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SESSIONAL PAPER

Seasonal mortality amongst UK occupational pension scheme members 2000–2016

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Abstract
Mortality at older ages varies by season, increasing the uncertainty associated with modelling and projecting mortality at older ages and ultimately contributing to pension providers' overall risk. As the population ages, it becomes more important to understand variations in seasonal mortality between pensioners and to identify those most vulnerable to seasonal mortality differences. Using data from the Self-Administered Pension Schemes mortality investigation of the Continuous Mortality Investigation of the Institute and Faculty of Actuaries, UK, this paper investigates variations in seasonal mortality amongst members of UK occupational pension schemes over the period 2000–2016. Results are also compared with the corresponding population of England and Wales. For the oldest age groups (80+), which are most affected by seasonality, females are more vulnerable to seasonal differences in mortality for each pensioner group relative to males. Following a long-term decline in the winter-summer mortality gap the gap increased over the period, particularly for female pensioners and dependants. Seasonality remains a feature of UK mortality at older ages and risk management for pension schemes should consider seasonality when analysing overall mortality experience.

Keywords: Seasonal mortality; seasonal mortality improvements; ill-health retirement pensioners

1. Introduction

Mortality at older ages varies by season with more vulnerable pensioners experiencing greater seasonal differences in mortality relative to the general pensioner population. The seasonality of mortality increases the uncertainty associated with modelling and projecting mortality at older ages ultimately contributing to insurers' and pension providers' overall risk. The effects of seasonal differences in mortality are not uniform varying by factors such as gender, region, socio-economic status and health status (Healy, 2003; Rozar, 2012). Seasonal mortality differences between populations, therefore, contribute to demographic basis risk while seasonal mortality trends influence projections of future mortality and are a source of trend risk. As the population ages, it becomes more important to understand variations in seasonal mortality between pensioners and to identify those most vulnerable to seasonal mortality differences. Using data from the Self-Administered Pension Schemes (SAPS) mortality investigation of the Continuous Mortality Investigation (CMI) of the Institute and Faculty of Actuaries, UK, this paper investigates variations in seasonal mortality amongst members of UK occupational pension schemes over the period 2000–2016.

Despite mild winters, Britain experiences relatively high seasonal variations in mortality compared with other European countries, often with much more severe winters (Healy, 2003; Liddell *et al.*, 2016a). In the UK, mortality peaks in the winter season and while the reasons for higher winter mortality are complex the increase is mainly attributed to cold or poor housing and influenza (Vestergaard *et al.*, 2017; Guertler & Smith, 2018). Following a long-term decline in excess winter mortality since the 1950s, the UK has experienced an increase in excess winter mortality in recent years (Office for National Statistics (ONS), 2015; NRS, 2021; NISRA, 2021). Furthermore, while mortality is lowest in the summer, deaths increase during heatwaves due mainly to the physical effects of overheating on the body and increased air pollution (House of Commons, 2018a). Climate change is projected to increase the frequency and intensity of heatwaves in the UK with consequent increases in heat-related deaths particularly among the elderly (Arbuthnott & Hajat, 2017; Huang *et al.*, 2022). Actuaries are required to consider the impact of climate change when setting mortality assumptions (Halis *et al.*, 2017) and more vulnerable pensioners can be expected to be more adversely affected by climate change relative to the general pensioner population.

The magnitude of seasonal differences in mortality varies between subpopulations with the effect greatest among more vulnerable groups (PHE, 2013). In particular, those who live alone tend to experience greater seasonal mortality differences relative to those living with a partner (Rau, 2006; Nazroo *et al.*, 2008). Most widow(er)s live alone (Gaymu *et al.*, 2007) and the proportion of the population who are widowed increases with age. Defined benefit pension schemes typically provide spouses or dependants pensions to deceased member's surviving partners. In the UK, the closure of defined benefit pension schemes in recent decades has resulted in more mature pension schemes for which dependants can be expected to form an increasing proportion of the membership in the future. Consequently, it will become increasingly important to understand the potential impact of seasonality on their mortality experience.

Mortality improvements also vary by season and analysis of mortality at older ages should consider seasonal differences in mortality trends and mortality improvements. Following a period of rapid mortality improvements at older ages in the first decade of the 21st century, the UK experienced a notable slowdown in the rate of improvement since 2011 for both males and females. The slowdown was mainly attributed to a reduction in improvements for circulatory diseases (ONS, 2018). According to a report by the CMI, average annual mortality improvements in England and Wales for age group 65–102 fell from 2.4% per annum between 2000 and 2011 to 0.1% per annum for the period 2011–2015 (CMI, 2015). Jones (2020) discusses the impact of excess winter mortality on stalling mortality improvements in the UK and internationally noting that the period 2000–2008 saw unusually low levels of excess winter mortality relative to earlier and later periods. Higher than normal winter mortality in 2015, 2017 and 2018 in the UK has also been noted by Barton and Hawkins (2018). The importance of considering the impact of seasonality on mortality improvements was highlighted by the UK Insurance regulator in a letter to chief actuaries in June 2019 in which the implications of the recent worsening of excess winter mortality on mortality trends were referenced (Malik, 2019).

This paper investigates seasonal mortality, in particular, the differences between summer and winter mortality, for UK SAPS occupational pension scheme members and the population of England and Wales over the period 2000–2016. Section 2 describes the data used in the investigation, sections 3 and 4 analyse variations in seasonal mortality among the SAPS members and section 5 analyses seasonal mortality and mortality improvement trends for the population of England and Wales and compares them with the SAPS pensioners. The paper concludes with a review of emerging factors which may potentially impact seasonal mortality differences in the future.

