Seasonal variations in incidence of femoral fractures in the state of Rio Grande do Sul, southern Brazil

Variações sazonais na incidência de fraturas do fêmur no estado do Rio Grande do Sul, sul do Brasil

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Abstract

Introduction: Femoral fractures are a major cause of morbidity and mortality, mainly among older people. **Objective:** To examine the effect of seasonality on hospitalizations due to femur fracture among people residing in the Rio Grande do Sul state, southern Brazil, from 2008 to 2019. **Methods:** Ecological study based on secondary data from the SUS Hospital Information System (SIH/SUS). A total of 74,374 reports of hospital admissions was considered. The generalized additive model (GAM) approach was employed to assess the seasonality of the time series, with stratification by sex and age groups and considering the monthly average number of events of femoral fractures per day as a dependent variable. **Results:** A considerably higher incidence of femoral fractures in women aged 70 years or more was described. Among people aged less than 50 years, there is not an apparent seasonal effect. Men aged 70 years or older and women aged 50 years or older have a higher frequency of hospitalizations due to femur fractures in the colder months. **Conclusion:** Among older people, more femoral fractures occurred during the winter compared to summer. This supports findings from other studies, although reasons for this seasonal variation are uncertain. The knowledge of these seasonal variations can help to plan the health care in the public health system.

Keywords: Age. Ecological studies. Femoral fractures. Seasonality. Time series.

Resumo

Introdução: *As fraturas de fêmur são uma das causas principais de morbidade e mortalidade, principalmente entre as pessoas idosas.* ***Objetivo:*** *Examinar o efeito da sazonalidade nas hospitalizações devido à fratura do fêmur entre residentes do estado do Rio Grande do Sul, sul do Brasil, de 2008 a 2019.* ***Métodos:*** *Trata-se de um estudo ecológico baseado em dados secundários do Sistema de Informação Hospitalar do SUS (SIH/SUS). Um total de 74.374 relatórios de internações hospitalares foi considerado. O modelo aditivo generalizado (GAM) foi usado para avaliar a sazonalidade da série temporal, com estratificação por sexo e grupos etários e considerando a média mensal de eventos de fraturas do fêmur por dia como uma variável dependente.* ***Resultados:*** *Descreveu-se uma incidência consideravelmente maior de fraturas do fêmur em mulheres com 70 anos de idade ou mais. Entre as pessoas com menos de 50 anos de idade, não há um efeito sazonal aparente. Homens com idade de 70 anos ou mais e mulheres com 50 anos ou mais têm maior frequência de hospitalizações devido a fraturas do fêmur nos meses mais frios.* ***Conclusão:*** *Entre as pessoas mais idosas, as fraturas do fêmur ocorreram mais frequentemente durante o inverno em comparação ao verão. Isto reafirma os resultados de outros estudos, embora as razões para esta variação sazonal sejam incertas. O conhecimento destas variações sazonais pode ajudar no planejamento da assistência médica no sistema público de saúde.*

Palavras-chave: *Idade. Estudos ecológicos. Fraturas femorais. Sazonalidade. Séries temporais.*

Introduction

Among the fractures that most affect the elderly population, femur fracture is the most prevalent. Regardless of the anatomical location, femur fractures are considered severe and a significant health problem.[1,2] This is because this injury demands an extended period for patient recovery and, in some cases, evolves with complications and sequelae that can be much more serious in the elderly population due to the physiological characteristics of this age group and associated diseases. Among the elderly, hospitalization time is longer, often requiring admission to intensive care units due to complications. The rehabilitation period is usually prolonged, and the sequelae may reach partial or total loss of independence in activities of daily living, in addition to high economic costs for health services and considerable social demands for the maintenance of life and health of those affected.[3-6]

Studies carried out in Northern Hemisphere countries have raised discussions regarding the determinants of fracture incidence in the elderly, in which the role of climate conditions, such as freezing and slippery winters, has been shown to be very relevant. These studies all agree that a deeper understanding of the relationship between climate and fracture incidence in different climatic conditions can lead to a better understanding of fracture etiology and seasonality of their incidence, allowing gains in preventive strategies, particularly among the elderly.[7-11] In a systematic review by Burget et al.,[8] it is discussed that knowledge about seasonal patterns in relation to geriatric fracture incidence still has many gaps and that divergent findings have been published in different populations. Of the sixteen included studies that examined seasonal variations and the incidence of some types of geriatric fractures in different parts of the world, thirteen studies were conducted in geographic areas located north of 40° latitude. Of these, four studies recorded an increase in the number of fractures in severe winter (December to February, Northern Hemisphere), and two showed an increased number of fractures in summer.[8]

