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Season of Birth and Survival to 105 Years: Demographic Evidence

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Abstract: This study provides the first comprehensive demographic analysis of Belgian semi-supercentenarians (SSCs, individuals aged 105+), with a particular focus on the role of season of birth in shaping survival to extreme ages. Using exhaustive, rigorously validated data covering 1471 SSCs born between 1870 and 1919, supplemented with data from population censuses or extracted from the Belgian *National Population Registry*, we examine long-term trends in SSC numbers, sex ratios, and seasonal birth distributions. The probability of surviving to 105 increased exponentially across cohorts, from fewer than 2 per 100,000 for the 1870 cohort to more than 50 for those born in 1915–1919. Although women continue to largely outnumber men at these ages, the female-to-male ratio narrowed from nearly 20:1 at the turn of the 20th century to 8:1 across successive cohorts, reflecting broader demographic and social changes. Our findings also reveal pronounced seasonal patterns: SSCs are disproportionately born in autumn and spring, with the autumn advantage strengthening across advancing ages and a late-emerging spring effect appearing beyond age 100. These dual seasonal effects suggest that favorable early-life conditions continue to influence survival even at the limits of the human lifespan, while highlighting the importance of selective processes acting at different age thresholds. By situating Belgian SSCs within broader international comparisons, this study underscores both the universality and context-specificity of seasonal birth effects on longevity. The results emphasize the lasting role of early-life exposures in shaping survival trajectories, while also pointing to the need for future interdisciplinary and comparative research to disentangle biological, environmental, and societal mechanisms underlying exceptional longevity.

Keywords: semi-supercentenarians; extreme longevity; season of birth; sex ratio; Belgium

1. Introduction

Reaching extremely advanced age offers valuable insights into the complex interplay of biological, genetic, demographic, and environmental factors that shape individual health and longevity trajectories. While the growing number of centenarians provides a robust foundation for research, our understanding of individuals who survive to age 105 remains limited. The probability of reaching 105 years is exceptionally low, with six to ten times fewer people surviving to this age compared to those reaching 100.

Individuals aged 105 and older, referred to as semi-supercentenarians (SSCs), represent a unique and challenging group for scientific inquiry. Their rarity makes them difficult to study, yet they provide unparalleled insights into survival at the limits of the human lifespan [1]. The recent and significant increase in the number of SSCs offers an unprecedented opportunity to investigate the characteristics of this exceptionally long-lived population.

This study examines long-term trends among Belgian SSCs, focusing on cohorts born from 1870 onwards and in more detail, those born from 1900 to 1919. We analyze their exponential increase, changes in sex ratios, and the influence of the birth season with the objective of determining whether the season of birth impacts the likelihood of surviving to age 105.

2. Research Context

Data from the *International Database on Longevity* (IDL) confirms an exponential increase in the number of SSCs in all countries represented [2]. Scientists have reported a marked rise in SSCs over recent decades in some populations [3,4]. This growth allows for a more reliable identification of factors associated with extreme longevity. While some determinants of health and longevity, such as lifestyle and socioeconomic status, are influenced by individual choices, others, including sex, place of birth, and season of birth, are fixed from the outset. The latter variables will be considered in this first contribution.

Although both men and women can achieve extreme old age, it is well-established that women, on average, live longer than men. This results in a much smaller proportion of men among the oldest age groups, primarily due to higher male mortality between ages 65 and 80, and, more recently, after age 80 [5,6]. Among centenarians, the female-to-male survival gap is pronounced and widens further among SSCs within the same birth cohorts [3]. The IDL reports that females account for approximately 90% of all validated SSC cases [1]. However, recent trends suggest a relative increase in the proportion of males at extreme ages [3].