2. Data

Data on the mortality experience of UK occupational pension scheme members was provided by the Self-Administered Pension Scheme (SAPS) investigation of the Continuous Mortality Investigation (CMI) of the Institute and Faculty of Actuaries (IFoA), UK. The CMI commenced

Table 1. Deaths by Pensioner Type for the SAPS Occupational Pension Scheme Members over the Period 2000–2016

Pensioner Type	Age Group	Males	Females
Normal Health Retirement Pensioners	50–95	524,403	253,775
Ill-Health Retirement Pensioners	50–95	80,144	45,894
All Pensioners	50–95	954,575	404,474
Dependants	85–100	14,548	311,090

an investigation into the mortality experience of UK SAPS members in 2002. Contributing pension schemes provide data, typically in line with their triennial valuation, on members split by pensioner type – namely pensioners who retired in normal health (normal-health retirement pensioners), pensioners who retired on ill-health grounds (ill-health retirement pensioners), combined pensioners where it is not possible to distinguish between normal-health and ill-health pensioners and dependants (mainly widows and widowers). Based on the mortality experience of the SAPS pensioners and dependants, the CMI has graduated three sets of life tables – the "S1" tables covering the period 2000–2006 (CMI, 2008), the "S2" tables covering the period 2004–2011 (CMI, 2014) and the "S3" tables covering the period 2009–2016 (CMI, 2018). Lives and amounts tables are graduated and split by gender, pensioner type and pension band.

The CMI has kindly provided the data underlying working paper 158 (CMI, 2021) for the period 2000–2016 (the "S1," "S2" and "S3" periods) for this analysis. The following data was provided for each member: unique ID, date of birth, date pension commenced, gender, pensioner type, date of death where applicable, the start and end dates of the exposure period for each member and the pension amount on the start and end dates. The pensioner type was categorised as normal-health retirement pensioners, ill-health retirement pensioners, combined pensioners and dependants. Dates of birth and start dates of pensions were anonymised to the 16th of each month.

Table 1 presents the number of deaths for each pensioner type over the period 2000–2016. Note that group "All Pensioners" aggregates the data for normal-health retirement pensioners, ill-health retirement pensioners and the combined pensioners. Ill-health retirements form a larger proportion of female pensioner liabilities compared to males. Noticeably, dependant liabilities have a higher average age profile than pensioner liabilities with the majority of deaths occurring at ages 85 and over. Hence, mortality is analysed for age group 85–100 for dependants and age group 50–95 for all other pensioner types. The proportion of female pensioners in the SAPS dataset increased over time with the exposure for female "All Pensioners" in the five-year period 2011–2015 exceeding 85% of the corresponding exposure for males.

To analyse population-level seasonal mortality trends for England and Wales, data on the number of deaths by single year of age, gender, month of occurrence of death and year of death were obtained from the ONS for England and Wales for the period 2000–2020. Corresponding exposure data was obtained from the Human Mortality Database (2022).

3. Seasonal Mortality – SAPS Pensioners

Studies of seasonal mortality in the Northern Hemisphere tend to define winter as the period from December to the following February or March. For this analysis, months were allocated to seasons as follows with the winter season spanning two consecutive calendar years:

Spring: March, April, May
Summer: June, July, August
Autumn: September, October, November
Winter: December, January, February

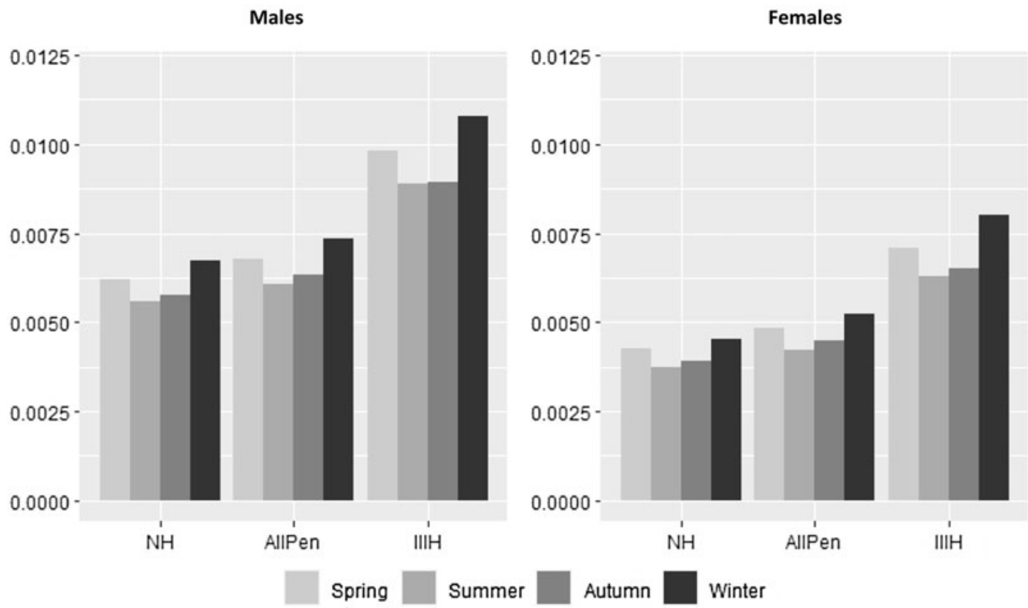

Figure 1. Seasonal SMR by pensioner type for age group 50–95 for males and females for the period 2011/12–2015/16 (winter) and 2011–2015 (spring, summer, autumn).

Seasonal mortality for the SAPS members was analysed using directly age-standardised mortality rates standardised to the 2013 European Standard Population (2013). Figure 1 presents the five-year average Standardised Mortality Rate (SMR) by season for age group 50–95 for normal-health retirement pensioners (NH), ill-health retirement pensioners (IllH) and "All Pensioners" (AllPen) for males and females, respectively. The five-year average SMR by season was calculated by averaging the SMR for each season over the five-year period 2011/12–2015/16 for winter and 2011–2015 for spring, summer and autumn. The SMR for season *s* and age group *j*-*k* in year *t* was calculated as follows:

$$d_{s,x,t} = \sum_{months,\ m,\ in\ season\ s} \left(\frac{d_{m,x,t}}{E^{c}_{m,x,t}} * SP_x \right) \tag{1}$$

$$Seasonal\ SMR = \frac{\sum_{x=j}^{k} d_{s,x,t}}{\sum_{x=j}^{k} SP_x} \tag{2}$$

where $d_{m,x,t}$ is the number of deaths aged x in month m in year t, $E^{c}_{m,x,t}$ is the corresponding central exposed to risk and SP_x is the 2013 European Standard Population at age x. Deaths in each season are standardised to 92 days. The 2013 European Standard Population is provided in five-year age bands and for calculation purposes it was assumed that the population was split equally across all five ages in each age band.