A study conducted in Queensland[12] showed that from 2009 to 2015, there was a significant difference in the number of hip fractures in different seasons of the year, with winter having a higher number of reported fractures compared to the other seasons. Queensland is a state in Australia where the climate is essentially tropical, which can be compared to the climate of Northeast Brazil, with two well-defined seasons - a dry and a rainy one. Thus, through this study, it was possible to observe that, even in subtropical climates, there seems to be an association between the number of fractures and the climatic conditions of different seasons of the year. Seeking to investigate the effect of seasonality on the incidence of femur fractures in the population residing in the State of São Paulo, Souza et al.[13] observed significant seasonal effects in the female population aged 60 years or older. Among younger men (< 20 years old), no clear seasonal effects were observed, but according to the authors, among the other age groups, there seems to be a higher number of femur fracture cases during the colder months of the year. Thus, there is evidence

that milder temperature variations may also impact the seasonality of fractures in the elderly population, and not only in regions where winter is very severe, such as in the United States and Europe, which highlights a gap in the literature on the seasonality of this health hazard in regions with warmer climates and a high incidence of cases, such as Brazil.

Using statistical time series models, the objective of this paper is to study the seasonality of monthly cases of hospitalization due to femur fracture, by sex and age group, in the population living in the Rio Grande do Sul (RS) state, Brazil.

Methods

Design and ethical considerations

This is an ecological study conducted from January 2008 to December 2019. A total of 74,374 reports of hospital admissions caused by femoral fractures recorded in RS state was considered. We used data from the SUS Hospital Information System (SIH/SUS), available at the website of the Brazilian Health Informatics Department (DATASUS).[14] These data are freely accessible.

The study was performed in accordance with the ethical standards of the Helsinki Declaration and local ethical guidelines. It was not necessary to submit a request to the Research Ethics Committee because public domain data were used and no research participants were identified.

Setting

RS has a territorial area of 281,748 km², located in the extreme south of Brazil, between latitudes 27°05' and 33°45' S and longitudes 49°43' and 57°39' W. According to Köppen's classification, RS presents the Cfa and Cfb climatic types.[15] The Cfb climate type (humid subtropical climate, with warm summer) is found in the northeastern part of the state and in the higher parts of the southeast region. In the other parts, the climate is of type Cfa (temperate oceanic climate, with hot summer).[15] The air temperature in RS presents great seasonal variation with hot summers and harsh winters, with the eventual presence of snow in the higher regions. The warmest month is January (average maximum 27°C) and the lowest temperatures are observed in July (average minimum 11°C).

Statistical analysis

Let us consider that Y_t is a time series related to the number of cases of femoral fractures recorded each month in the state of São Paulo, divided by the number of days of the corresponding month. Thus, Y_t refers to the monthly average number of events of femoral fractures per day, recorded at the month t in the RS state. Considering the period from January 2008 to December 2019, we have t = 1, 2,…,144. Let us consider a generalized additive model (GAM)[16] where the mean of Y_t is given by the expression $a + s_1(trend_t) + s_2(month_t)$. In this formulation, a is an intercept, "trend" is the time series trend, "month" is the corresponding month of the fracture occurrence, and s_1 and s_2 are nonparametric smoothing functions representing the flexible functional form of the association between each covariate and the dependent variable. The GAM allows the estimation of a possible trend in the number of fractures over time and how these numbers change within each month (seasonality). We fitted the GAM based on six different smooths (thin plate regression splines, Duchon splines, cubic regression splines, cyclic cubic regression splines, P-splines, and bivariate adaptive smooths) and used Akaike's information criterion (AIC) for comparisons. This criterion gives preference to the model with the lowest AIC value.[17] For the fit of the model to the data to be considered adequate, the residuals (differences between the observed values of the series and those predicted by the model) should not be autocorrelated, that is, there should be no correlation between successive values of the residuals over the period studied. We used plots of the autocorrelation function (ACF) and the partial autocorrelation function (PACF) to verify this assumption. We use the "mgcv" package of the R program version 3.6.0 for fitting the GAM.[18] The analysis was stratified by sex and age groups: < 15 years; 15–19; 20–29; 30–39; 40–49; 50–59; 60–69; 70–79; and ≥ 80 years.

