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Descriptive Finding

Winter life expectancy reduction in Europe

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Abstract

BACKGROUND
Mortality is known to be higher in winter than in summer, with excess winter deaths ranging between 5% and 30% in Europe. A recent study conducted in the USA sought to quantify the excess winter mortality in terms of life expectancy reduction, by calculating the difference between summer and winter life expectancy.

OBJECTIVES
We aimed to calculate Winter Life Expectancy Reduction (WLER) in Europe, illustrate the extent to which this indicator depends on definitions of summer and winter, introduce a novel indicator of WLER based on a statistical model accounting for country-specific seasonal cycles, and compare men and women in terms of WLER.

METHODS
WLER indicators were calculated from weekly mortality data in 24 European countries over the period 2000–2019.

RESULTS
On average, WLER was a few months higher in Europe than in the USA, while depending heavily on country and sex, as well as the chosen indicator. Our model-based indicator measured the highest WLER values, ranging from 11 months (Finnish men) to 36 months (Portuguese women), with a European average of 18 months for men and 22 months for women. In most countries, WLER was higher for women than for men, regardless of the indicator used.

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CONTRIBUTION

This is the first study to calculate WLER in Europe. It raises the intriguing scientific question of why women have a greater WLER than men. While life expectancy remains systematically higher in summer than in winter, our model also revealed a decline at the height of summer in Mediterranean countries.

1. Introduction

It has long been known that mortality is higher in winter than in summer (Guy 1881; Rau 2007) due to cold exposure (Keatinge et al. 1997), although "few people die of cold as such, but many die of related illnesses" (Grut 1987), such as influenza (Fleming 2000; Reichert et al. 2004). This issue has received particular attention in the United Kingdom (Keatinge, Coleslaw, and Holmes 1989; Curwen 1990; Laake and Sverne 1996) but has also been observed "in many countries in almost every year" (Rau 2007: 5), including most European countries (McKee 1989; Healy 2003; Fowler et al. 2015).

To quantify excess winter mortality, the latter authors use an indicator of Excess Winter Death (EWD), calculated as a ratio (A-B)/B, where A is the number of deaths observed from December to March, and B is half the number of deaths in the remaining months. Most countries in Europe have an EWD of between 5% and 30% (Healy 2003) and this has remained stable over recent years (Fowler et al. 2015). On the other hand, EWD varies considerably from country to country, with the striking result that it is generally higher in Mediterranean countries, i.e., countries with warmer winters, than in Nordic countries (except for the United Kingdom). This is called the 'excess winter paradox', which can be partially explained by better home insulation in colder countries (Healy 2003), particularly in Scandinavia (McKee 1989).

Another well-known indicator for summarizing mortality is Life Expectancy (LE). Ho and Noymer (2017) introduce the concept of 'pseudo-seasonal' summer and winter LE, defined as the LE at birth that would be achieved by individuals living their entire lives in summer, and respectively in winter. Considering 6 months of summer and winter, they calculate the difference between summer and winter LE in the USA over the period 1959–2014 and find an average of about 8 months for men and 1 year for women. This is an alternative indicator for quantifying excess winter mortality, hereinafter referred to as Winter Life Expectation Reduction (WLER), which is expressed on an absolute scale (in months or years), while EWD is expressed on a relative scale (in %).

To our knowledge, the only other study that has attempted to quantify seasonal impacts on mortality in terms of reduced LE is that of Marinetti et al. (2025). These authors do not calculate a difference between summer and winter LE, but rather compare an annual LE to an 'upper LE' calculated over the 13 weeks with lowest mortality for a given year, sex, and country in Europe over the period 2000–2019.

Our first objective in what follows is to calculate WLER in Europe using Ho and Noymer's indicator. Another objective is to illustrate the extent to which this indicator depends on the different possible definitions of summer and winter. A third objective is to introduce a novel WLER indicator that compares LE at best (summer) and worst (winter) times in the year, using a statistical model to account for specific seasonal cycles in the different countries. In all analyses, we also pay particular attention to the difference between men and women in terms of WLER.