From Figure 1, it can be seen that mortality is highest in the winter followed by spring with the summer and autumn seasons showing similar levels of mortality. Deaths, therefore, are not uniformly distributed across the year with mortality higher in the first half of the year relative to second half. As expected, ill-health retirement pensioners exhibit the greatest mortality in each season. To illustrate variations in the difference or gap between the winter and summer mortality rates, Figure 2 presents the corresponding 5-year average of the relative difference or ratio of the winter to the previous summer SMR. From Figure 2, we can see that for males the gap between summer and winter mortality is similar across the pensioner groups. For females, the

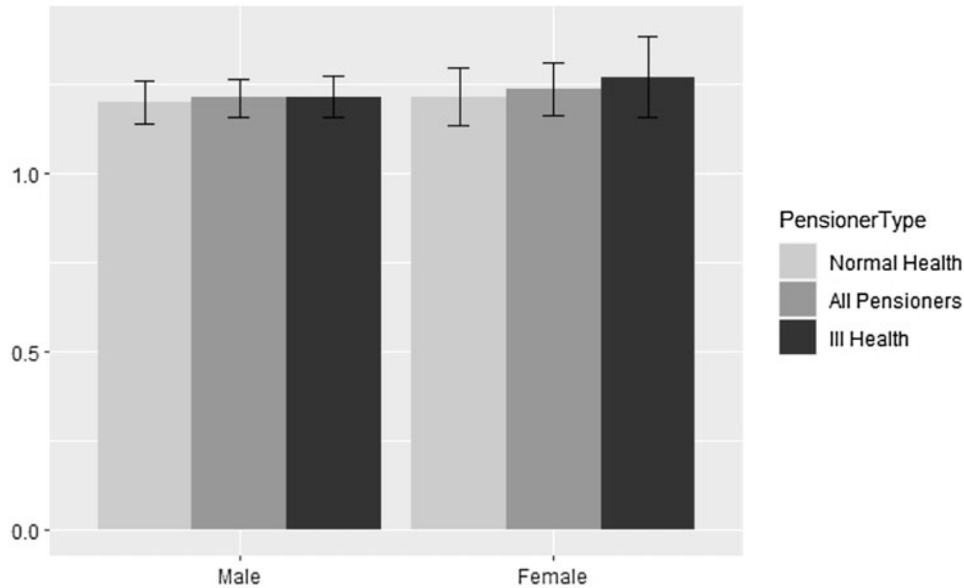

Figure 2. Average and standard deviation of the ratio of winter to summer SMR for age group 50–95 for the period 2011/12–2015/16 (winter) and 2011–2015 (summer) by pensioner type for males and females.

winter-summer mortality gap is greatest for ill-health retirement pensioners while the "All Pensioners" group displays a slightly greater winter-summer mortality gap compared with normal-health retirement pensioners which is consistent with the inclusion of both normal-health and ill-health retirements within this group. While the lower data volumes for female pensioners relative to males contribute to the greater variation in the winter-summer mortality gap seen for females as noted earlier, the difference in exposure between males and females over this period is less than 15%.

Seasonal differences in mortality increase with age and Figure 3 presents the relative differences between summer and winter mortality for the 15-year age groups, 50–64, 65–79 and 80–95, for the male and female pensioners. From Figure 3, we can see that female ill-health retirement pensioners exhibit the greatest relative difference in each age group. The gap between winter and summer mortality for both male and female ill-health retirement pensioners for age group 50–64 is exceptionally large for such a young cohort indicating greater vulnerability to seasonal mortality differences during the reverse select period for ill-health retirement pensioners. For normal-health retirement pensioners, the relative differences are small to non-existent for the younger age groups 50–64 and 65–79. The differences increase significantly in the oldest age group, age group 80–95, which experiences an approximate 25% gap in winter and summer mortality with females experiencing a slightly greater gap and greater volatility than males. For "All Pensioners," the winter-summer mortality gap in the youngest age group is closer to that for ill-health retirements reflecting the large proportion of deaths from ill-health retirements in this age group. At older ages, the gap for "All Pensioners" is on a par with that for normal-health retirement pensioners. As noted previously, female pensioners tend to experience greater volatility of the winter-summer mortality gap compared to male pensioners.

The mortality of the SAPS members is known to vary by pension amount and the CMI produces graduated life tables for male and female normal-health retirement pensioners split by pension band. Table 2 presents the pension bands used in the graduation of the "S3" amounts-based tables for males and females.

Using the "S3" pension bands, Figure 4 presents the ratio of the average winter to summer SMRs by pension band over the approximate "S3" periods 2009/10–2015/16 for winter and

Table 2. Pension Bands used in "S3" Graduations for Male and Female Normal-Health Retirement Pensioners

Pension Band	Males	Females
Heavy	€300–€5,000	€0–€1,000
Middle	€5,000–€20,000	€1,000–€8,000
Light	€20,000+	€8,000+
Very Light	€40,000+	€16,000+

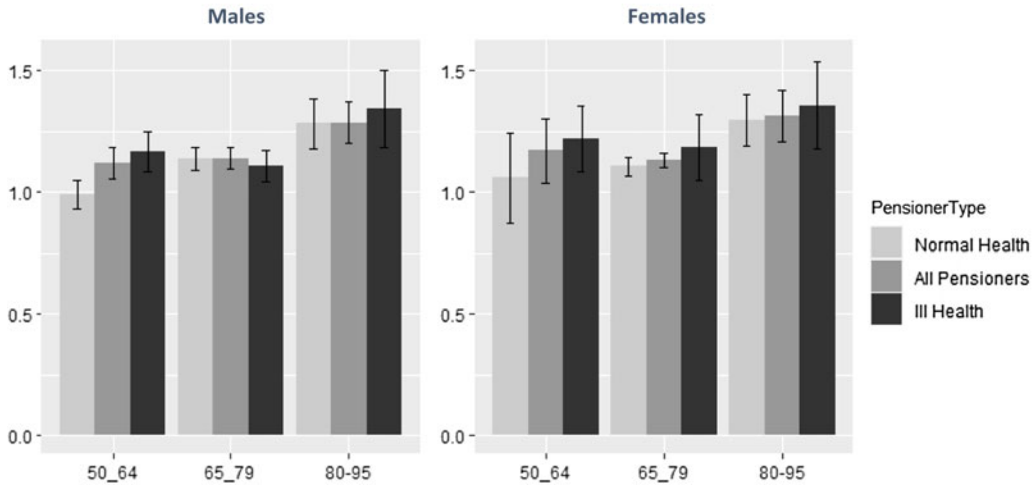

Figure 3. Average and standard deviation of the ratio of the winter to summer SMR for the period 2011/12–2015/16 (winter) and 2011–2015 (summer) by age group for male and female pensioners.