Results

Table 1 shows the yearly crude incidence of femoral fractures according to age groups and sex, between 2008 and 2019, with the rates per 100,000 population. The denominators used in these calculations are the population projections obtained by the Brazilian Institute of Geography and Statistics (IBGE), also available on the DATASUS web page. Among men, we observe an

increase in fracture rates in the 20-29 age group, perhaps due to more exposure to risky work activities or sports practices. The rates decrease in the following age groups and increase rapidly after the age of 50.

The graphs in Figure 1 describe the monthly average number of events of femoral fractures per day, considering all age groups and both sexes. Panels (b) to (g) in Figure 1 show that the number of hospitalizations due to femoral fractures is higher among men than among women up to the age of 59. After 70 years of age, the number of hospitalizations is much higher among women than among men.

Figure 2 shows plots of the seasonal components s2(montht) obtained from the GAM analysis, according to the months of femoral fracture occurrence, stratified by age groups and considering the male population. The cyclic cubic regression spline smoothing was considered, as it was the one that showed the best fit to the data according to Akaike's information criterion. The GAM analysis showed no evidence of seasonality in the number of hospitalizations due to femur fractures for men aged up to 69 years. However, panel (h) of Figure 2 shows that men aged 70 to 79 years have a higher frequency of hospitalizations due to femur fractures in June, and those aged 80 years and older have a higher frequency of hospitalizations in June and July (panel (i) of Figure 2).

Figure 3 is similar to Figure 2 but comprises the results of the GAM analysis for the female population living in RS. Panels (f) and (g) of Figure 3 showed a slight seasonal behavior for the time series, with a higher number of hospitalizations in August for women aged 50 to 59 years and in July and August for women aged 60 to 69 years. More marked seasonal behavior is observed for women aged 70 years and older. In these age groups, panels (h) and (i) of Figure 3 show that hospitalizations are more frequent in June and July.

Table 1 - Incidence rate of femoral fractures in men and women per 100,000 population per year in Rio Grande do Sul state, Brazil

Age (years)	Years											
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Men												
< 15	18.7	18.1	16.2	18.3	18.1	20.3	18.8	18.3	15.7	18.8	14.5	17.5
15-19	46.4	48.7	45.6	48.9	51.1	53.3	61.5	59.3	55.9	64.6	48.4	48.8
20-29	54.5	59.2	61.4	58.2	58.4	64.0	61.3	64.7	67.7	51.4	57.3	57.1
30-39	36.5	41.7	36.6	39.6	35.6	40.1	37.9	46.1	42.5	42.8	38.6	37.1
40-49	33.1	42.0	34.6	33.2	36.1	32.9	40.2	43.6	35.9	41.8	43.6	40.4
50-59	45.7	44.6	43.2	39.9	38.7	43.2	40.9	44.1	57.7	47.6	47.9	47.4
60-69	68.1	66.7	61.0	63.8	57.9	62.1	76.7	62.4	63.5	70.4	75.0	70.6
70-79	162.8	127.0	134.0	144.0	128.2	164.8	165.9	178.4	172.5	168.5	174.2	147.8
≥ 80	322.5	381.2	393.0	401.8	382.9	385.4	436.0	481.7	473.8	481.0	419.6	462.8
Women												
< 15	8.1	7.8	8.8	8.1	9.2	6.7	8.9	9.5	10.1	7.7	7.7	6.6
15-19	9.3	14.4	12.6	15.4	12.3	13.7	18.4	13.4	17.8	20.9	16.3	15.8
20-29	8.5	11.7	10.0	12.9	12.1	13.7	12.4	14.7	12.8	15.2	13.7	17.9
30-39	9.2	8.9	5.3	7.2	6.0	7.0	10.7	9.1	8.8	10.1	7.7	9.2
40-49	10.3	9.5	8.3	9.0	7.7	9.8	10.8	10.8	14.4	11.9	10.1	11.6
50-59	22.3	23.0	20.4	20.0	21.9	27.2	25.4	29.1	24.8	24.4	22.7	26.9
60-69	68.3	71.3	66.5	71.1	65.6	80.7	77.7	78.4	86.1	86.1	91.0	91.8
70-79	289.3	285.4	241.6	262.5	280.8	303.9	312.2	340.4	346.4	313.5	325.2	314.1
≥ 80	878.1	850.9	804.3	803.1	783.1	927.7	904.0	1006.3	1041.9	971.3	1015.8	958.1