An intriguing area of research has explored the influence of birth season on exceptional longevity. Studies on the impact of the month of birth have found that individuals born in autumn or early winter tend to live longer and have lower risks of certain diseases [7–10]. Doblhammer and Vaupel [11] found consistent longevity advantages for those born in autumn across Austria and Denmark. They noted that the pattern is reversed in Australia, in the Southern Hemisphere, which reinforces the role of seasons characterized by different environmental exposures such as temperature, infections, and maternal nutrition. They also concluded that while the birth month does have a measurable impact on longevity, its effect has weakened in more recent cohorts. Gavrilov and Gavrilova [12] found that siblings of centenarians born in September–November had significantly higher odds of reaching 100 than those born in spring. Similarly, numerous studies have linked birth month to the occurrence of various diseases [9,13], suggesting that early-life conditions play a lasting role in shaping survival trajectories.

Most studies on the possible impact of birth season on extreme longevity have focused on centenarians or younger elderly groups. Few have addressed SSCs: initial investigations by Doblhammer et al. [14] and Drefahl [15] confirmed among SSCs the observations made for centenarians and the higher survival of those born in autumn. No study has tracked changes in the impact of the season of birth from younger ages all the way to 105. In the present study, we first present trends in SSC numbers in Belgium and changes in the sex ratio. Subsequently, we analyze patterns of seasonality in births among Belgian SSCs starting at age 60 to assess whether we can detect the emergence of the impact of the birth season and whether it persists or even increases up to 105.

3. Methodological Challenges

The study of extreme longevity faces several major methodological challenges that render data analysis and interpretation particularly complex.

- Validation of Extreme Ages: One of the most critical obstacles lies in the reliable validation of ages at the upper limits of the human lifespan. Anticipation, misreporting, and, in some cases, deliberate exaggeration of age increases the likelihood of errors as individuals advance into very old age. This persistent risk of overestimation and erroneous data has led demographers to develop extensive age-validation procedures.
- Survivorship Bias: The so-called “survivor bias” arises when analyses focus exclusively on individuals who have reached extreme ages, while neglecting those who may have shared similar characteristics but died earlier. This selective perspective can distort the identification of factors associated with survival to exceptional ages.
- Survey Bias and Nonresponse: Survey-based studies are often threatened by low response rates. When only a subset of individuals participates, the resulting sample is no longer representative of the target population, introducing selection bias. Longevity may thus be overrepresented among respondents, whereas nonresponse is frequently associated with isolation, illness, or precarious living conditions.

- Completeness of Data Collection: Data completeness is rarely guaranteed for centenarians, semi-supercentenarians, and supercentenarians. In any given population, it is difficult to ensure that no individuals have been omitted. High mobility, residential changes, and gaps in civil registration systems complicate the longitudinal tracking of very old individuals.
- Small Population Sizes: Despite the recent increase in the number of centenarians, the populations of semi-supercentenarians and supercentenarians remain extremely small. Consequently, statistical analyses often suffer from limited power, reduced robustness, and heightened uncertainty regarding the generalization of findings.
- Selection of Appropriate Control Groups: Identifying suitable control populations poses an additional challenge. Comparing centenarians with individuals who died before reaching 100 or 105 years raises important methodological issues, as generational, social, and living-condition differences may bias results. Moreover, such control groups are rarely demographically, socioeconomically, or medically comparable.
- Cohort Comparability: Ensuring comparisons within the same birth cohorts is fundamental. The exponential growth in the number of very old individuals over recent decades implies that successive cohorts may differ substantially in their socio-health context, risk exposures, and life-course trajectories. To ensure the validity of results, comparisons should be restricted to individuals from the same cohort groups who experienced similar historical conditions.
- Missing or Inaccurate Birthplace Data: Information on the birthplace of individuals aged 105 years or older may be missing or inaccurate in demographic databases. Yet such data are crucial for distinguishing between natives and immigrants, and for calculating the probability of reaching age 105 by relating the number of semi-supercentenarians to the corresponding number of newborns.

