What is the impact of seasonal ambient changes on the incidence of falls among older adults?

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Abstract

Purpose – *This systematic review paper aims to investigate seasonal ambient change's impact on the incidence of falls among older adults.*

Design/methodology/approach – *The population, exposure, outcome (PEO) structured framework was used to frame the research question prior to using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis framework. Three databases were searched, and a total of 12 studies were found for inclusion, and quality appraisal was carried out. Data extraction was performed, and narrative analysis was carried out.*

Findings – *Of the 12 studies, 2 found no link between seasonality and fall incidence. One study found fall rates increased during warmer months, and 9 of the 12 studies found that winter months and their associated seasonal changes led to an increase in the incidence in falls. The overall result was that cooler temperatures typically seen during winter months carried an increased risk of falling for older adults.*

Originality/value – *Additional research is needed, most likely examining the climate one lives in. However, the findings are relevant and can be used to inform health-care providers and older adults of the increased risk of falling during the winter.*

Keywords *Older adults, Gerontology, Geriatric, Falls, Seasonal changes, Season(s), Fall rate*

Paper type *Research paper*

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1. Introduction

The World Health Organization (WHO) (2021) defines falling as "an event which results in a person coming to rest inadvertently on the ground or floor or other lower-level." It is known that older adults, those aged 65 years and older, are more likely to fall (approximately one in three) (WHO, 2021; National Health Service, 2021) and that 50% of older over the age of 80 will experience at least one fall per annum (National Health Service, 2021). In acute hospitals, falls are the most frequently reported safety incident (Morris and O'Riordan, 2017). Falls can have devastating effects on older adults, with 20% resulting in serious injuries, for example, broken bones and head injuries (Centers for Disease Control and Prevention, 2017). In addition to this, 90% of fractured hips in older adults are a direct result of a fall, and approximately 9% of older adults who fracture a hip die within one month of doing so (Morley, 2010). This frightening statistic increases to 30% of older adults with fractured hips passing away within a year of the causative fall (Morley, 2010). In addition to the negative individual outcomes associated with falls, they also negatively affect health systems with high costs (Peel, 2011). In Ireland, the Health Service Executive (HSE) estimates that the treatment of fall-related injuries in older adults will cost between 1,587m and 2,043m euros by the year 2030 (Health Service Executive, 2020).

There is much literature and studies available about falls among older adults, especially in care settings where observation can take place (Trevisan *et al.*, 2021; Vu *et al.*, 2004;

Lach *et al.*, 2017). A lot of the available literature focuses on intrinsic and extrinsic factors associated with falling. When one focuses on available studies examining the effect of extrinsic factors, it becomes clear that many studies and subsequent systematic reviews (SRs) focus on controllable extrinsic factors such as flooring, lighting and medication (Enderlin *et al.*, 2015). However, no SR could be found that analyses studies that examine the uncontrollable extrinsic factor which is seasonal ambient changes. Dent *et al.* (2020) write that the human species have been overcoming seasonal ambient changes for thousands of years. They write that humans, in any part of the world, can be deemed "seasonality flexible" due to their ability to adapt to seasonal changes (Dent *et al.*, 2020). There is also research that indicates that these seasonal ambient changes can affect our health and well-being. One such study was conducted by Iwamoto *et al.* (2020) who investigated the effects of natural light on the incidence of fall rates in older hospital patients. They found that those with a bed beside a window received an average daytime light intensity of 327.9 lux and had a fall incidence of 1.21 (per 1,000 person-days). Those not in a bed beside a window only received 118.4 lux on average and the fall incidence rose to 3.15. In another study, Ersoy *et al.* (2018) established a link between seasonal changes and the nutritional intake of older adults. They found that in winter, older adults were more likely to consume a higher number of calories. Carbohydrates, vegetable protein, n-3 fatty acids and sodium intake also increased in winter. Changes were also observed during the summer months and notably, serum vitamin D levels were observed to be at their highest in August while serum parathyroid hormone levels were at their lowest in winter (Ersoy *et al.*, 2018). It is evident that seasonal ambient changes can have a significant impact on various aspects of health and well-being, particularly as we age. However, to the best of the authors' knowledge, as no SR has been done on the impact of seasonal ambient changes on the incidence of fall rates in older adults, this study, therefore, set out to address the following research questions and the aim.