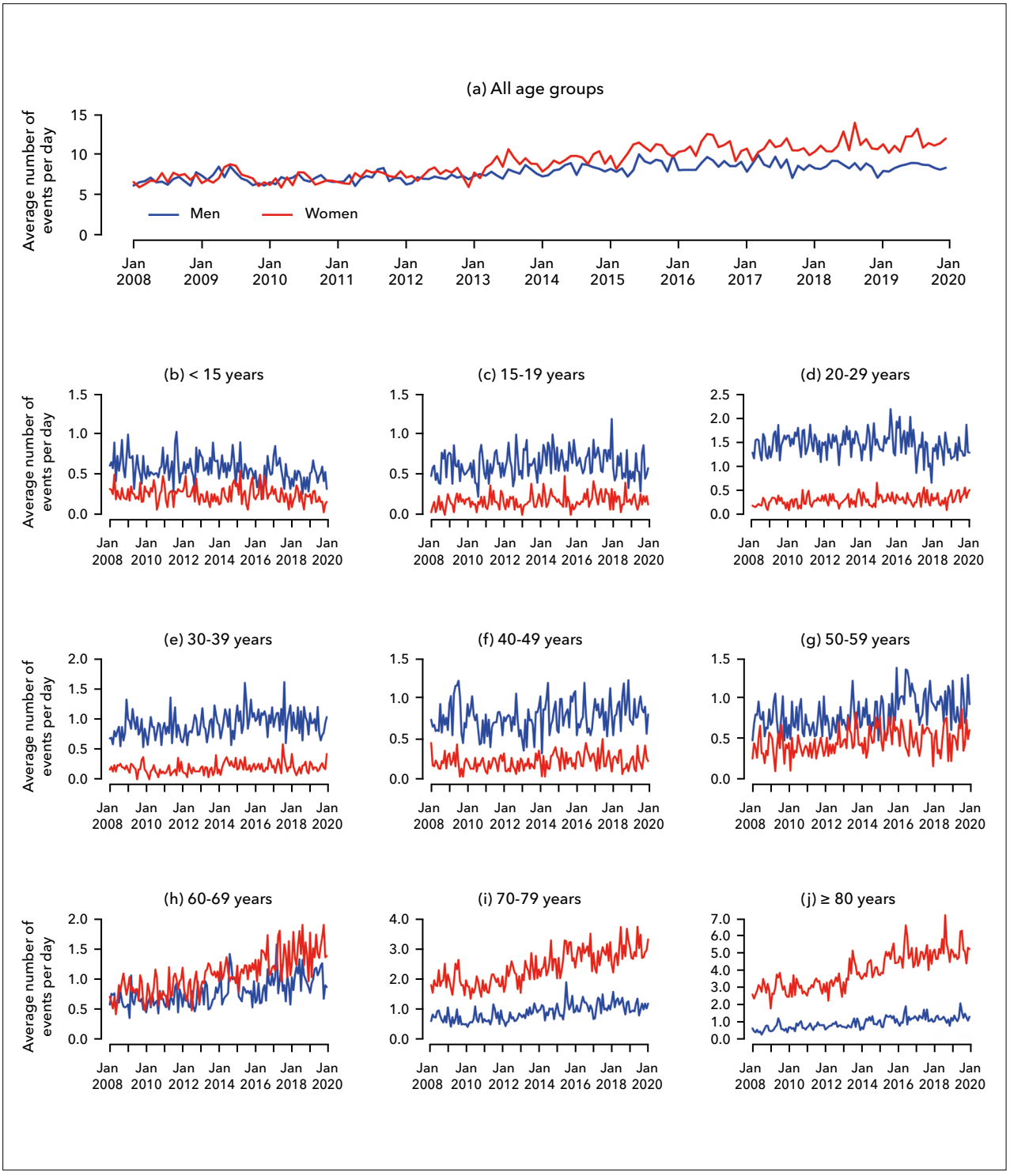

Figure 1 - Monthly average number of events of femoral fractures per day by sex and age group. Rio Grande do Sul state, Brazil, 2008-2019.