As scientific and societal interest in extreme longevity has grown considerably, these limitations call for constant methodological caution and for the establishment of international standards for the collection, verification, and dissemination of reliable data on the oldest-old populations. Therefore, the *Human Mortality Database* (HMD) [16] and the *International Database on Longevity* (IDL) [2], maintained by the *Max Planck Institute for Demographic Research* (MPIDR) and the *Institut National d'Études Démographiques* (INED), have been established to centralize validated information for scientific investigations. HMD and IDL represent a major advancement in filling substantial gaps in our understanding of the potential determinants of exceptional longevity. By using comprehensive and exhaustive coverage of strictly validated Belgian SSCs, our study minimizes many of these limitations and enables robust analyses of survival to age 105 including the exponential increase of the number of SSCs, possible changes in sex ratios, and potential seasonal birth effects.

4. Data and Methods

We utilize two comprehensive datasets: (1) an exhaustive validated database of Belgian SSCs developed and continuously updated by the Belgian IDL team; and (2) individual records from population and housing censuses (1981 and 1991) and from the *National Register of Natural Persons* (RNPP) (1996, 2001 and 2006) provided by *Statistics Belgium* (Statbel). The Belgian SSC database includes 1471 validated SSCs born in Belgium between 1870 and 1919. Validation was performed by cross-referencing RNPP records with birth certificates. Of these, 76 were still living (11 men, 65 women) on 1 January 2025. For the analysis of seasonal birth distributions, we focused on the 1088 SSCs born between 1900 and 1919, as monthly birth data are available only from 1900 [17]. Census and RNPP data cover people aged 61–80 in 1981 (1.5 million persons), who were followed up to ages 86–105 in 2006 (137,522 persons).

Our analysis is primarily demographic and descriptive. We first examine trends in the number of SSCs, their sex ratio, and the evolution of the probability of reaching age 105 on a yearly basis for cohorts born between 1870 and 1919 (Figure 1). The probability of reaching age 105 is simply defined as the ratio between the number of SSCs and the corresponding number of live births for each birth cohort. If some Belgians born in these years emigrated and reached age 105 while living abroad, this information may be missing; however, most of those who died abroad were included in our SSC database, so only a slight underestimation is expected.

We then focus on the distribution of precise birth dates throughout the year to test for a possible impact of the season of birth on exceptional longevity. The relative distribution of the number of newborns by birth date was computed for each birth year from 1900 to 1919. This distribution was compared with that of living persons from the same birth cohorts at different time points between 1981 and 2006, using census and RNPP data. In addition, the SSC database provides the distribution of all individuals from these same cohorts who reached age 105 between 1 January 2005, and 2025.