2. Methods

2.1 Design

An SR of all published literature was conducted in line with the recommendations and guidelines set out in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins *et al.*, 2021). In addition to this, the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were adhered to Page *et al.* (2021).

2.2 Aim and research question

The aim of this SR is to determine if seasonal ambient changes influence the incidence of falls among older adults.

The study question was framed using a structured approach referred to as a PEO question. This type of question format can be used when studying the effect of an exposure (or lack of exposure) on a certain population (Virginia Commonwealth University, 2022).

2.3 Search strategy and search methods

The present SR included studies that met the following criteria, inclusion criteria were as follows:

- adults aged 60 or older;
- published in English (or available to read suitably translated);
- quantitative studies; and
- studies/research appraised as suitable for answering the SR question.

The exclusion criteria were as follows:

- adults under 65 years of age;
- studies/research that was not published or available to read in English; and
- qualitative studies.

The following electronic databases were searched:

- MEDLINE (EBSCO) (1950 to January 2022);
- CINAHL Plus (EBSCO) (1982 to January 2022); and
- EMBASE (2002 to January 2022).

A preliminary search was conducted using one database, Medline via the EBSCO host. This was done to establish search terms that would produce studies relevant to the SR question.

After deciding on search terms, the following terms were searched together on all three chosen databases:

- "older adults," "elderly," "geriatrics(s)," "aging," "senior," "aged," "older people" and "65+";
- "fall," "falls" and "accidental fall(s)"; and
- "seasonal changes," "seasonal ambient changes," "ambient changes" and "seasons."

2.4 Data extraction, analysis and synthesis

Munn *et al.* (2018) note that in SRs, data extraction must be done prior to synthesis. Data extraction is conducted to gather certain characteristics such as population, country of study and timeframe from each study included in the SR (Taylor *et al.*, 2021). This information is used not only to inform the researcher conducting the SR but also to aid in quality appraisal and reducing the risk of bias (Taylor *et al.*, 2021).

The use of a data extraction table was used (see Appendix 1). Table 1 included author, date, title, country, aims/purpose, design, setting, participants, inclusion/exclusion criteria, duration, primary outcome, a secondary outcome, results, limitations, conclusions and recommendations.

Heterogeneity was present in the studies. As such, a meta-analysis could not be performed. The narrative analysis will be used to describe the findings of this SR.

2.5 Quality appraisal

Evidence-based librarianship (EBL) was used to appraise the quality of the selected studies in this SR. EBL is comprised of two main elements – appraising how the research was performed and how the research and its findings are presented (Glynn, 2006). EBL offers a tool, "the EBL checklist," that can be used when carrying out an SR. This checklist is made up of generic, but thorough, questions that assess the validity, applicability and appropriateness of a study (Glynn, 2006). Ultimately, evidence-based practice is the goal of health-care research, particularly in the field of nursing. As such, the authors chose to use EBL for quality appraisal as not only does it assess validity but also seeks to find out if the research findings are applicable to practice.

3. Results

3.1 Search

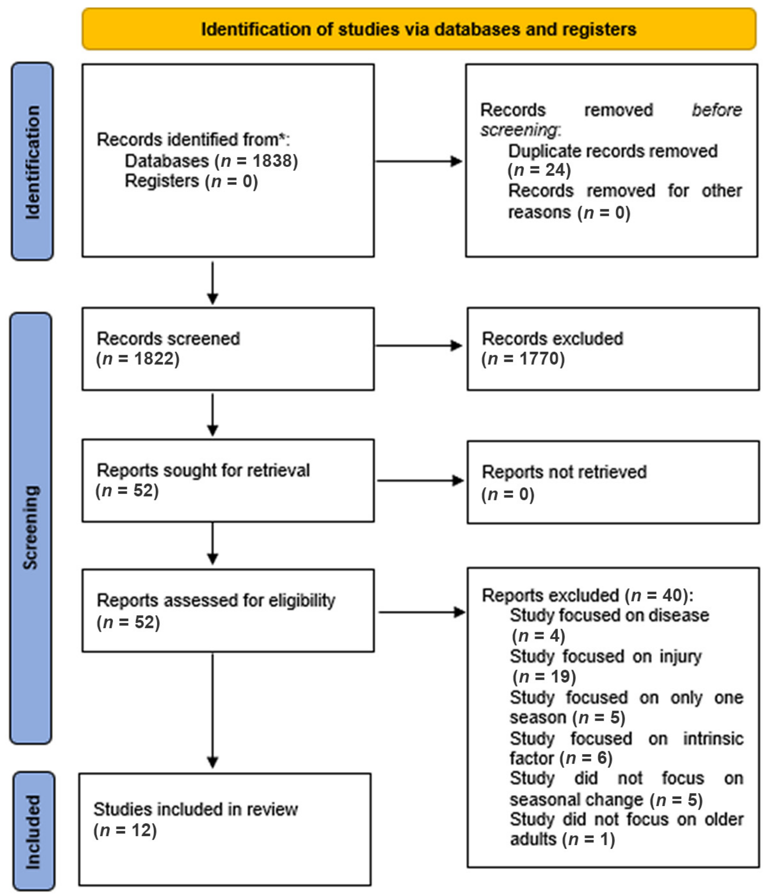
The combined PRISMA flow diagram (figure 1), below, outlines the flow of article screening and selection through the SR. Following the use of the above search strategy, 1,838