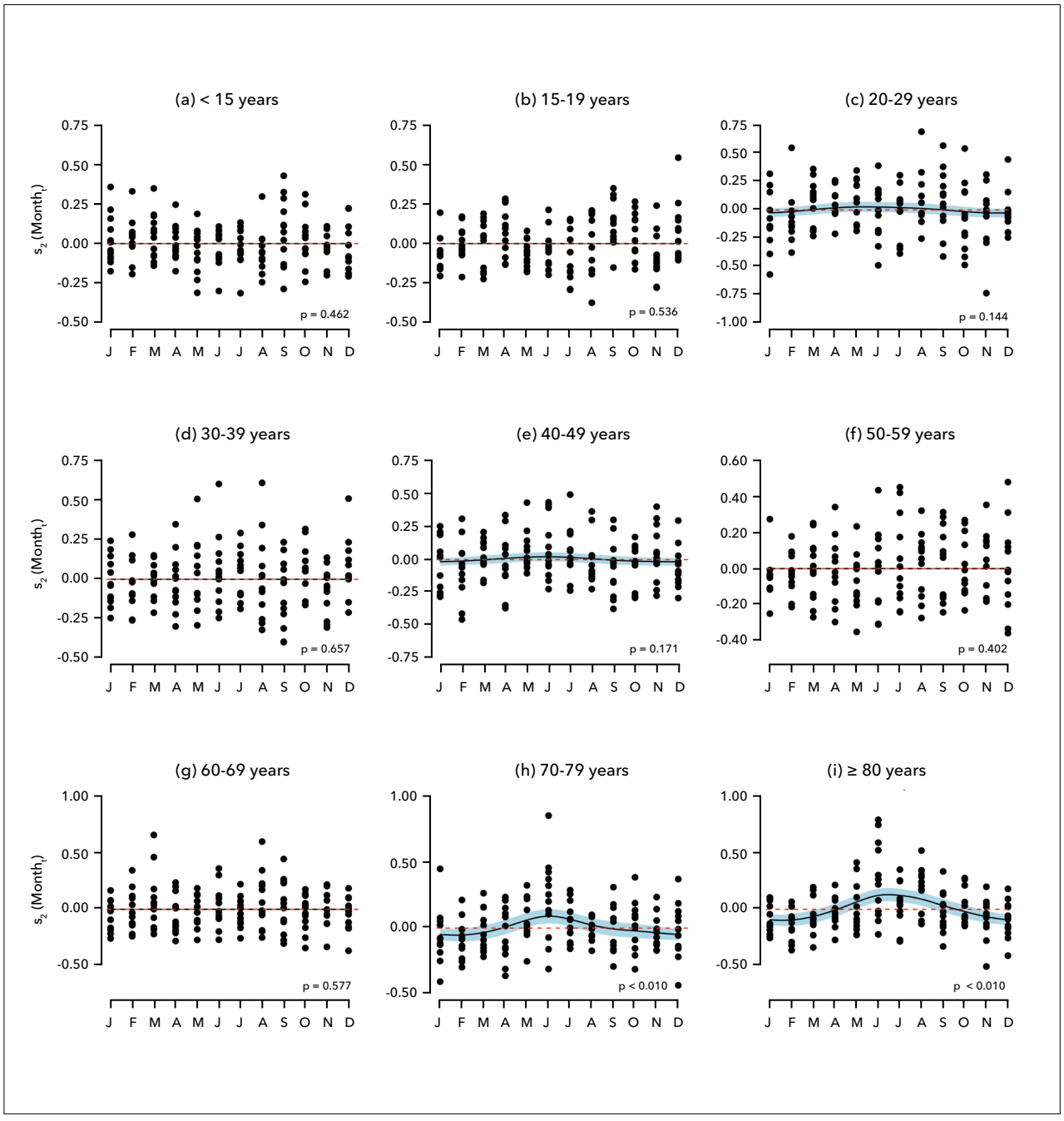

Figure 2 - Plots of the smooth seasonal effects s_2 (Month$_t$) obtained from the GAM analysis, according to the months of femoral fracture occurrence, stratified by age groups and considering the male population. Rio Grande do Sul state, Brazil, 2008-2019.