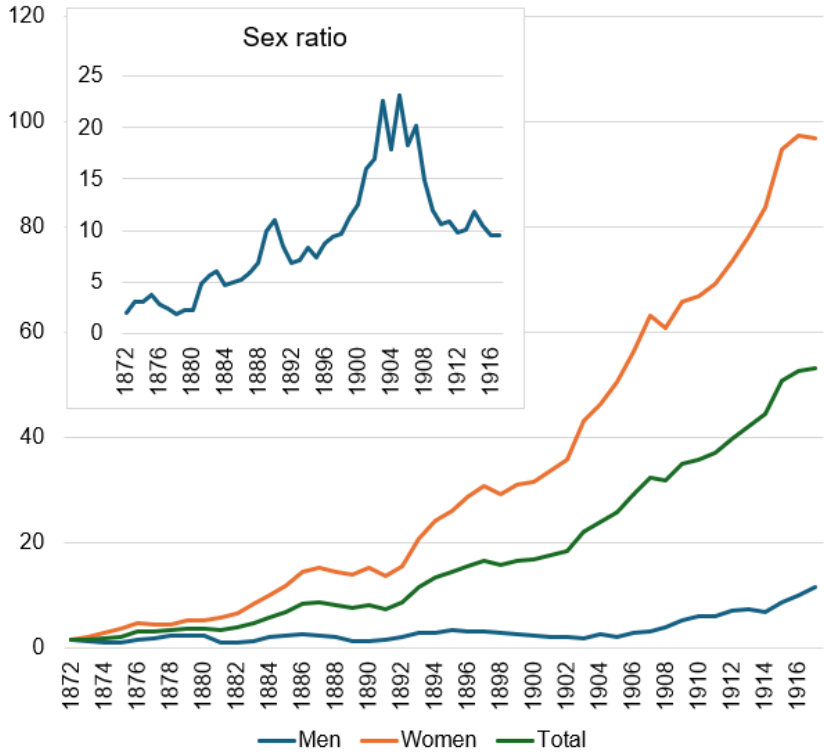

Figure 1. Probability for newborns in 1870–1919 in Belgium to reach age 105 (per 100,000, 5-year moving average) and sex ratio. Data is provided in Supplementary Materials Table S1. Sources: SSC database and Statbel.

To reduce strong fluctuations in the number of births by individual day and to better emphasize seasonal patterns, we used daily birth counts smoothed with a 91-day moving average. More precisely, for each day between 1 January 1900, and 31 December 1919, we summed the number of births occurring on that day and during the 45 days before and after it, and then divided this total by 91. This moving average was applied to all datasets used, including those in the SSC database as well as the census and RNPP data, based on the number of individuals by day of birth in each source.

To compute indices of the seasonal distribution of SSC birthdays (as shown in Figure 2 and subsequent figures), we first averaged the number of SSCs for each day of birth across all birth cohorts from 1900 to 1919 and then divided this by the corresponding total number of live births during this 20-year period.

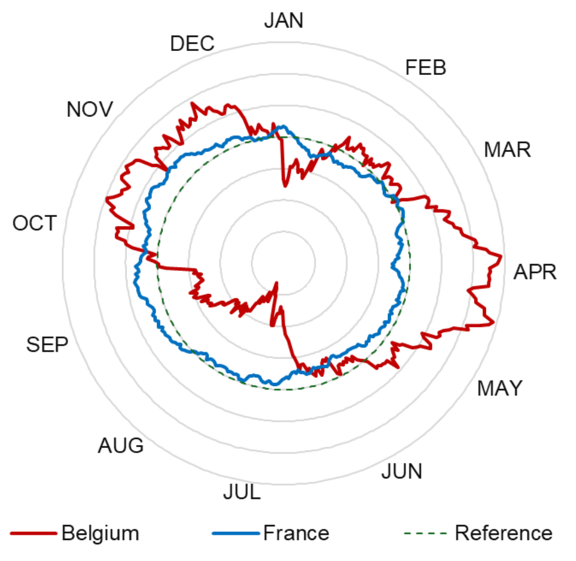

Figure 2. Indices of seasonal distribution of birthdays of SSCs born between 1900 and 1919 in Belgium and France. Data is provided in Supplementary Materials Table S2. Sources: IDL for France and SSC database for Belgium. Note: The reference is a constant that represents the annual average value, relative to which seasonal indexes are calculated.

Since the probability of reaching age 105 has increased substantially over time, the indices also tend to rise on average from January 1 to December 31. Therefore, we adjusted these indices to account for this trend, assumed to be linear across the 365 days. Finally, the indices were normalized to the overall annual mean for all birth cohorts, such that a reference level of 1000 indicates the absence of any seasonal effect, values below 1000 indicate a negative effect, and values above 1000 indicate a positive one. The seasonal distributions of these indices by day of birth are displayed as radial graphs to highlight seasonal variations.

5. Results

5.1. Growth in SSC Numbers

The number of Belgians reaching age 105 has increased substantially since the cohorts born in 1870 (see Supplementary Materials Table S1). While only a few dozen individuals born in the 1870s–1880s survived to 105, this number grew fivefold for cohorts born around 1900, peaking with 84 individuals born in 1914. A sharp decline followed among the 1915–1919 cohorts, reflecting the drastic drop in births during World War I (over 40%). These cohort effects remain visible even after more than a century. More recently, the COVID-19 pandemic further reduced SSC survival, though prior research has indicated that those born before the 1918 Spanish Flu were more resilient [18].