2. Data

We used weekly mortality data (number of deaths) by country, sex, and 5-year age group (0–4, 5–9, …, 85–89, with a last open age group of 90+), and annual population size (on January 1) by country, sex, and age from Eurostat (2024a, 2024b). We included 24 European countries with available data, namely Austria (AT), Belgium (BE), Bulgaria (BG), Switzerland (CH), Czechia (CZ), Denmark (DK), Estonia (EE), Greece (EL), Spain (ES), Finland (FI), France (FR), Croatia (HR), Hungary (HU), Italy (IT), Lithuania (LT), Latvia (LV), the Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Sweden (SE), Slovenia (SI), Slovakia (SK), and the United Kingdom (UK). A few countries were not included, such as Germany because no mortality data by sex and below age 40 was available, Ireland because no mortality data by age was available, and Iceland and Luxembourg because of the high variability in these small countries. Weekly mortality data were available for all years between 2000 and 2019 in most countries. Exceptions were Croatia (data available only from 2001), Czechia (from 2005), Denmark (from 2007), Italy (from 2011), France (from 2013), Greece and the United Kingdom (from 2015). We did not consider mortality data after 2019 to avoid COVID-19 confounding our analysis.

3. Methods

Let D_{ywa} be the number of deaths for age group a in week w of year y for a given country and sex, and N_{ya} the corresponding population size on January 1 of that year. The mortality rate for age $i = 0,\ldots,110$ in week w of year y was approximated as $m_{ywi} = (365.25/7) \cdot D_{ywa(i)}/N_{ya(i)}$, where $a(i)$ denotes the age group a to which age i belongs, thus assuming a constant population throughout the year (as, e.g., in Marinetti et al.

2025). A weekly LE at birth e_{yw} was calculated from the m_{ywi} using standard life table calculations (Preston, Heuveline, and Guillot 2001: Chapter 3).

All WLER indicators were calculated from these e_{yw}, as described below and implemented in the supplied R code. Summer and winter LE in year y were calculated by averaging the e_{yw} over weeks w attributed to summer, and respectively to winter. We considered different definitions of summer and winter. In a first definition, six months (May to October) were attributed to summer (weeks 18–43) and six months (November to April) to winter (weeks 1–17 and 44–52), as done in Ho and Noymer (2017). In a second definition, following Healy (2003) and Fowler et al. (2015), eight months (April to November) were attributed to summer (weeks 14–48) and four months (December to March) to winter (weeks 1–13 and 49–52). In a third definition, three months (mid-June to mid-September) were attributed to summer (weeks 25–37) and three months (mid-December to mid-March) to winter (weeks 1–11 and 51–52), corresponding to a traditional division of the year into four seasons of 13 weeks. In years with 53 weeks (2004, 2009, 2015), week 53 was attributed to winter. Differences between summer and winter LE were calculated for each year and averaged over available years for each country and sex, obtaining three variants of WLER indicators, one for each definition of summer and winter. The first variant corresponded to Ho and Noymer's original indicator.

To study specific seasonal effects on weekly LE in the different countries, we fitted regression models to the e_{yw}, separately for each country and sex. We considered the following regression equation:

$$e_{yw} = \beta_0 + \beta_1 \sin(2\pi f) + \beta_2 \cos(2\pi f) + \beta_3 \sin(4\pi f) + \beta_4 \cos(4\pi f) + \beta_5 (y + f) + \beta_6 (y + f)^2 + \varepsilon_{yw}. \quad (1)$$

In (1), $f = (w - 0.5)/n(y)$ represents the fraction of the year elapsed until week w, where $n(y)$ is the number of weeks (52 or 53) in year y. Sine and cosine terms in (1) model the average LE seasonal cycle, with typically higher LE in summer and lower LE in winter. Two sine and cosine terms were introduced to allow sufficient flexibility, so that a 'peak' was not necessarily followed by a 'trough' exactly six months after. A fourth and novel WLER indicator was obtained as the LE difference between the best (peak) and worse (trough) times in the year, as fitted by the model. Linear and quadratic terms in (1) account for the secular increasing trend of LE over the years, while ε_{yw} is a residual error capturing the autocorrelation between consecutive weeks using a first-order autoregressive process. Sensitivity analyses, ignoring autocorrelation or the quadratic term in (1), yielded similar results. Model (1) was estimated with the *arima* function of the R statistical package (version 4.3.1).

