} = \frac{SDR^{w}_{r,t}}{SDR^{s}_{r,t}}$$

The index assumes a value equal to 1 when there is no difference between winter and summer mortality, while values > 1 correspond to higher winter mortality. To detect the trend, we use the OLS regression method and 95% confidence intervals are computed.

Results

Trends in seasonal excess mortality

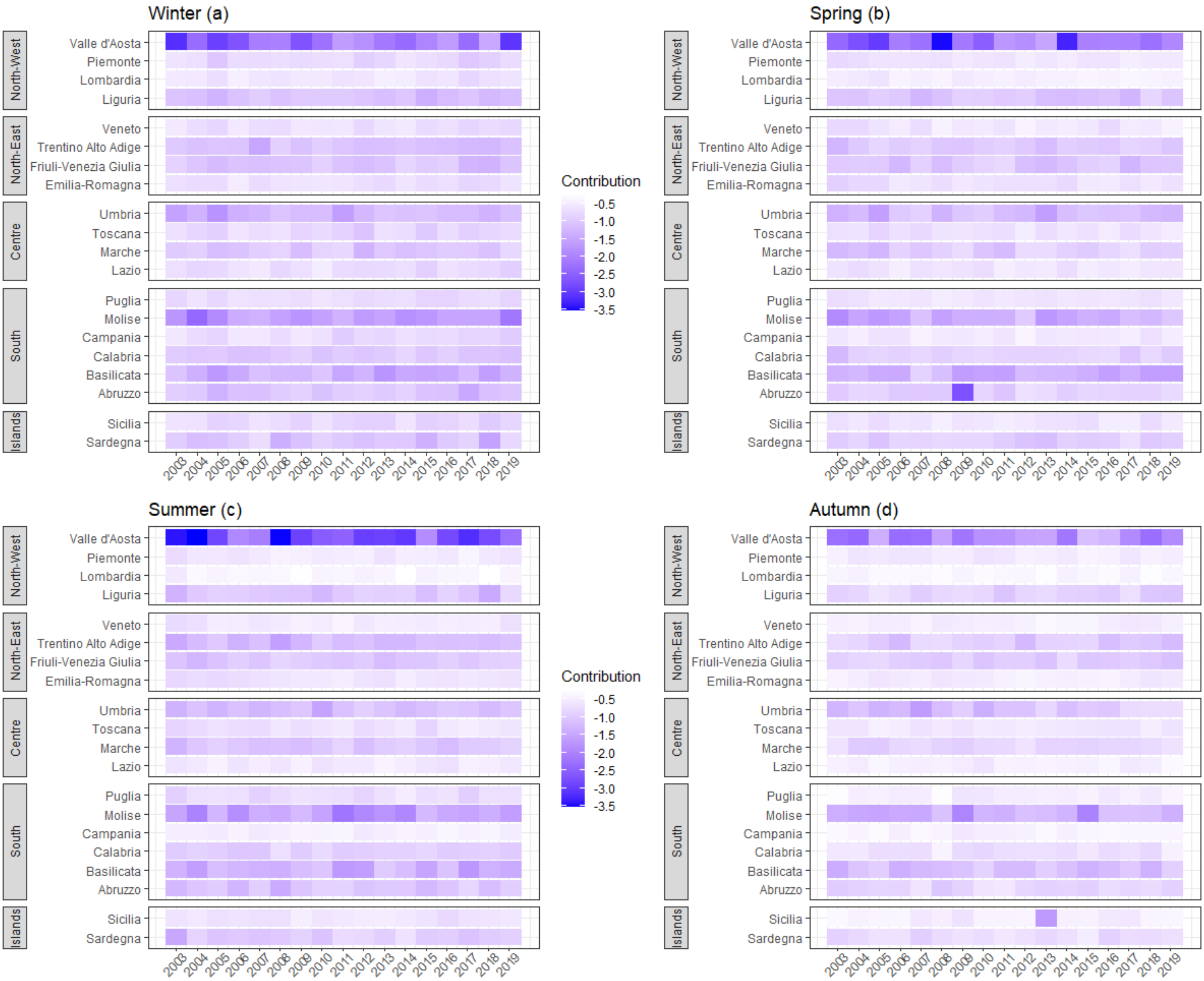
The excess mortality attributed to seasonal risk factors was estimated as seasonal components of decomposition of difference between the "ideal" life expectancy based on the mortality schedule of the three best months and the observed life expectancy. The four panels of Figure 1 represent the seasonal contributions by region and year. Lighter tile colors denote lower values of the contribution to the difference in life expectancy at birth, hence values closer to the baseline mortality schedule based on the three months with the lowest mortality for that region in that year. Darker colors, instead, reflect a greater heterogeneity within the year. The results for Valle d'Aosta and Molise should not be used to draw conclusions, as the regions' populations are too small (ca. 120 thousand inhabitants in the first, ca. 290 thousand in the latter) and results are affected by random fluctuations.