The probability of reaching 105 can be measured relative to cohort births [14,15] or as the Centenarian Ratio—the number of survivors at age 60, 45 years earlier [19]. Both approaches confirmed a significant increase in survival probabilities over time. As shown in Figure 1 for Belgium, the probability of reaching 105 from birth increased from less than 2 per 100,000 for the 1870 birth cohort to more than 50 for the 1915–1919 cohorts. Using the Centenarian Ratio, Caselli et al. [20] observed a similar increase in Italy, from 0.04% of those alive at age 60 reaching 105 for the 1896 cohort to 0.10% for the 1910 cohort.

5.2. Changing Sex Ratio

Women consistently outnumber men at age 105. Female-to-male ratios often approach 10:1 [IDL], although significant regional variation exists, such as the near parity found in certain Sardinian villages [21]. In Belgium, while the probability of living to age 105 has increased for both sexes, the ratio of women to men has changed significantly between cohorts born before and after the turn of the century (Figure 1). The sex ratio peaked at approximately 20:1 for cohorts born near 1900, before declining to about 8:1 in the 1917–1919 cohorts. This narrowing may reflect more gender equality in lifestyle, healthcare, well-being and social status [22].

5.3. Seasonal Patterns of Birth among SSCs

Research has long suggested that the season of birth influences longevity. The radial graphs displayed in Figure 2 compare the relative numbers of Belgian and French SSCs, both series being adjusted for the seasonal distribution of the initial cohorts born between 1900 and 1919. For Belgium, our analysis reveals that the distribution of SSC births is disproportionately concentrated in autumn and spring with a highest representation of SSCs born around April and May and another, though somewhat lower, concentration from mid-October until early December. The lowest representation appears in July, August, and September, but also in January. Indices for French SSCs extracted from the IDL also show higher values in autumn, with an excess from the beginning of September to the end of November, partially compensated by slightly lower values in other seasons. In comparison, two higher concentration seasons appear in Belgium distinct from France, one in spring and another in autumn, and the difference between high and low concentration seasons in Belgium appears to be more substantial. Moreover, the peak of spring-born individuals occurs later in the season in Belgium than in France. These cross-country differences suggest that local conditions may modulate some seasonal differences between the two countries.

In further analysis, we examine how the seasonal distribution of birthdays among survivors from the 1900–1919 birth cohorts changed by age starting at 60. To do so, we compare the distributions at several observation points using census data for 1981, 1991, and the RNPP in 1996, 2001, and 2006. Figure 3 illustrates how the distribution evolved as the same cohorts aged, from 61–80 in 1981 to 86–105 in 2006. All values are adjusted for the original seasonal distribution of births in 1900–1919. In 1981, the baseline distribution was relatively even, with slightly fewer individuals born in spring and summer, and more in autumn. Over the following 10–15 years, the share of autumn-born individuals increased, while the overall shape of the distribution remained fairly stable. The most pronounced shifts emerged after two decades, in 2001 and 2006, when the cohorts were aged 81–100 and 86–105 years, respectively. By then, the proportion of autumn-born survivors had grown substantially, with a corresponding decline in those born in summer. These later changes were much more pronounced than the earlier shifts observed when the population was 10–20 years younger.