Table 1 Characteristics of included studies

Author	*Country*	*Sample size*	*Primary outcome*	*Secondary outcome*	*Study type*	*EBL score*
Ashley *et al.* (1977)	Canada	441	Incidence of falls (not explicitly stated)	Injury (not explicitly stated)	Longitudinal observational cohort study	61% (Not valid)
Parker and Martin (1994)	UK	429	Relationship between weather and hip fractures (not explicitly stated)	Fall rates (not explicitly stated)	Prospective study	70% (Not valid)
Bulajic-Kopjar (2000)	Norway	10,992	Fall related fractures and seasonal variation	Fall rates (not explicitly stated)	Prospective observational population based cohort study	82.5% (Valid)
Mamdani and Upshur (2001)	Canada	455,103	Temporal patterns of fall-related hospitalizations (not explicitly stated)	Injury (not explicitly stated)	Retrospective, population-based study	82.5% (Valid)
Stevens *et al.* (2007)	USA	1.63 million	Seasonal patterns of falls (not explicitly stated)	Effect of climate on falls (not explicitly stated)	Retrospective study	87.5% (Valid)
Kojima *et al.* (2008)	Japan	849	Fall rates (not explicitly stated)	Injury (not explicitly stated)	Retrospective study	77% (Valid)
Bird *et al.* (2013)	Australia	88	Effect of serum vitamin D levels on postural sway and fall rates (not explicitly stated)	Injuries (not explicitly stated)	Longitudinal observational cohort study	88% (Valid)
Magota *et al.* (2017)	Japan	464	Impact of behavioral and ambient changes on falls (not explicitly stated)	Injury (not explicitly stated)	Retrospective study	66% (Not valid)
Kihara *et al.* (2019)	Japan	403	Fall rates (not explicitly stated)	Injury (not explicitly stated)	Prospective cohort study	83% (Valid)
Molés Julio *et al.* (2020)	Spain	966	Description and characteristics of falls	Injury (not explicitly stated)	Cross-sectional observational and descriptive study	97% (Valid)
Kim *et al.* (2020)	Korea	2,012	Fall characteristics (not explicitly stated)	Injury (not explicitly stated)	Cross-sectional study	78% (Valid)
Xing Xing *et al.* (2020)	Hong Kong	89,100	Self-reported falls	None listed.	Retrospective study	88% (Valid)

Source: Table by authors

Figure 1 PRISMA flow diagram



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

Source: Figure by Page *et al.* (2021)

published papers were found. Twenty-four were found to be matches and were excluded. A further 1,770 were excluded following screening as they were not related to the SR question. Subsequently, 52 papers were reviewed; however, 40 of these were not deemed eligible for various reasons (see Appendix 2). Twelve published papers were found to meet the inclusion criteria (Ashley *et al.*, 1977; Bird *et al.*, 2013; Bulajic-Kopjar, 2000; Molés Julio *et al.*, 2020; Kihara *et al.*, 2019; Kim *et al.*, 2020; Kojima *et al.*, 2008; Magota *et al.*, 2017; Parker and Martin, 1994; Stevens *et al.*, 2007; Xing Xing *et al.*, 2020).