Note: The solid line is the fitted line, while the shaded areas represent 95% confidential intervals; p-values refer to the approximate significance of smooth terms. GAM = generalized additive model.

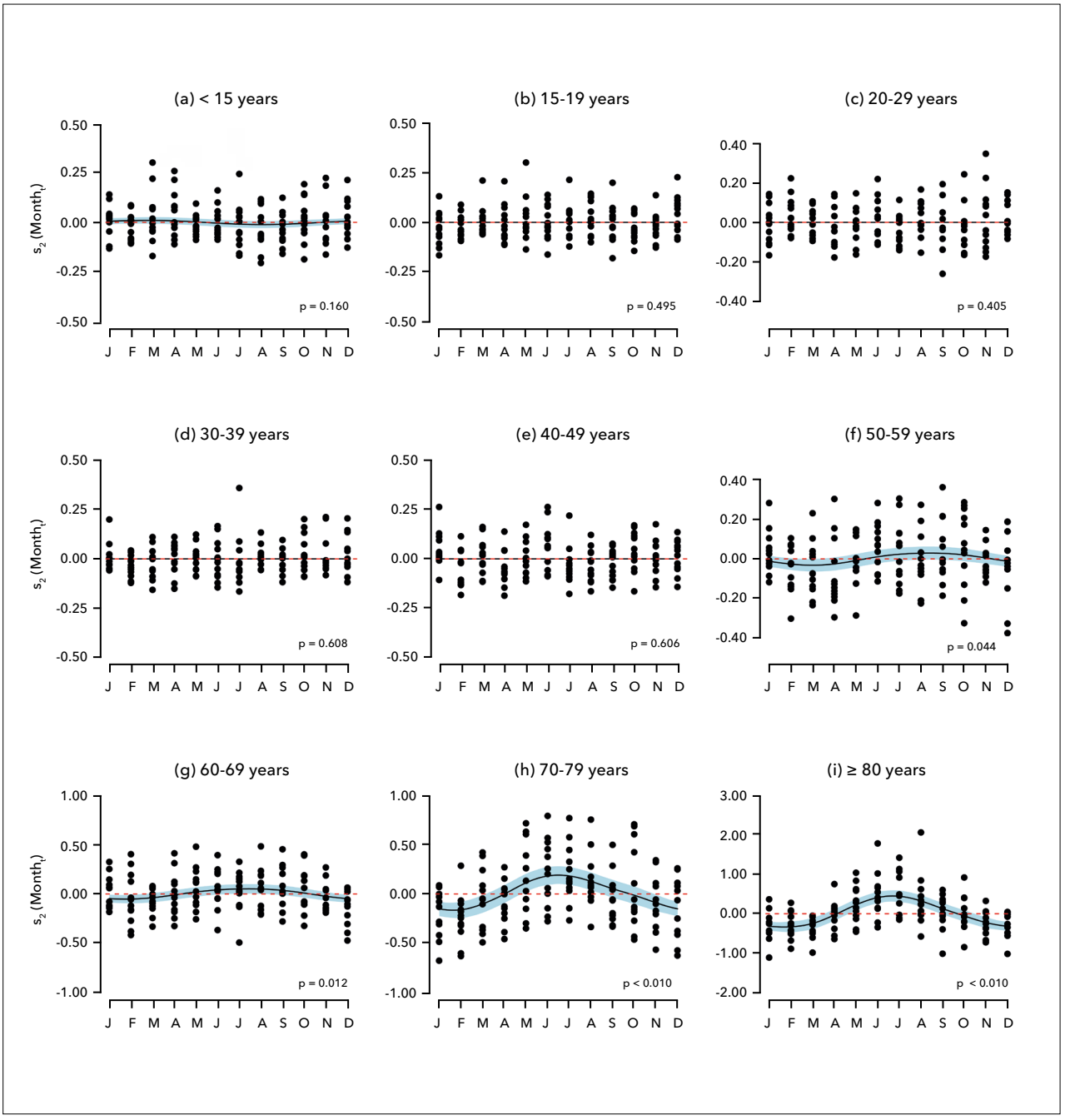

Figure 3 - Plots of the smooth seasonal effects s_2 (month$_t$) obtained from the GAM analysis, according to the months of femoral fracture occurrence and stratified by age groups and considering the female population. Rio Grande do Sul state, Brazil, 2008-2019.