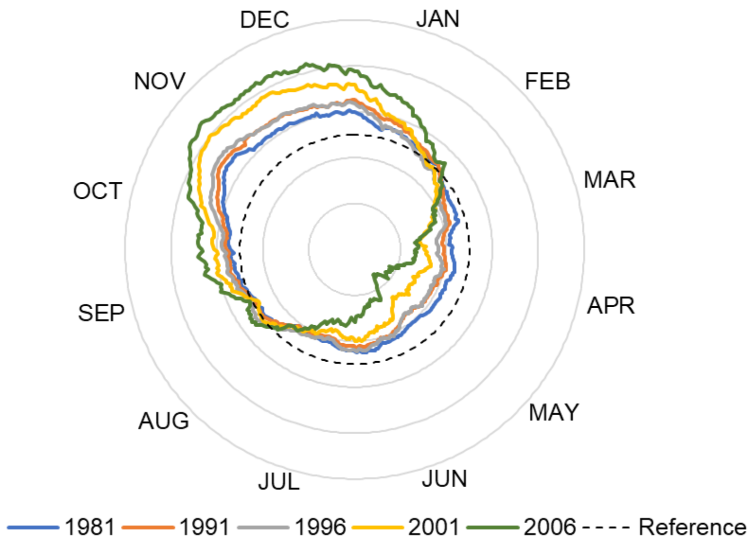

Figure 3. Indexes of seasonal distribution of birthdays of people born in 1900–1919 in 1981, 1991, 1996, 2001, and 2006. Data is provided in Supplementary Table S2. Sources: SSC database and Statbel. Note: The reference is a constant that represents the annual average value, relative to which seasonal indexes are calculated.

The distribution of birthdays of the 1088 SSC born in 1900–1919 still remains largely different, even when compared with the one obtained from people aged 86 to 105 years in 2006 (Figure 4). The autumn peak around November is visible in both, but a spring peak emerges only among the SSCs.

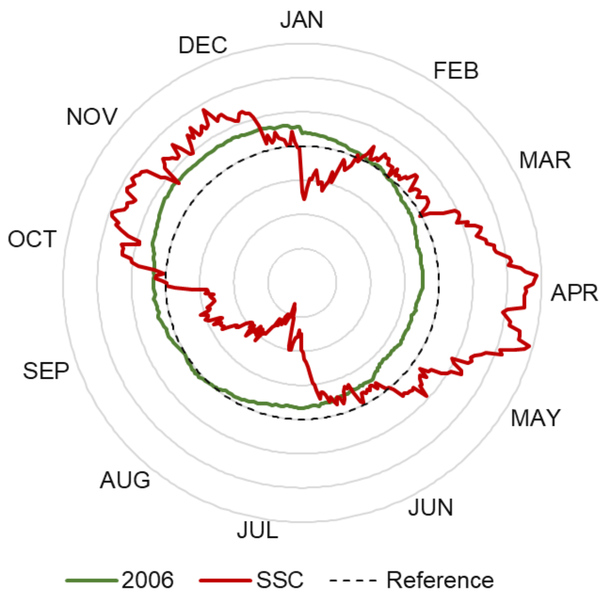

Figure 4. Indexes of seasonal distribution of birthdays of people born in 1900–1919 in 2006 at age 85–105 and SSCs. Data is provided in Supplementary Materials Table S2. Sources: SSC database and Statbel. Note: The reference is a constant that represents the annual average value, relative to which seasonal indexes are calculated.

This late-emerging spring effect is evident when comparing 5-year survival probabilities between 1996–2001 and 2001–2006 for individuals born in 1900–1904 (Figure 5). Survival from 1996 to 2001 covers ages 91–95 through 96–100, while survival from 2001 to 2006 covers ages 96–100 through 101–105. The spring peak appears among survivors in the latter group, between ages 96–100 and 101–105, thereby demonstrating a seasonal distribution of birthdays that increasingly resembles that of SSCs, as shown in Figure 4.

As such, our investigation on the seasonal distribution of birthdays among survivors in the cohorts 1900–1919 at several given timepoints indicates seasonal patterns shifting across age groups with a clear appearance of a spring advantage in reaching 105.