3.2 Study designs

Study designs varied. Ashley *et al.* (1977) carried out a five-year longitudinal study. Bird *et al.* (2013) also carried out a longitudinal study that lasted one year. Parker and Martin (1994), Bulajic-Kopjar (2000) and Kihara *et al.* (2019) conducted prospective studies. The remaining seven studies (Mamdani and Upshur, 2001; Stevens *et al.*, 2007; Kojima *et al.*, 2008; Magota *et al.*, 2017; Kim *et al.*, 2020; Xing Xing *et al.*, 2020) were retrospective in nature.

3.3 Geographical location

The chosen studies are from all over the world. One study is from the UK (Parker and Martin, 1994), one is from the USA (Stevens *et al.*, 2007), one is from Norway (Bulajic-Kopjar, 2000), one is from Spain (Molés Julio *et al.*, 2020) and another is from Australia (Bird *et al.*, 2013). The remaining studies can be grouped as they were either conducted in the same country or on the same continent. Two studies are from Canada (Ashley *et al.*, 1977 and Mamdani and Upshur, 2001). Five studies took place in Asia, namely, Japan (three studies), Korea and Hong Kong (Kojima *et al.*, 2008; Magota *et al.*, 2017; Kihara *et al.*, 2019; Kim *et al.*, 2020; Xing Xing *et al.*, 2020). The inclusion of a Korean study was important as Korea has the highest growth rate of the older adult population (Lee *et al.*, 2018).

3.4 Participants and sample size

The sample size in all studies was satisfactory. The mean sample size was 182,571. However, this is high due to Stevens *et al.* (2007) and can be seen in the standard deviation value of 474,0637. The lowest sample size of participants was seen in the study on serum vitamin D levels and postural sway conducted by Bird *et al.* (2013). This study had 88 participants that were invited to take part via posters in their community clubs. Other studies had over 400 participants. It is not possible to calculate the mean age of participants across all studies as some authors did not provide enough information. The majority of studies classed older adults as being 65 years or older however Kim *et al.* (2020) classed older adults as 60 years or older. This is being seen more in older adult literature and with some gerontologists classing older adulthood as beginning at 55 years (Petry, 2002).

3.5 Exposure

The chosen studies all observed or noted the exposure of seasonal differences or changes. No study intervened in any way with the daily lives of participants. Other exposures were noted in some studies such as Kim *et al.* (2020) where ground type and causation were observed. Kihara *et al.* (2019) monitored intrinsic factors of participants, namely cognitive and physical function.

3.6 Primary outcome

The primary outcome (Table 2) of this SR is the incidence of fall rates among older adults. This outcome is measured in all included studies. For this SR, the authors use the WHO's

Table 2 Outcomes measured

Authors	*Primary outcome* *Incidence of falls*	*Secondary outcomes* *Injury*	*Mortality*
Ashley *et al.* (1977)	√	√	N/M
Parker and Martin (1994)	√	N/M	N/M
Bulajic-Kopjar (2000)	√	√	N/M
Mamdani and Upshur (2001)	√	N/M	N/M
Stevens *et al.* (2007)	√	√	√
Kojima *et al.* (2008)	√	N/M	N/M
Bird *et al.* (2013)	√	√	N/M
Magota *et al.* (2017)	√	N/M	N/M
Kihara *et al.* (2019)	√	N/M	N/M
Molés Julio *et al.* (2020)	√	N/M	N/M
Kim *et al.* (2020)	√	N/M	N/M

Notes: N/M = not measured; √ = present in the study
Source: Table by authors

definition of a fall which they define as “an event which results in a person coming to rest inadvertently on the ground or floor or other lower-level” (WHO, 2021).

Ashley *et al.* (1977) conducted a longitudinal observational cohort study on nursing home residents to explore the aetiology and circumstances of falls in older adults as well as the relationship between intrinsic factors and falls. 441 residents of a nursing home were observed over five years (the average observation period was 2.2 years per participant). Various observations and findings were made in relation to falls however no major evidence of seasonal variation and fall incidence was found with falls being observed to be relatively evenly distributed by month and season. The authors do note that most falls occurred in residents’ areas (such as the bedroom) but that the occurrence of falls happening outdoors increased during the summer which the researchers expected.

Parker and Martin (1994) conducted a prospective study aimed at investigating a relationship between sub-clinical hypothermia, which impairs coordination in older adults, and hip fractures. The researchers collected data at ED over one year, and in total 429 hip fractures were captured. A constant frequency of falls was observed throughout the year and no relationship between season and falls was observed. Interestingly, a slight association between the day of fall and the presence of ground frost was found. However, this was not found for air frost or temperature.