4. Results

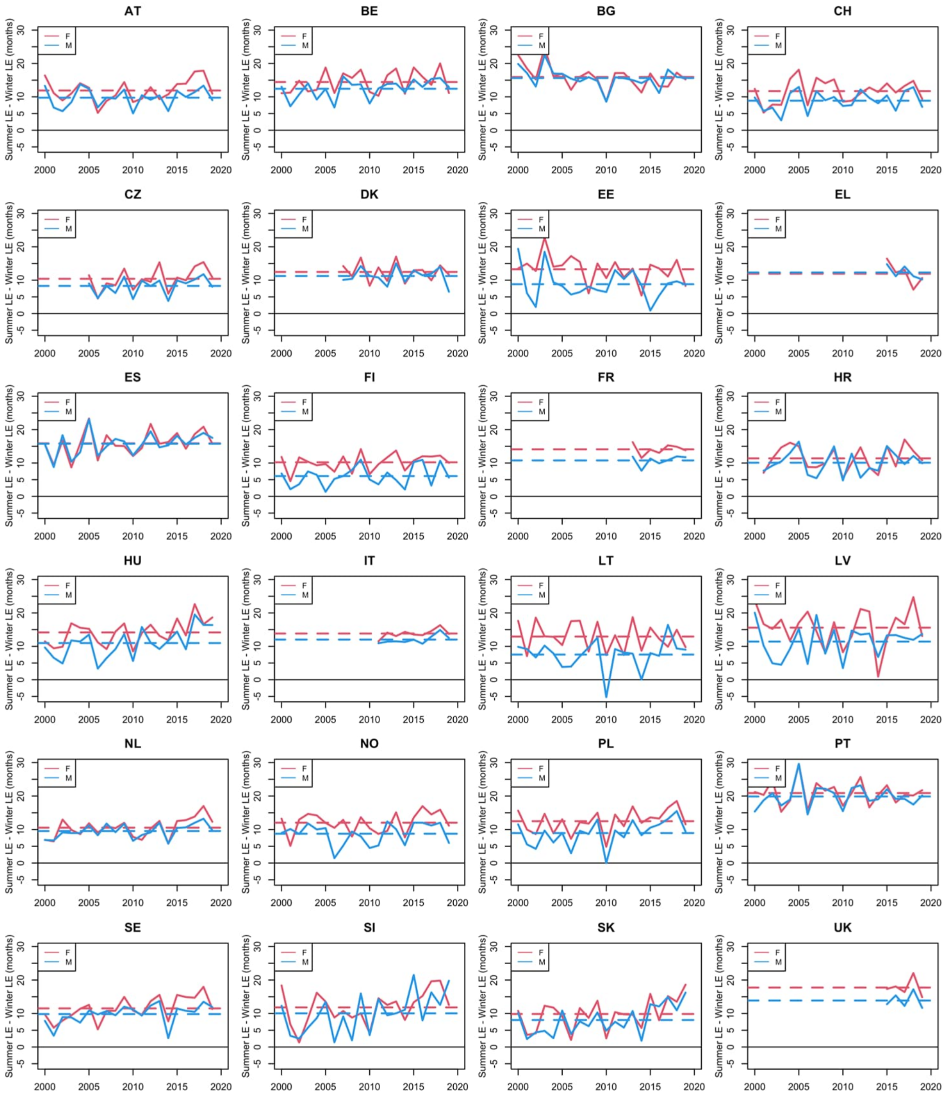
Yearly differences between summer and winter LE according to the first definition, for each country and sex, are shown in Figure 1. While these differences were (almost) systematically higher than zero, and consistently higher for women than for men (in 80% of the cases across years and countries), they varied considerably from year to year, with no clear, consistent upward or downward trend in most countries. Ho and Noymer's WLER indicator was obtained by averaging these differences over available years (horizontal lines in Figure 1).