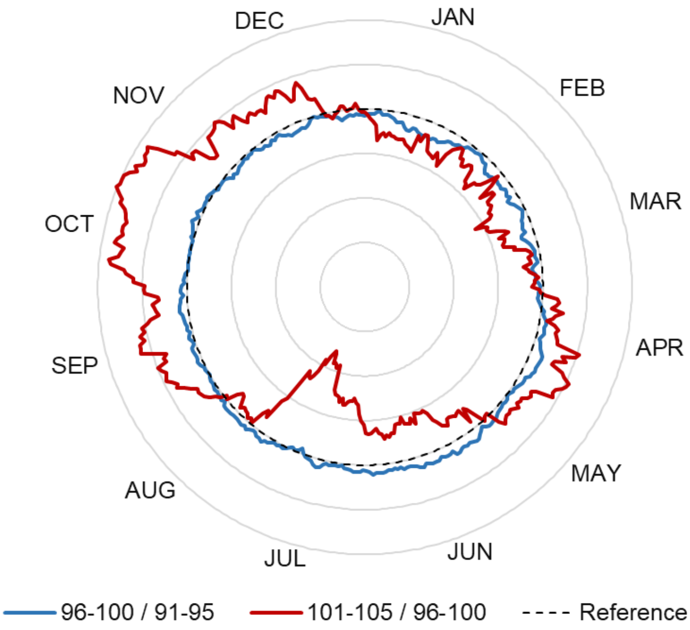

Figure 5. Indexes of seasonal distribution of birthdays of people born in 1900–1904 by 5-year survival by age groups. Data is provided in Supplementary Table 2. Sources: SSC database and Statbel. Note: The reference is a constant that represents the annual average value, relative to which seasonal indexes are calculated.

6. Discussion and Conclusions

The present study provides the first comprehensive demographic analysis of Belgian SSCs, highlighting the influence of the season of birth on the probability of reaching age 105. We exhaustively and thoroughly validated the ages of 1471 SSCs born in Belgium between 1870 and 1919, of whom 76 were still alive on January 1, 2025. By using data from the Belgian large-scale population censuses of 1981, and 1991 and registry data enabling the reconstruction of the whole Belgian population in 1996, 2001 and 2006, we were able to overcome common limitations faced in studies of extreme longevity, such as reduced population size, problems associated with age validation, and sample representativeness.

Our findings confirm the exponential growth in numbers of SSCs observed in other populations in the last decades. This increase reflects general improvements in survival as well as the impact of demographic shocks such as the decline in births during World War I and the consequences of the 1918 Spanish Flu pandemic. Adjusted to the number of newborns, the Belgian data confirm the exponential increase in the probability of surviving to age 105 over the last fifty years. Equally important, the evolution of sex ratios highlights a significant demographic shift: although women still represent the vast majority, the narrowing female-to-male gap indicates that men have experienced greater relative gains from the social, medical, and behavioral improvements of the 20th century. Our results are consistent with evidence from other countries reporting a relative rise in male representation among the oldest-old, though the extent of the shift remains highly context-specific [4,20].

Although the increasing number of SSCs has created a strong interest in their study, understanding of the specific characteristics that contribute to living to 105 years of age is limited. Our study contributes to filling this gap with a demographic perspective focusing on the impact of season of birth in addition to age and sex.

Considering the difficulty of gathering a large number of validated and unbiased SSCs, very few studies investigated the possible impact of the season of birth on their extreme survival. These studies compared the extreme survival by month of birth [14,15], whereas ours proposes daily indexes computed as 91 days moving average. By doing so, and using radial graphs, we were able to provide clearer evidence of seasonal effects.

Our analysis of the French SSCs listed in IDL confirms previous findings and a survival advantage to 105 for babies born in autumn [12,14,15]. For Belgian SSCs, the distribution of SSCs by birth season also shows a similar autumn advantage, but a more substantial one appears for those born in spring, that has not been found in studies of other researchers.