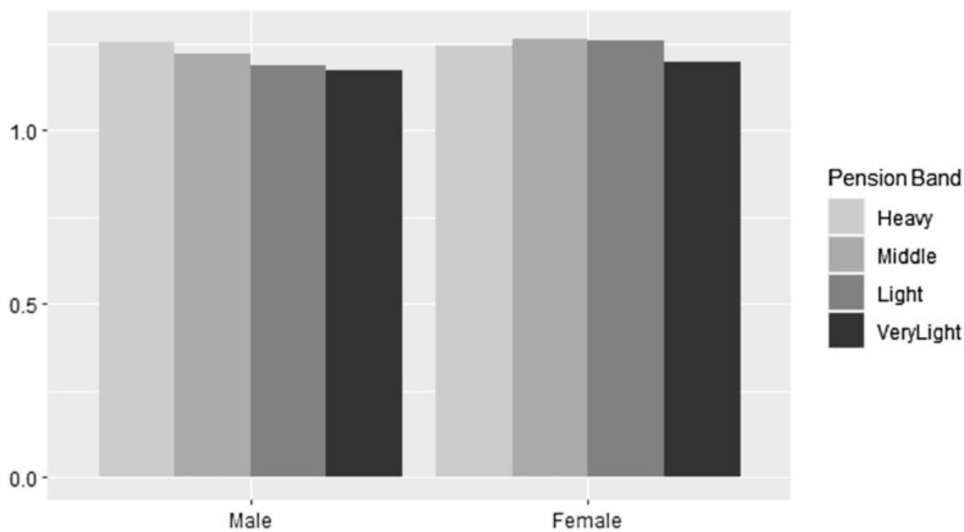

Figure 4. Ratio of the winter to summer SMR for age group 60–95 by pension band for male and female normal-health retirement pensioners for the period 2009/10–2015/16 (winter) and 2009–2016 (summer).

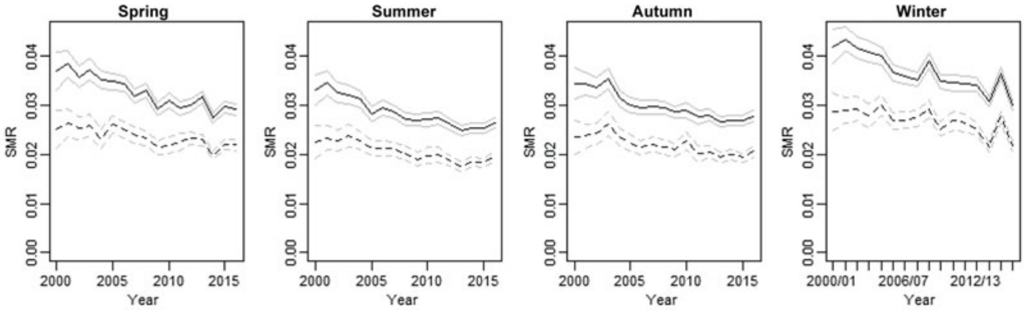

Figure 5. Seasonal SMR trends and corresponding 95% confidence intervals for the SAPS All Pensioners for age group 80–95 for the period 2000/01–2015 (winter) and 2000–2016 (spring, summer and autumn) – males (___), females (_ _ _).

2009–2016 for summer for normal-health retirement pensioners. To ensure sufficient data for analysis, particularly for the "Very Light" pension band, the SMRs were calculated for the age range 60–95. Males show a clear pattern of a decreasing winter-summer mortality gap with increasing pension band. Pension band is known to have less of an effect on female pensioner's mortality and from Figure 4 it can be seen that the winter-summer mortality gap fluctuates by pension band though those with the largest pensions (band "Very Light") do show the smallest winter-summer mortality gap.

3.1. Seasonal Mortality Trends

Figure 5 presents the trends in the standardised mortality rates by season for age group 80–95, the group most affected by seasonal mortality differences, for All Pensioners (normal-health + ill-health + combined) for males and females, respectively. Trends are analysed for the period 2000–2016 for the spring, summer and autumn seasons and 2000/01–2015/16 for the winter season. In general, mortality declines in each season over the period though, a levelling-off of the mortality decline can be seen from about 2011 onwards with the summer season actually showing a small upward trend in the most recent years. A significant peak in winter mortality can be seen in 2014/15 and is attributed to the ineffectiveness of the influenza vaccine in this instance (Pebody *et al.*, 2018). Similarly, autumn 2003 also shows a peak in mortality which is attributed to the early onset of the influenza season in that year (Cooke *et al.*, 2006).

Figure 6 summarises the changes in the relative risk or ratio between winter and summer mortality over the three five-year periods shown for the age group 80–95. For comparison, the corresponding ratios for the population of England and Wales are also shown. For the male SAPS pensioners, there is no real change in the relative risk over time in contrast to females who show an increased winter-summer mortality gap over time. The trends are consistent with those for the population of England and Wales with males showing a marginal increase in the winter-summer mortality gap and females showing a greater widening of the gap between winter and summer mortality over the time periods. Similarly, the volatility of the mortality gap has increased over time for both the SAPS pensioners and the population of England and Wales, particularly for females. Overall, females tend to show a greater volatility of the winter-summer mortality gap compared to males. In particular, the winter of 2014/15 showed an exceptionally high winter mortality rate relative to the previous summer with female SAPS pensioners showing an approximate 46% increase in winter mortality relative to the previous summer and male pensioners showing an approximate increase of 41% – the increase being even higher for the population of England and Wales with an approximate 46% and 54% increase for males and females, respectively.