Figure 2 compares Ho and Noymer's indicator (bars F1 and M1) with its variants obtained using the second (bars F2 and M2) and third (bars F3 and M3) definitions of summer and winter, by country and sex. All WLER indicators were above zero, indicating that summer LE was systematically above winter LE. They were also consistently higher for women than for men (in 22 or 23 countries depending on the indicator, with EL, BG, and ES being the occasional exceptions). The first indicator was generally lower than the second and the second lower than the third, with an average (across 24 countries) of respectively 11, 13, and 16 months for men, and 13, 15, and 20 months for women. The ranking of countries was similar regardless of the indicator used, with Finnish men having the lowest WLER (respectively 6, 8, and 10 months) and Portuguese women the highest (21, 24, and 30 months).

The fits provided by model (1) for each country and sex on weekly LE data over the period 2000–2019 are shown in Figure 3, together with 95% prediction intervals. Except in the Baltic states (EE, LT, LV) between 2005 and 2010, at a time when LE was stagnating in these countries, our fits were generally satisfactory, with most weekly LE data (between 94% and 96%) falling within the prediction intervals.

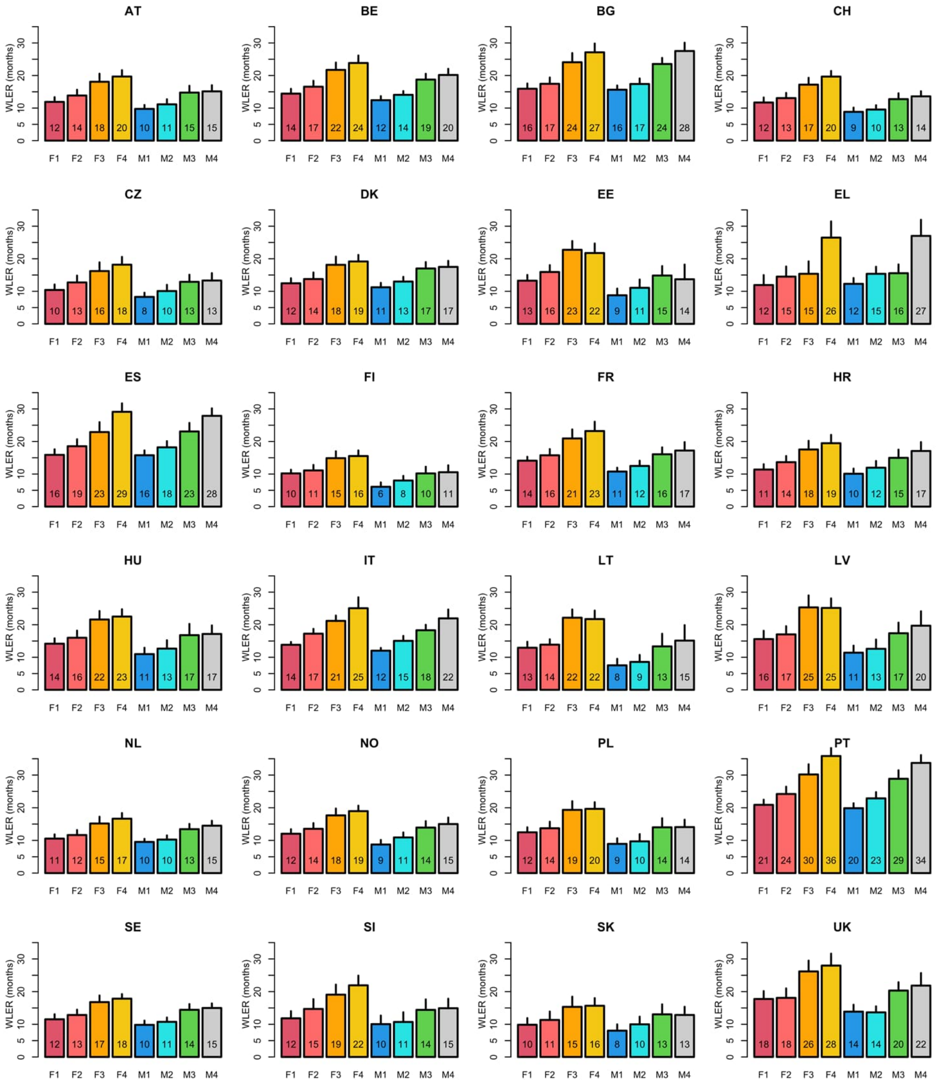
Seasonal cycles in LE fitted by sine and cosine terms in model (1) are shown in Figure 4 as average deviations from the fitted annual LE. In all countries and for both sexes, LE was at its lowest in January or early February. Differences between countries were more pronounced as to when LE was at its highest, ranging from late June (e.g., CH, CZ, SI) to early October (EL), and often in September (e.g., BG, ES, HR, IT, PT, i.e., Southern countries). Of note, Mediterranean countries (EL, ES, IT, PT) had two local optimums for both sexes, the first in May or early June, the second in late September or early October. Between these two optimums there was a slight drop in LE, which was not seen in other countries. The fourth WLER indicator (bars F4 and M4 in Figure 2) was calculated as the difference between the maximum and minimum values of these seasonal cycles. It showed even higher values than the first three WLER indicators, ranging from 11 months (Finnish men) to 36 months (Portuguese women), with an average of 18 months for men and 22 months for women.