To understand how this spring advantage emerges, we follow the SSC cohorts as they aged, starting with the 1981 census, when their ages ranged from 61 to 80 years, up to 2006, when the age of surviving and potential future SSCs ranged from 86 to 105. The radial figures presented in this contribution show a gradually increasing advantage for those born in autumn and a corresponding increasing disadvantage for those born in spring. This is confirmed by a second analysis dealing only with individuals born in 1900–1904. Their survival rates between 1996–2001 compared to those between 2001–2006 confirm the advantage of those born in autumn in their nineties. However, in the second period, when these individuals aged from 96–100 to 101–105, a spring advantage emerges. This finding highlights a change in the seasonal impact among centenarians, with a growing advantage for those born in spring. In our SSC database, the statistical significance is clear in absolute numbers: 313 SSCs were born during the 91 days around April 12 (from 26 February to 27 May) compared to 230 SSCs born around 29 July (from 14 June to 12 September). These numbers represent 41 more and 42 fewer than the expected average of 272, respectively. By comparison, the autumn peak occurring around 26 October includes 286 SSCs born between 11 September 10 and December.

The strengthening of the autumn advantage and the emergence of another one, increasingly important in spring for those aged 100 and above may suggest that favorable early-life conditions still act up to age 100 and indicate a further selective process in individuals who survive up to 105 and beyond. This dual seasonal pattern highlights the need to account for age-specific selection when interpreting longevity determinants. Moreover, this dynamic underscores the complexity of survival trajectories at extreme ages and reinforces the need for analyses that follow cohorts across multiple age thresholds.

Despite its strengths, the study has several limitations. First, although Belgium offers high-quality demographic data and exhaustive SSC validation, the findings may not be generalizable to populations with different climates, cultural practices, or epidemiological histories. Second, while demographic analysis can identify robust patterns, it cannot by itself disentangle the precise biological and environmental mechanisms underlying seasonal effects. Finally, the strong influence of cohort effects—such as war, epidemics, or economic crises—on survival trajectories indicates that contextual shocks must be carefully integrated into future research.

By situating Belgian SSCs within a broader international literature, the study contributes new evidence on the demographic pathways leading to survival beyond 105 and provides a foundation for future comparative and interdisciplinary research. Overall, this research illustrates how demographic analyses of validated SSC populations can shed new light on the interplay between biological, environmental, and social determinants of survival. The persistence and amplification of seasonal effects suggest that early developmental exposures remain a key mechanism underlying exceptional longevity. Nevertheless, the discovery of a spring peak for Belgian SSCs call into question the plausible explanations suggested so far in the literature. More investigations are needed and hopefully these will be supported by a growing number of SSCs. In this respect, we remain aligned with the conclusion formulated two decades ago by Drefahl [15] in his PhD thesis, in which he stated: "*Along with the finding that survival differences by month of birth in semi-supercentenarians can probably be attributed to random variation, I conclude that mortality at these extreme ages is generally more affected by random factors. This pattern is probably caused by heterogeneity.*"

Supplementary Materials

The additional data and information can be downloaded at: https://media.sciltp.com/articles/others/2512031009138423/ALR-25090065-Author-Supplementary-V2.xlsx. Table S1. Indexes of seasonal distribution of birthdays: Belgian SSC and France SSC born in 1900–1919, the Belgian population born in 1900–1919 as observed in 1981, 1991, 1996, 2001 and 2006, and survivors in birth cohorts 1900–1904 from 1996 to 2001 (ages 91–95 through 96–100) and from 2001 to 2006 (ages 96–100 through 101–105). (Sources: our SSC database and STATBEL). Table S2. Number of SSC and number of births in cohorts born in 1870–1919 (born in Belgium, died or alive on 1 January 2025), the corresponding probability to reach 105 (per 100,000 newborns) and sex ratio of SSC (the rates and sex ratio are computed as 5-years moving averages) (Sources: our SSC database and STATBEL).

Author Contributions

M.P.: conceptualization, methodology, data curation, writing. A.H.: investigation, validation; writing, reviewing and editing. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

Please contact the corresponding author if you would like to access the data relevant to this paper.

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Conflicts of Interest

The authors declare no conflict of interest. Given the role as Editorial Board, Michel Poulain had no involvement in the peer review of this paper and had no access to information regarding its peer-review process. Full responsibility for the editorial process of this paper was delegated to another editor of the journal.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

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