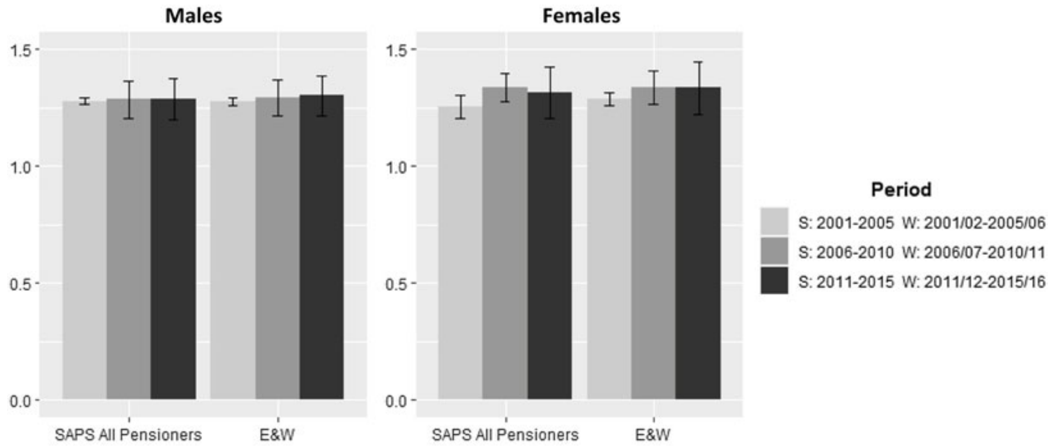

Figure 6. Average and standard deviation of the ratio of the winter to summer SMR for age group 80–95 by five-year period for the SAPS All Pensioners and the population of England and Wales for males and females.

3.2. The 2003 Heatwave

While mortality in the UK is highest in the winter, there is an increasing risk of heatwave-related mortality in the summer months due to climate change. In 2003, the UK and the rest of Europe experienced an exceptionally hot summer (the hottest summer in almost 500 years) culminating in a heatwave in early August. The August heatwave was attributed to the deaths of over 30,000, mainly elderly, people in Europe, while in the UK, there were an estimated 2,000 additional deaths attributed to the heatwave which peaked on 10 August (UNEP, 2004). It is expected that summers as hot as 2003 could become the norm by the 2040s in the UK and that heat-related deaths could triple by the 2050s (House of Commons, 2018a). The elderly and those with underlying conditions are most at risk from heat-related deaths (PHE, 2015) with females more affected than males (Hajat *et al.*, 2007; Schifano *et al.*, 2009; WHO, 2009). More recently, the record-breaking heat during the summer of 2022 in the UK resulted in an estimated 2,803 excess deaths (excluding deaths from Covid-19) in England amongst those aged sixty-five and older with females more affected than males (ONS and UKHSA, 2022).

From Figure 5 above it can be seen that females in the oldest age group, 80–95, experienced the highest summer mortality of the period 2000–2016 in 2003. No similar peak in mortality was seen in the summer of 2003 for male pensioners. The peak in mortality in the summer of 2003 represented an approximate 9% dis-improvement over the average mortality of the previous three summers (2000–2002) for the female pensioners aged 80–95. While winter deaths still exceed summer deaths, climate change and the expected resulting increase in future heatwave events could increase mortality volatility for females at older ages.

4. Seasonal Mortality – SAPS Dependants

Dependants generally have a higher average age profile than pensioners. For the years 2011–2015 over 60% of SAPS dependants deaths occurred at ages 85+ compared with less than 40% of deaths for SAPS all pensioners. For female dependants, almost 65% of deaths occurred after age 85. Consequently, for the SAPS dependants seasonal differences in mortality are analysed for the fifteen-year age group 85–100. Figure 7 presents the five-year average SMR by season for age group 85–100 for dependants for males and females, respectively. As previously, the five-year average SMR by season is calculated by averaging the SMR for each year and for each season over the five-year period 2011/12–2015/16 for winter and 2011–2015 for spring, summer and autumn.

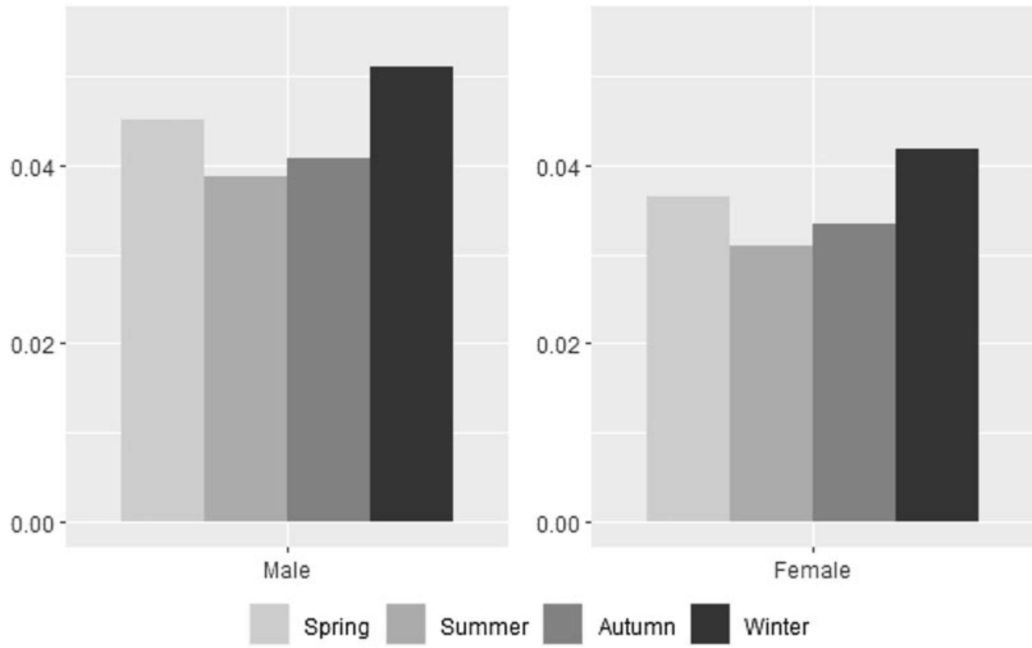

Figure 7. Seasonal SMR for dependants for age group 85–100 for males and females for the period 2011/12–2015/16 (winter) and 2011–2015 (spring, summer, autumn).