Figure 1: Summer and winter life expectancy difference in Europe, 2000–2019



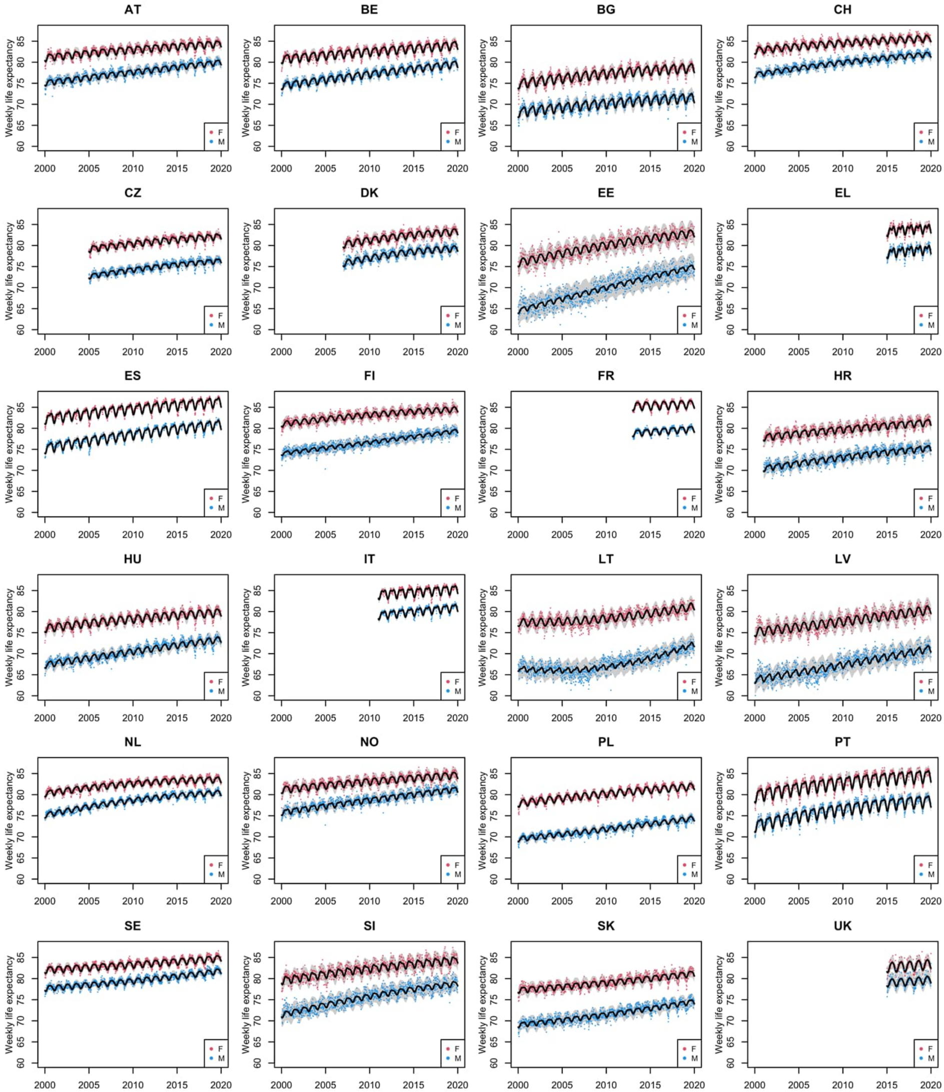
Note: Difference between summer and winter life expectancy (LE), expressed in months, according to first definition of summer and winter, for women (F) and men (M) in 24 European countries, over available years in 2000–2019. Dotted horizontal lines represent average difference over those years, corresponding to Ho and Noymer's indicator of winter life expectancy reduction (WLER).