Bulajic-Kopjar (2000) carried out a prospective observational population-based cohort study to investigate seasonal variations in the incidence of fractures that occurred due to falls among older adults. Data from 10,992 older adults living in three urban areas in Norway was used. Differences between warm and cold seasons can be observed when one focuses on arm fractures. The incidence of arm fractures was 69% higher during the cold period for those aged between 65 and 79 years. The incidence decreased but was still notable for those aged 80 years or more; it was 30%. For all age groups, the incidence of arm fractures was higher among men than women. More hip fractures (27%) were also observed in cold seasons compared to warm seasons. The researchers found that 12% of all hip fractures among those aged 65–79 were a result of the seasonal effect. Only 4% of hip fractures in those aged 80 years or more were attributed to the seasonal effect.

Mamdani and Upshur (2001) conducted a retrospective, population-based study to explore temporal patterns of falls that resulted in hospitalizations among different age groups. This study captured 455,103 falls from April 1, 1988, to February 28, 1999, and included all ages, not just older adults. However, the data pertaining to older adults’ falls can be used in this SR. Seasonal variations in fall prevalence were weaker in those aged 60 years or more when compared to younger age groups (0–9 years, 10–29 years and 30–59 years). However, the researchers did note that peak admission numbers (due to fall related injuries) occurred during the colder months of December to April. The study also concluded that the rate of inpatient admission in the over 60 age group was 4–10 fold higher than in younger age groups.

Stevens *et al.* (2007) conducted a retrospective study that examined data on falls among older adults across the USA that resulted in attending an emergency department. The study used data captured between December 2001 and November 2002. The study used each state’s average temperature as of January 1, 2001, and those with an average temperature of $\leq$32˚F were classed as a “colder climate” while those with an average temperature $>$32˚F were classed as a “warmer climate.” The season of injury was determined based on the date of death for fatal falls and the date of ED treatment for non-fatal falls. Data on falls were retrieved from two national databases. Fatal falls were found via the National Centre for Health Statistics by locating the code for unintentional falls, W00-W19. Non-fatal fall information was obtained from the National Electronic Injury Surveillance System All Injury Program which collects data on types and causes of injuries across the USA. The study found no correlation between seasonal patterns and fatal falls but did find that more men sustained fatal falls than women and that rates rose sharply with age. White men were found to be 2.4 times more likely to experience a fatal fall than black men. For non-fatal falls, a seasonal pattern was observed. In colder climates, the annual fall rate was 9.1% higher than in warmer climates. This could be further broken down between sexes where the annual fall rate was 8.8% higher for men and 9.8% higher for women in colder climates.

Kojima *et al.* (2008) conducted a retrospective study via a questionnaire to determine why few falls are reported by older adults living in Hokkaido, an area of Japan that experiences heavy snow. 849 older adults, aged 65 years or more and living in their own home, returned the questionnaire which asked about fall history including the number of falls, season falls took place in, place of occurrence and cause of the fall (within the past 12 months). In relation to the primary outcome of this SR, it was found that 87.9% of those that had fallen had done so during winter, most commonly on roads or paths. Slipping (48.0%) was the most common cause of falls, and 88% of slip-related falls occurred during winter.

Bird *et al.* (2013) conducted a longitudinal, observational cohort study of 88 community-dwelling older adults to investigate whether postural swap varies seasonally and is associated with serum vitamin D levels and the incidence of falls. Balance measures were taken periodically, and the highest sway scores (poor balance) were observed at the first end of spring measurement. No association between postural sway and serum vitamin D level was observed but vitamin D levels did have a 15% variation throughout the year with the highest serum levels being detected at the end of summer and the lowest serum levels being in winter. 33% of participants had fallen at least once, and 10% had multiple falls. The researchers combined autumn and winter and spring and summer. More falls were reported in autumn and winter compared to spring and summer (30 compared to 18), and no other seasonal differences were recorded.

Magota *et al.* (2017) carried out a retrospective study investigating the impact of seasonal ambient changes on inpatient falls. The average age of the 464 participants was 76.4 years ± 11.0 years. They found the most common activity preceding a fall was using the toilet and that fall rates were significantly higher during the night compared to during the day. In addition to this, the highest rate of falls occurred during the winter months with 07.00 a.m. in February being the time with the highest prevalence of falls. During the day, the female sex was associated with the highest incidence of falls. The longer nights in winter also contributed to additional falls occurring during this season.