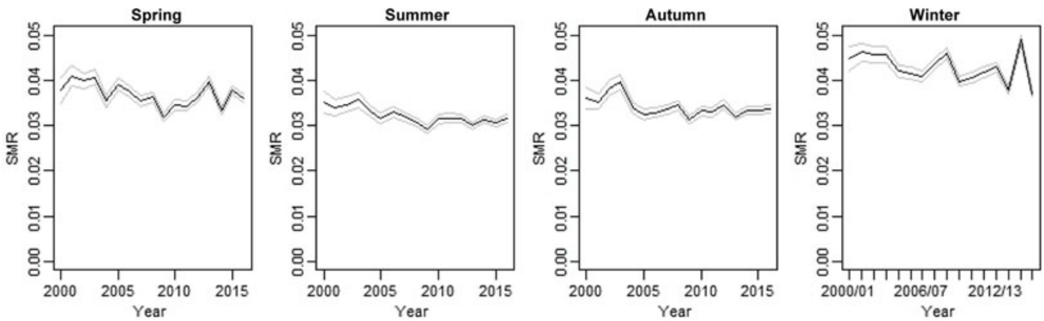

Figure 8. Seasonal SMR trends and corresponding 95% confidence intervals for the SAPS female dependants for age group 85–100 for the period 2000/01–2015 (winter) and 2000–2016 (spring, summer and autumn).

Analysis of the corresponding gap between the winter and summer SMR showed a similar gap for males and females with females again showing a slightly greater gap.

Figure 8 presents the trends in the standardised mortality rates by season for the female dependants aged 85–100 for the period 2000–2016 (spring, summer and autumn) and 2000/01–2016/16 (winter). Trends are not shown for male dependants due to low data volumes in earlier years. The trends are similar to those seen for the female pensioners with female dependants recording the highest winter mortality of the period 2000/01–2015/16 in the winter of 2014/15. Summer mortality peaked in the summer of 2003 with female dependants experiencing an approximate 6% dis-improvement in mortality over the previous three summers again highlighting the vulnerability of females at older ages to heatwaves. Figure 9 summarises the corresponding change in the relative risk between winter and summer mortality over the five-year periods shown

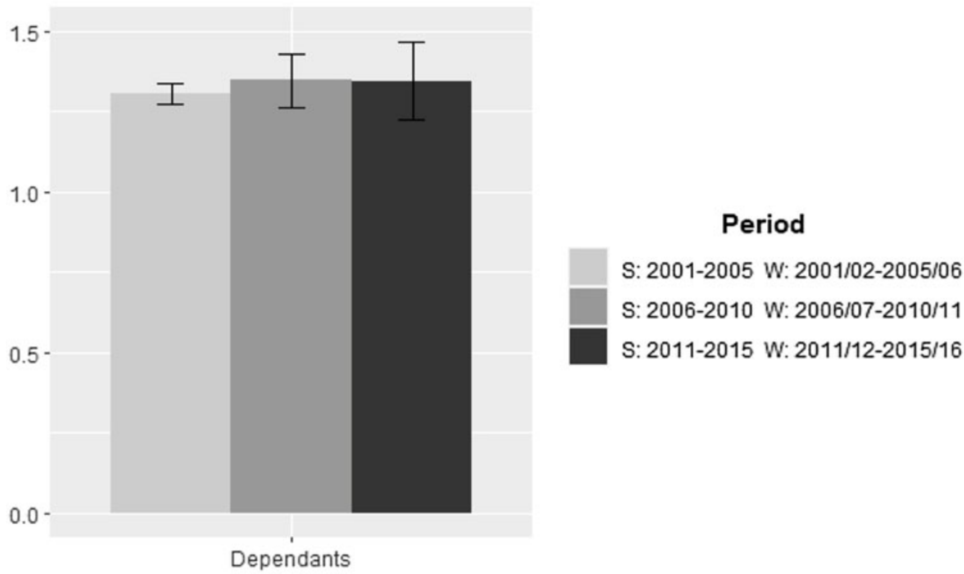

Figure 9. Average and standard deviation of the ratio of winter to summer SMR for age group 85–100 by five-year period for the SAPS female dependants.

from which we can see that, similar to the female pensioners, both the gap and the volatility of the gap between summer and winter mortality increased over time for the female dependants.

5. Seasonal Mortality – England and Wales

In 2009, the CMI developed the CMI Mortality Projections Model (CMI, 2022) to project future mortality rates. The model is based on the population of England and Wales and is widely used in the UK pensions and insurance industries. Differences in seasonal mortality between the SAPS pensioners and the population of England and Wales contribute to demographic basis risk for mortality projections for the SAPS pensioners. Figure 10 presents the trends in the SMRs and the corresponding 95% confidence intervals by season for age group 80–95 for the population of England and Wales for the period 2000–2020 (spring, summer and autumn) and 2000/01–2019/20 (winter). Trends are similar to those seen for the SAPS pensioners for the period 2000–2016 and the volatility of the winter mortality post 2011 is clearly visible. An increase in summer mortality in 2003 can again be seen for females but not for males. The impact of the SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2 – commonly referred to as Covid-19) pandemic is also evident with a sharp spike in mortality in the spring of 2020 and a smaller increase in mortality in the autumn of 2020.

Mortality improvements vary by season and Figure 11 plots the corresponding 5-year average annualised mortality improvements for the summer (2000–2020) and winter (2000/01–2019/20) seasons for males and females, respectively. In general, for the oldest age group 80–95, winter improvements are lower than summer improvements and exhibit greater volatility than summer improvements, particularly for females. The volatility of the winter improvements increased post 2011 with several years recording negative improvements (dis-improvements) in winter mortality. For both males and females, summer improvements peaked around 2008, subsequently declining steadily over the following years to reach their lowest level around 2016.