Overall, we can observe a heterogeneous pattern of contribution values between the regions in all four seasons, while the seasonal differences, although existent are less visible. The graph shows that there is no significant trend in the contribution to the change between the observed seasonal life expectancy and the hypothetical life expectancy based on the best mortality-performing months. This result confirms that despite winter and summer mortality peaks in specific years, the influence of seasonal risk factors throughout the year didn't change in the last 20 years.

However, the size of the seasonal contribution varies by region. In winter, there are some regions such as Lombardia (North-East), Emilia-Romagna and Veneto (North-West) that report a value of the contribution smaller than 1 year, while territories like Umbria (Centre) and Basilicata (South) have more than 1.3 years winter contribution to the difference between observed and the ideal life expectancy level. During summertime, the situation is quite similar with northern regions (with the addition of the southern region of Campania) that report the lowest values of the contribution. Moreover, with this type of representation, we can highlight specific outliers, such as the exceptionally higher mortality contribution in Abruzzo in the spring of 2009, due to the catastrophic earthquake in April of that year.

It should be highlighted that in this type of analysis, the choice of the baseline mortality has a fundamental impact on the estimates obtained, therefore the absence of a temporal trend might be caused by the baseline chosen.

Figure 1. Seasonal decomposition of difference in life expectancy between observed data and virtual mortality schedule based on best three months per year, Italian regions, 2003-2019