Note: The solid line is the fitted line, while the shaded areas represent 95% confidential intervals; p-values refer to the approximate significance of smooth terms. GAM = generalized additive model.

Discussion

A study based on the hospitalizations of elderly patients with femoral fractures in the Brazilian Unified Health System (SUS) between 2008 and 2018 estimated that an average annual expenditure of almost 100 million Brazilian reals (almost 19 million US dollars) is needed to fund this health care.[19] These fractures have a high impact on older people's abilities, function, and quality of life.[20] Physiotherapy is an important part of the care pathway for people who have had fragility fractures, and it involves interventions such as early mobilization and the prescription of structured exercise programs to maximize functional recovery and reduce the risk of further fractures.[21] Physiotherapists play a crucial role in the prevention of falls in older people.[22] According to Sherrington and Tiedemann,[23] falls occur because of a mismatch between an individual's physiological functions, environmental requirements and behaviors, and many of these physiological functions can be improved by physiotherapy intervention, particularly through the implementation of structured exercise interventions. As a result, identifying groups at higher risk for fractures and the seasonality of their occurrence can benefit physical therapy services, which will be able to target prevention activities to people who are more vulnerable to falls and optimize resource distribution based on seasons when there are more fracture accidents.

In this way, the present study's findings show that among men, the presence of seasonal behavior in the number of hospitalizations is only present among those over 70 years of age, with a higher occurrence in the colder months. Among women, there is a slight seasonality in the 50 to 69 age groups, but the seasonal behavior of the hospitalization series is more evident after age 70, also with a higher frequency of cases observed in the colder months. This result is compatible with that reported by another Brazilian study carried out in the São Paulo state, which also showed evidence that more fractures occur in the colder season.[13]

The results from the GAM analysis of the data from RS provided convincing evidence of seasonality among the elderly population, which is in agreement with most previous studies where seasonality with a winter peak was found.[7-11] For example, in a systematic review including 24 studies, Shi et al.[24] showed that the incidence of fractures was increased in lower temperatures, days with freezing rain, and snow. Although many studies describe this seasonal variation in fracture incidence, its reasons remain uncertain. A hypothesis studied by some authors highlights the role of low exposure to sunshine in vitamin D deficiency.[25] It is known that this deficiency in adults is associated with bone loss, mineralization defects, and fractures, and the primary circulating form of vitamin D is 25-hydroxyvitamin D (calcidiol).[26] Seasonal variations in serum calcidiol occur with a decline during the winter months, and they are accompanied by responsive changes in serum parathyroid hormone concentrations, later increases in bone resorption markers and bone formation markers, and decreases in bone mineral density.[27] While some authors argue that slippery surfaces due to ice and snow conditions increase the number of fractures,[28,29] other studies show that much of the fracture events during the winter period occur in indoor environments.[30] Bastow et al.[30] argue that elderly patients have weaker coordination in winter due to undernutrition and consequent hypothermia. Alternative reasons include influenza infection,[31] clumsiness due to the use of additional layers of clothing,[32] seasonal differences in sunlight,[28] and indicators of air pollution.[7,33]

This study has some limitations that should be noted. The ecological design does not permit further exploration of causal relationships between seasons and the number of hospitalizations. There is the possibility of underreporting of events and miscoding of femur fracture.34 The SIH/SUS covers only records obtained from the hospitals affiliated with SUS, excluding admissions from the Private Health System and the Supplementary Health System. In addition, the data does not include important information, such as the environment in which the fracture occurred, the type of accident (e.g., falls, traffic accidents, sports accidents, and others), and the severity of the trauma.

Conclusion

Among older people, more femoral fractures occurred during the winter compared to the summer. This supports findings from other studies, although the reasons for this seasonal variation are uncertain. The knowledge of these seasonal variations can help plan health care in physiotherapy services and the public health system.

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Authors´contributions

BAP, MLZ and EZM participated in all stages of the study, from its conception to writing the manuscript, and were responsible for planning and carrying out the research, as well as data analysis and interpretation. AAN assisted in study planning, revised data interpretation, and supported in writing the manuscript. MMS assisted in the statistical design, revised data analysis and interpretation and supported in writing the manuscript. All authors approved the final version

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