Figure 2: Four indicators of winter life expectancy reduction in Europe



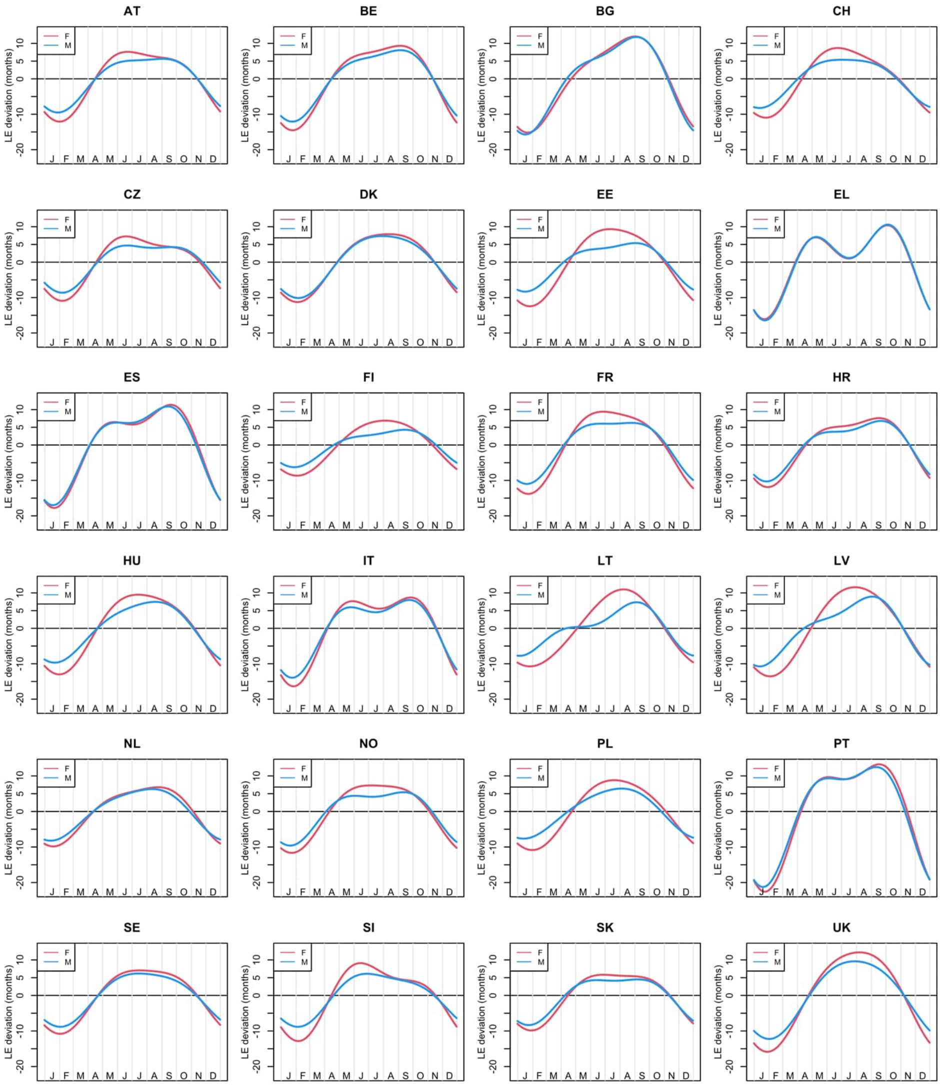
Note: Four indicators of winter life expectancy reduction (WLER), expressed in months, for women (F1, F2, F3, F4) and men (M1, M2, M3, M4) in 24 European countries. Thin bars represent two standard errors.

Figure 3: Weekly life expectancy in Europe, 2000–2019



Note: Weekly life expectancy calculated from Eurostat weekly mortality data, for women (F) and men (M) in 24 European countries, over available years in 2000–2019, together with the fit and 95% prediction intervals provided by model (1).