Winter and summer mortality ratios

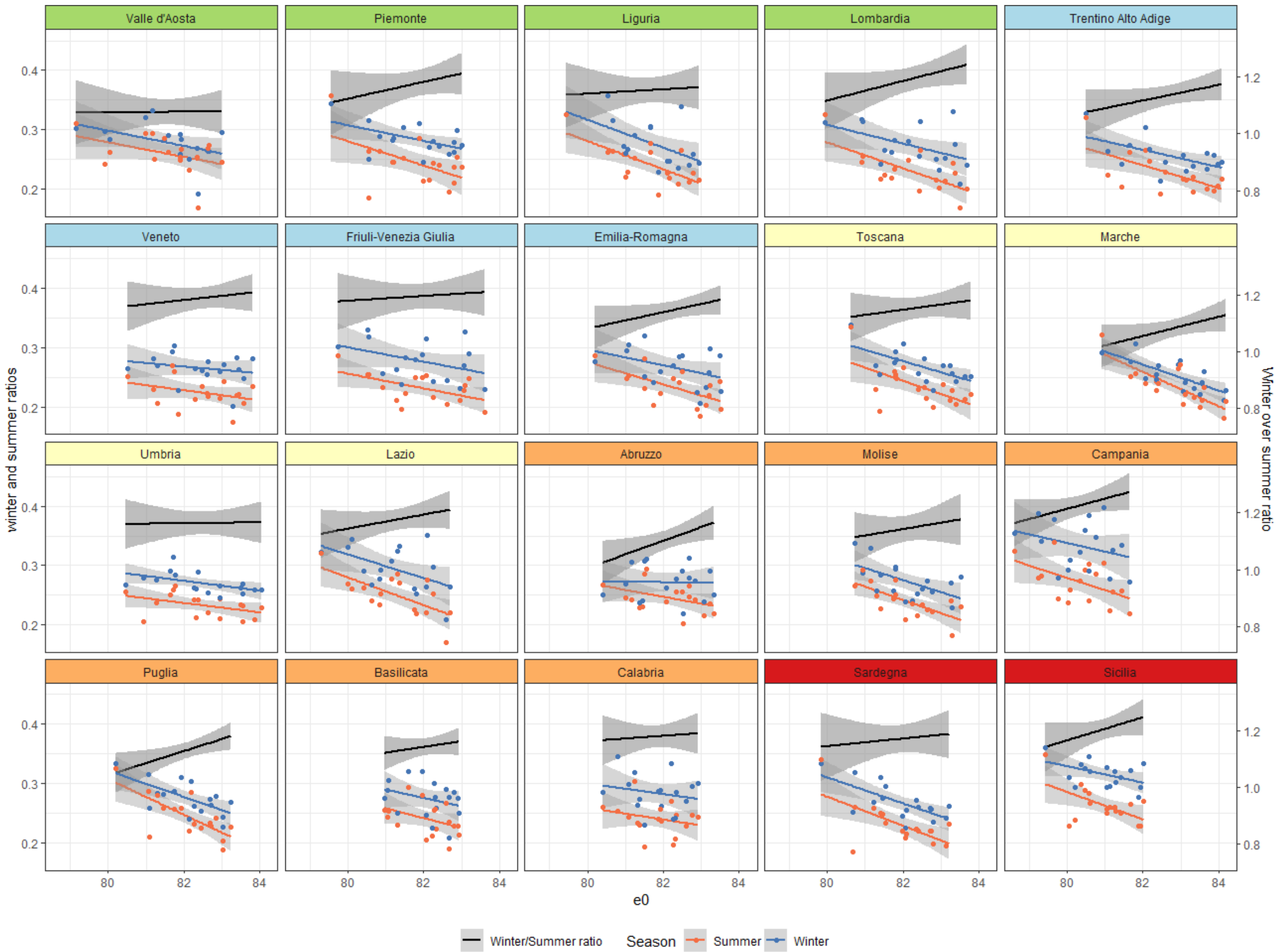
The analysis of the winter $\left(R_{r,t}^{w}\right)$ and summer $(R_{r,t}^{s})$ mortality rate ratios allows obtaining another insight into the relationship between the seasonality and the longevity trends observed in the Italian regions in the last 20 years (Figure 2). In the graph presented, the Italian regions are divided into groups of regions: North-East in green, North-West in blue, Centre in yellow, South in orange and Islands in red. The value of the ratios presented depends on observed life expectancy at birth. Additionally, on the second y-axis, it is shown the ratio of winter over summer SDR, to provide an understanding of the trend in the difference between the impact of these two seasons.

The graph shows that overall, the winter mortality ratio is almost always higher than the one observed in summer and that with an increase in life expectancy, there is also a reduction in both winter and summer mortality. However, the pattern is not clear and straightforward for all the regions, with specific peaks of winter and summer mortality ratios throughout the considered period.

The heatwave of 2003 is well visible for almost all the territories. Indeed, this year, the summer ratios are closer, if not even higher, than those in winter (with the exception of the southern regions of Campania and Calabria). The extremely high mortality due to the flu epidemic in 2015, on the other hand, seems to be evenly distributed around all seasons and not only during colder months. In fact, in this year, a lower value of winter mortality ratio is observable throughout the whole country (around 25 percent winter attributable mortality) with respect to the overall period considered.

Furthermore, if we analyse the ratio between winter and summer mortality (on the graph presented in the second y axis), we can observe a significant increase of the index as the life expectancy increases for almost all regions. For the majority of the territories, the winter/summer ratio is around 1 at the beginning of the period and reaches values of 1.3/1.4 at the end, meaning growing importance of the winter attributable mortality.

Figure 2. Winter and summer mortality ratios and winter over summer mortality rate ratio depending on life expectancy at birth, Italian regions, 2003-2019



Bibliography

Ballester J, Robine JM, Herrmann FR, Rodó X. Effect of the Great Recession on regional mortality trends in Europe. Nat Commun. 2019 Feb 8;10(1):679.