Kihara *et al.* (2019) conducted a prospective cohort study aimed at investigating the functional characteristics of older adults who fall in winter and other seasons. Participants (403 in total) participated in a survey and also had in-person interviews where their physical and cognitive function was measured. Of participants, 31.5% had fallen within the past 12 months. Of these falls, 63% had occurred in non-winter months (April to November). Interestingly, those that fell in the winter months had higher levels of activity than those that fell in non-winter months. From a physical perspective, those that fell in non-winter months had a significantly lower maximum walking speed ($P < 0.01$), timed get up and go (TUG) ($P < 0.05$), hip walking distance ($P < 0.05$) and knee extensor strength ($P < 0.05$) when compared to those that fell in winter.

Molés Julio *et al.* (2020) conducted a cross-sectional observational and descriptive study that aimed to describe the circumstances surrounding, and characteristics, of falls among community-dwelling older adults in two areas in Spain. Data was collected at primary health centers from a total of 966 older adults (aged 75 years or more). Participants were asked about falls experienced in the past 12 months. The prevalence of falls in the past year among the participants was 25.9% with almost 70% of these older adults experiencing multiple falls. After examining the circumstances surrounding the falls it was discovered that falls were most common in the morning during colder seasons. Accident was found to be the most common cause of falling, and no major differences were found between the sexes.

Kim *et al.* (2020) compared the characteristics of falls among older adults in urban and rural areas in Korea via a retrospective, cross-sectional survey of 2,012 participants who were over the age of 60 years. Of these, 807 lived between two rural areas, and the remaining 1,205 participants lived between three urban areas. Participants were asked about the month and time of falls they experienced. Falls occurred most frequently in the summer months (June to August) (29.8%) and spring months (March to May) (29.0%) for those living in urban areas. In rural areas, falls most commonly occurred in the summer months (27.8%) and autumn months (26.3%). Seasonal fall rates were statistically different between the two area types ($P = 0.009$). 55.2% of urban falls occurred between 12.00 and 18.00 while 45.9% of rural falls were between 06.00 and 12.00.

Xing Xing *et al.* (2020) conducted a retrospective study examining seasonal patterns of falls (single and recurrent) among older adults in Hong Kong who were living in their own homes but applying for long-term care. This study used the Minimum Data Set-Home Care assessment to extract data. Their results found that those aged 85 years and above were more at risk of experiencing a single fall compared to those aged between 65 and 75 and that females were more likely to fall compared to males. The study classed November to February as winter months for the geographical location and February had the highest incidence of falls. For recurrent falls, the month of February was also associated with the highest incidence of falls; however, females were at a lower risk of experiencing recurrent falls in comparison to males. Older age was also associated with a lower risk of recurrent falls.

3.7 Secondary outcomes

The secondary outcomes (Table 2) of this SR are injury and mortality. The injury was discussed in four studies (Ashley *et al.*, 1977; Bulajic-Kopjar, 2000; Stevens *et al.*, 2007; Bird *et al.*, 2013), and mortality was discussed in one (Stevens *et al.*, 2007).

Ashley *et al.* (1977) observed the severity of injury sustained as a result of falling. They found that the severity of injury varied based on the location of where a fall occurred. The researchers regarded soft tissue damage, the need for suturing or a fracture as a severe injury. It was found that falls that occurred outside or in a resident's own room were linked with severe injuries more than any other location. 21.6% of outdoor falls and 21% of bedroom falls resulted in severe injury.

Bulajic-Kopjar (2000) notes that the difference in the prevalence of falls between seasons is made clear by injuries. They found that the incidence of arm fractures in those aged 65–79 increases by 69% during colder seasons. It is also higher by 30% for those aged 80 years and more. A higher rate (27% higher) of hip fractures was also observed, and 12% of these were in people aged 65 to 79.

Stevens *et al.* (2007) was the only study to reference injury and mortality. The researchers used statistics on both to study the incidence of falls. The researchers retrospectively analyzed the falls across the USA from December 2001 to November 2002. It was found that 12,700 older adults died as a result of falling in this time period, and an additional 1.63 million older adults were treated in EDs for fall-related injuries.