Figure 4: Seasonal deviation from annual life expectancy



Note: Average deviation from annual life expectancy (LE), expressed in months, depending on the time of year, from J = January to D = December, for women (F) and men (M) in 24 European countries, according to model (1).

5. Discussion

Although there is a vast literature on winter mortality, Ho and Noymer (2017) were the first and only ones to calculate a Winter Life Expectancy Reduction (WLER), contrasting six months of summer and winter. They did so in the USA, and our first objective was to replicate these calculations in Europe. We found a European average of 11 months for men and 13 months for women, slightly higher than in the USA (8 and 12 months), with considerable differences between European countries, ranging from 6 months for Finnish men to 21 months for Portuguese women.

Ho and Noymer interpreted the difference between summer and winter LE as the possible life expectancy savings if a fully effective influenza vaccine were available and considered their results as "neither negligible nor enormous". However, they would have found greater differences using other definitions of summer and winter. Our second objective was to illustrate how WLER depends on these definitions. Unsurprisingly, we found that WLER systematically increases when the number of months assigned to winter is reduced, i.e., with a sharper contrast between summer and winter. Nevertheless, certain results were retrieved regardless of the indicator used, such as a generally higher WLER in Southern than in Northern countries (retrieving the 'excess winter paradox'), and a consistently higher WLER for women than for men (as found by Ho and Noymer in the USA). This latter finding contrasts with the recent study by Marinetti et al. (2025), which reported, for a median European country, an "annual reduction in life expectancy due to seasonal excess mortality" of 0.88 years for women and 1.14 years for men, i.e., a greater reduction for men than for women. Although they did not compare men and women in terms of WLER, these contrasting results suggest the presence of a subtle sex-dependent seasonal mortality pattern that warrants further investigation, including from an epidemiological perspective.

The first three WLER indicators above use the same definitions of summer and winter in each country. This can be considered a limitation, as seasonal cycles are very different, e.g., between Scandinavian and Mediterranean countries (Liddell et al. 2015), implying that comparisons between countries in this regard might not be entirely relevant. This led us to our third objective, namely the introduction of a novel WLER indicator for modeling the country-specific seasonal cycles, defined as a "peak-to-trough LE difference". This indicator is the WLER counterpart of the 'peak-to-trough mortality ratio' used by Madaniyazi et al. (2022) to study seasonal variation in mortality around the world. The contrast between high (summer) and low (winter) LE is maximized with this novel WLER indicator, ranging from 11 months (Finnish men) to 36 months (Portuguese women), with a European average of 18 months for men and 22 months for women.

Unlike the first three WLER indicators, which are empirical, the fourth is based on a statistical model which, by nature, has limitations. In this context, a good compromise must be found between flexibility, to be able to detect various types of seasonal cycles, and simplicity, to smooth out stochastic fluctuations in weekly data. A more flexible model than ours would, for example, allow seasonal cycles to evolve over time (although this is not suggested by Figure 1). On the other hand, Serfling (1963) chose a simpler model using single sine and cosine terms to model pneumonia/influenza deaths. Using two sine and cosine terms in our model allowed us to identify more subtle patterns. For example, we were able to identify September as the month with the highest LE in Mediterranean countries, a phenomenon already reported in the literature on mortality (Falagas et al. 2009). Another remarkable feature was the bimodal shape of summer LE in Mediterranean countries, with a drop in LE at the height of summer. This is likely related to high temperatures, which may become more pronounced over coming years. This illustrates the potential impact of global warming on summer mortality, although winter mortality could also be reduced with rising temperatures, so it is difficult to infer what the net balance would be (e.g., Burkard et al. 2021).

While evidence about seasonal impacts on LE “remains very scarce” (Marinetti et al. 2025), we hope to stimulate research on this topic with this first study on WLER in Europe. One reviewer suggested repeating the analysis with remaining LE at age 60, or with relative (instead of absolute) LE differences. Analyses could also be conducted at the regional (rather than national) level, or the merits of the different indicators could be further compared to determine which is most appropriate. Attempting to understand sex differences in WLER also remains an intriguing scientific challenge.

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