Rau R. Seasonality in human mortality: a demographic approach. Berlin; New York: Springer; 2007. 214 p. (Demographic research monographs).

Burkart K, Khan M, Krämer A, Breitner S, Schneider A, Endlicher W. Seasonal variations of all-cause and cause-specific mortality by age, gender, and socioeconomic condition in urban and rural areas of Bangladesh. International Journal for Equity in Health. 2011;10:32–32.

Ballester J, Robine JM, Herrmann FR, Rodó X. Long-term projections and acclimatization scenarios of temperature-related mortality in Europe. Nat Commun. 2011 Jun 21;2(1):358.

Gardner JL, Amano T, Sutherland WJ, Clayton M, Peters A. Individual and demographic consequences of reduced body condition following repeated exposure to high temperatures. Nevitt GA, editor. Ecology. 2016 Mar;97(3):786–95.

Ledberg A. A large decrease in the magnitude of seasonal fluctuations in mortality among elderly explains part of the increase in longevity in Sweden during 20th century. BMC Public Health. 2020 Dec;20(1):1674.

Kovats RS, Hajat S. Heat stress and public health: a critical review. Annu Rev Public Health. 2008;29:41-55. doi: 10.1146/annurev.publhealth.29.020907.090843. PMID: 18031221.

Martínez-Solanas È, Quijal-Zamorano M, Achebak H, Petrova D, Robine JM, Herrmann FR, et al. Projections of temperature-attributable mortality in Europe: a time series analysis of 147 contiguous regions in 16 countries. The Lancet Planetary Health. 2021 Jul;5(7):e446–54.

SwissRe. 22 May 2023. The future of life expectancy, Forecasting long-term mortality improvement trends for insurance. [press release]

Sakamoto-Momiyama M. Changes in the seasonality of human mortality: a medico-geographical study. Soc. Sci. & Med. 1978 Vol 12. pp. 29 to 42. Pergamon Press

Quijal-Zamorano M, Martínez-Solanas È, Achebak H, Petrova D, Robine JM, Herrmann FR, et al. Seasonality reversal of temperature attributable mortality projections due to previously unobserved extreme heat in Europe. The Lancet Planetary Health. 2021 Sep;5(9):e573–5.

Madaniyazi L, Chung Y, Kim Y, Tobias A, Ng CFS, Seposo X, et al. Seasonality of mortality under a changing climate: a time-series analysis of mortality in Japan between 1972 and 2015. Environ Health Prev Med. 2021 Dec;26(1):69.

Salinari G, Benassi F, Carboni G. The Effect of the Great Recession on Italian Life Expectancy. *Population Research and Policy Review*, 2023 *42*(1), 3.

Conti S, Meli P, Minelli G, Solimini R, Toccaceli V, Vichi M, et al. Epidemiologic study of mortality during the Summer 2003 heat wave in Italy. Environmental Research. 2005 Jul;98(3):390–9.

Kosatsky T. The 2003 European heat waves. *Eurosurveillance*, 2005 *10*(7), 3-4.

Rosano A, Bella A, Gesualdo F, Acampora, A, Pezzotti P, Marchetti S et al. Investigating the impact of influenza on excess mortality in all ages in Italy during recent seasons (2013/14–2016/17 seasons). *International Journal of Infectious Diseases*, 2019 *88*, 127-134.

Rizzo C, Bella A, Viboud C, Simonsen L, Miller MA, Rota MC et al. Trends for influenza-related deaths during pandemic and epidemic seasons, Italy, 1969–2001. *Emerging infectious diseases*, 2007 *13*(5), 694.

Menotti A, Mulder I, Nissinen A, Giampaoli S, Feskens EJ, Kromhout D. Prevalence of morbidity and multimorbidity in elderly male populations and their impact on 10-year all-cause mortality: The FINE study (Finland, Italy, Netherlands, Elderly). *Journal of clinical epidemiology*, 2001 *54*(7), 680-686.