Figure 12 presents the relative differences for age group 80–95 between the SAPS pensioners and the population of England and Wales for the summer and winter seasons. The relative

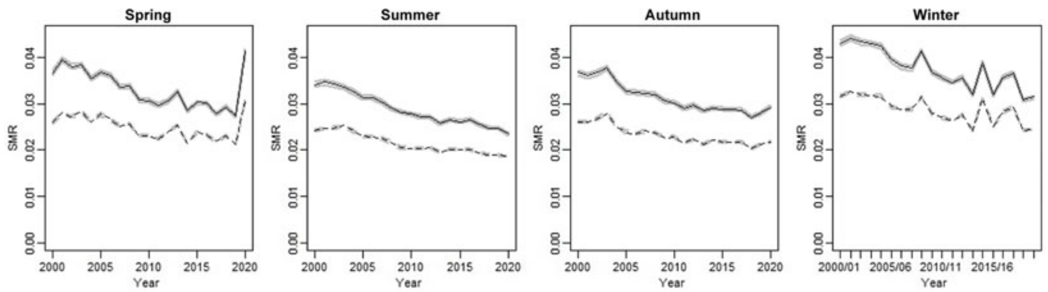

Figure 10. Seasonal SMR trends and corresponding 95% confidence intervals for England and Wales for age group 80–95 for the period 2000/01–2019/20 (winter) and 2001–2020 (spring, summer, autumn): males (—–), females (- - -).

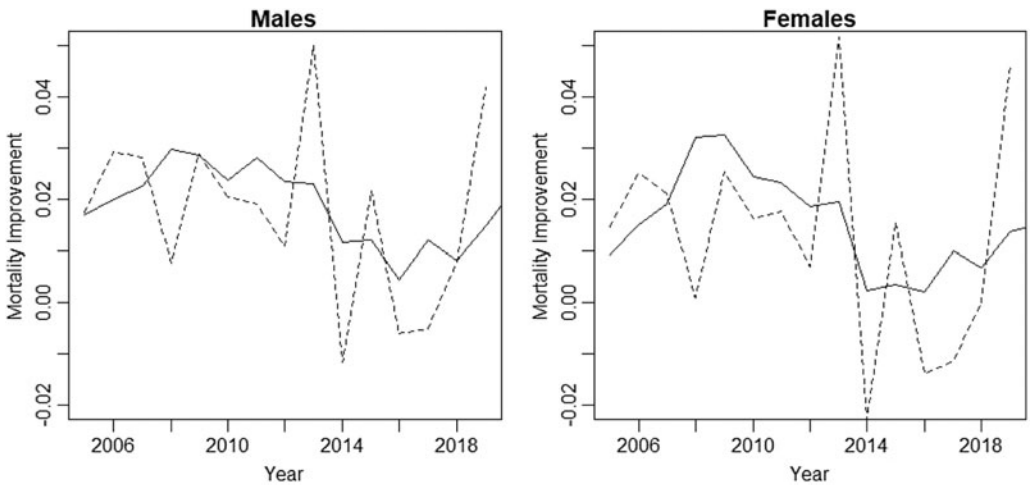

Figure 11. 5-year average annualised mortality improvements for males and females for the summer (—) and winter (——) seasons for the period 2000/01–2019/20 for winter and 2001–2020 for summer for age group 80–95.

difference is calculated as the average of the ratio of the SMR for England and Wales to the SMR for the SAPS pensioners for the winter season (2011/12–2015/16) and the summer season (2011–2015). For both males and females, the difference between the SAPS pensioners and the population of England and Wales is slightly greater in the winter than in the summer.

5.1. Cause of Death

Seasonal differences in mortality also vary by cause of death and changes in the underlying causes of death over time impact seasonal all-cause mortality trends. Table 3 presents the proportion of deaths for the five major causes of death for age group 80–95 and the corresponding ratio of deaths from January to July for the three-year period 2017–2019. Deaths are classified according to the International Classification of Diseases Revision 10. The five major causes of death are Circulatory Diseases (I00-I99); Respiratory Diseases (J00-J99); Mental & Behavioural Disorders (F00-F99); Neoplasms (C00-D48); and all other causes of death combined (A00-B99, D50-E90, G00-H95, K00-R99, U00-Y89). The vast majority of deaths from mental and behavioural disorders at older ages can be attributed to dementia, with the proportion increasing with age.

As expected, deaths due to respiratory diseases show the greatest difference between the summer and winter with over twice as many deaths occurring in January compared to July. Neoplasms show the least difference between deaths in the summer and winter for both males and

Table 3. Deaths by Cause of Death for Age Group 80–95 for the Period 2017–2019 for England and Wales for Males and Females, Respectively

	Males		Females	
	% of deaths	January deaths/ July deaths	% of deaths	January deaths/ July deaths
Circulatory diseases	27%	1.40	26%	1.38
Respiratory diseases	16%	2.06	15%	2.58
Mental & behavioural disorders	11%	1.63	16%	1.77
Neoplasms	25%	1.10	18%	1.12
Other	21%	1.42	25%	1.38

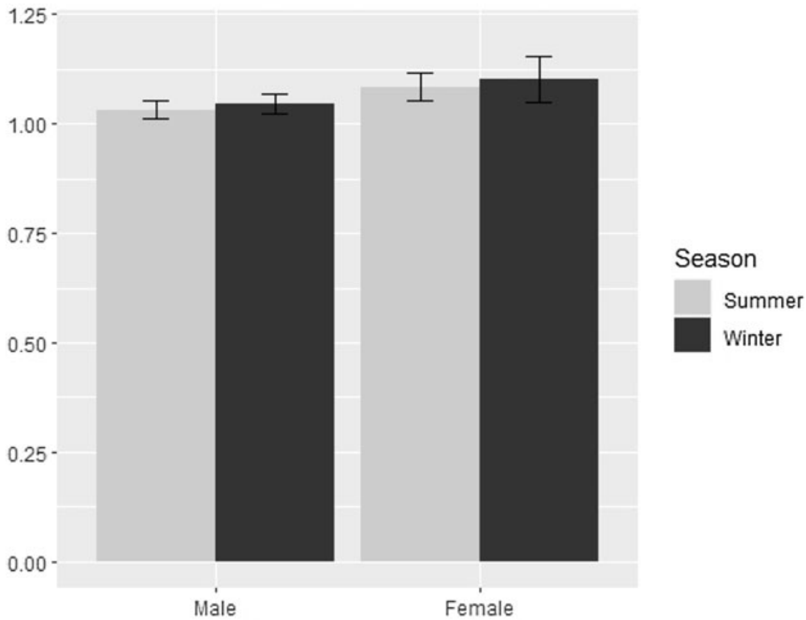

Figure 12. Average and standard deviation of the ratio of the SMR for the population of England and Wales to the SMR for the SAPS pensioners for age group 80–95 for the period 2011/12–2015/16 (winter) and 2011–2015 (summer) for males and females.

females. For the top two causes of death with the greatest gap between deaths in January and July, respiratory diseases and mental & behavioural disorders, respectively, females show a substantially greater difference than males.

As discussed by Liddell *et al.* (2016a) the reasons for higher winter deaths for respiratory and circulatory diseases are mainly physiological – cold weather impairs lung functioning exacerbates existing respiratory conditions and also increases blood pressure both of which place added strain on circulatory systems. The reason for higher winter deaths amongst those with Alzheimer's and dementia are more complex. Liddell *et al.* (2016b) propose a combination of factors to help explain higher winter mortality amongst those suffering from Alzheimer's and related dementias – physiological processes which prevent sufferers from getting warm in cold conditions, an inability to perceive heat and cold as normal and an inability to remedy cold conditions by making adaptive choices in relation to heating and clothing. Future changes in the underlying composition of cause of death will impact trends in seasonal differences in mortality.

6. Discussion and Conclusion

Seasonal differences in mortality increase the uncertainty associated with modelling and projecting mortality at older ages ultimately increasing overall risk for insurers and pension scheme providers. Seasonality of mortality increases with age with those aged eighty and over experiencing over 25% higher mortality in winter compared to the summer. Mortality in the UK peaks in winter followed in descending order by mortality in the spring, autumn and summer. Deaths, therefore, are not uniformly distributed across the year and the non-uniform distribution of deaths is greater at older ages and for more vulnerable pensioners. This has implications when aggregating data across multiple pension schemes contributing data over different time periods. When analysing mortality data, it is important to ensure that exposure volumes are consistent across each month and, in particular, for pensioners and dependants who experience large seasonal differences in mortality.

For the oldest age group, 80–95, the group most affected by seasonal mortality, analysis of the SAPS pensioners showed that female pensioners were more vulnerable to seasonal mortality differences than males – exhibiting a slightly greater gap and a greater volatility of the gap between winter and summer mortality rates in the most recent period, a greater increase in the winter-summer mortality gap over time and an increase in summer mortality during the 2003 heatwave. As the proportion of women in occupational pension schemes increases, seasonal mortality will become more important for mortality experience investigations. Furthermore, female dependants aged 85–100 showed similar seasonal mortality patterns to female pensioners in the oldest age group. Dependants are the most exposed to the risks associated with seasonal mortality due to their higher average age profile.

At the oldest ages, the seasonal mortality trends for the SAPS pensioners were consistent with those for England and Wales. In general, for the population of England and Wales, mortality declined in each season over the period 2000–2020 with mortality post 2011 tending to level off for the spring, summer and autumn seasons and increased winter volatility post 2011. Females in England and Wales experienced greater volatility of winter mortality improvements or, equivalently, greater fluctuations in winter mortality, compared to males particularly post 2011. The gap between the mortality of the SAPS pensioners and the population of England and Wales was slightly higher in the winter than in summer for both males and females. Variations in seasonal mortality between the SAPS pensioners and the population of England and Wales increase the basis risk associated with applications of the CMI Mortality Projections Model for occupational pension schemes.

The problem of higher winter mortality and morbidity is widely recognised in the UK and recent major government initiatives to reduce the higher winter death toll include:

- the Cold Weather Plan for England was introduced in 2011 with the aim of "preventing the major avoidable effects on health during periods of cold weather in England by alerting people to the negative effects of cold weather and enabling them to prepare and respond accordingly" (UKHSA, 2015)
- the Warm Home Discount Scheme also introduced in 2011 provides a rebate on electricity bills and is designed to help those in fuel poverty (Ofgem, 2022)
- and guidance issued by the National Institute for Health and Care Excellence (NICE) in 2015 on improving the health and well-being of people vulnerable to the cold (NICE, 2015).

Vaccine effectiveness continues to improve with the introduction in the UK of quadrivalent vaccines in 2014, which provide protection against four influenza strains compared to the earlier trivalent vaccines that only offered protection against three stains and adjuvanted vaccines in 2017, which increased and lengthened the duration of the immune response to the vaccine in the elderly (Tisa *et al.*, 2016; House of Commons, 2018b). The UK also introduced a childhood influenza vaccination programme in 2012 on a phased basis with all children aged 2 to 16 offered an influenza vaccine for the first time in 2021/22. Vaccinating children provides direct protection for children as well as indirect protection for the entire population by reducing community transmission (UKHSA, 2022a, 2022b). Such initiatives could potentially reduce the magnitude and fluctuation of seasonal mortality differences over time.

Future trends in seasonal mortality are uncertain. Research is ongoing to develop both improved influenza vaccines and a universal influenza vaccine to provide broad and long-lasting protection against influenza, as opposed to the current vaccines, which target particular influenza strains only. A successful universal influenza vaccine would be "game-changing" in the fight against influenza, both removing the need for annual revaccination and enhancing pandemic preparedness (Krammer *et al*., 2018). However, seasonal differences in mortality vary by cause of death with respiratory diseases exhibiting the greatest seasonal differences in mortality and the emergence of Covid-19 at the end of 2019 is likely to further increase seasonal differences in mortality (Fontal *et al*., 2021; Hoogeveen & Hoogeveen, 2021; Nichols *et al*., 2021). As discussed, cold or poor housing is a major cause of higher winter deaths in the UK and the recent increases in energy costs are also likely to negatively impact seasonal mortality differences.

Seasonality of mortality remains a feature of UK mortality and as the population continues to age seasonal differences in mortality will become more important. Risk management for occupational pension schemes should consider seasonal differences in mortality when analysing their mortality experience.

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