Bird *et al.* (2013) commented on the injury when noting that 28 of the recorded falls among their participants resulted in injury; however, only four of these required medical treatments. One of the four requiring treatment was a confirmed fracture. It was noted that spring was the season with the least reported number of injuries.

3.8 Quality appraisal

The mean validity score between all included studies was 80.04% (S.D. = 10.29). The minimum score was 61% (Ashley *et al.*, 1977), and the highest was 97% (Molés Julio *et al.*, 2020). The majority of studies ($n = 9$, 75%) scored $\geq 75\%$, which means they are valid studies

(Bird *et al.*, 2013; Bulajic-Kopjar, 2000; Molés Julio *et al.*, 2020; Kihara *et al.*, 2019; Kim *et al.*, 2020; Kojima *et al.*, 2008; Stevens *et al.*, 2007; Xing Xing *et al.*, 2020). The remaining three studies (25%) scored below 75% indicating that they are invalid (Ashley *et al.*, 1977; Magota *et al.*, 2017; Parker and Martin, 1994). These results can be seen in Table 3, below.

4. Discussion

This SR's main goal was to investigate the effects of seasonal ambient changes on the incidence of falls in older adults. In this SR, 12 articles met the criteria for inclusion and were

Table 3 Validity scores of included studies

		The validity of included studies % *Study category %*			
Author	*Population*	*Data collection*	*Study design*	*Results*	*Overall results %*
Ashley *et al.* (1977)	60% (Not valid) Population not bias free, not large enough and not all eligible users recruited. It is not clear if consent was obtained	43% (Not valid) It is unclear if the data collection instrument is validated, if questions were posed clearly	60% (Not valid) It is unclear if ethics approval was granted	80% (Valid)	61% (Not valid)
Parker and Martin (1994)	67% (Not valid) Inclusion/exclusion criteria are not given and it is unclear if consent was obtained	50% (Not valid) Instrument is not included and it is unclear if it was validated. It is unclear if those collecting data were delivering care	80% (Valid)	83% (Valid)	70% (Not valid)
Bulajic-Kopjar (2000)	83% (Valid)	100% (Valid)	80% (Valid)	67% (Not valid)	82.5% (Valid)
Mamdani and Upshur (2001)	67% (Not valid) Inclusion/exclusion criteria are not given and it is unclear if consent was obtained	100% (Valid)	80% (Valid)	83% (Valid)	82.5% (Valid)
Stevens *et al.* (2007)	67% (Not valid) Inclusion/exclusion criteria are not given and it is unclear if consent was obtained	100% (Valid)	100% (Valid)	83% Valid)	87.5% (Valid)
Kojima *et al.* (2008)	83% (Valid)	57% (Not valid) The instrument was not listed, it is unclear if it was validated and if questions were posed clearly	100% (Valid)	67% (Not valid)	77% (Valid)
Bird *et al.* (2013)	83% (Valid)	100% (Valid)	100% (Valid)	67% (Valid)	88% (Valid)
Magota *et al.* (2017)	60% (Not valid) Population is not bias free and not representative of all eligible participants	57% (Not valid) The instrument was not listed, it is unclear if it was validated and if questions were posed clearly	80% (Valid)	67% (Not valid) It is unclear if cofounding variables are accounted for or if there was external validity	66% (Not valid)
Kihara *et al.* (2019)	100% (Valid)	50% (Not valid) It is unclear if the instrument was validated or if questions were posed clearly	100% (Valid)	83% (Valid)	83% (Valid)
Molés Julio *et al.* (2020)	100% (Valid)	87.5% (Valid)	100% (Valid)	100% (Valid)	97% (Valid)
Kim *et al.* (2020)	100% (Valid)	50% (Not valid) The instrument is not listed and is unclear if it was validated. It is unclear if questions were posed clearly	80% (Valid)	83% (Valid)	78% (Valid)
Xing Xing *et al.* (2020)	67% (Not valid) The population was not representative of all eligible participants and it is unclear if consent was obtained	86% (Valid)	100% (Valid)	100% (Valid)	88% (Valid)

Source: Table by authors

included for analysis. The results of the studies were mixed. Several studies such as Ashley *et al.* (1977) and Stevens *et al.* (2007) did not find any link between seasonal changes and fall rates. It should be noted that the study conducted by Ashley *et al.* (1977) took place in a nursing home where older adults are assisted 24 h per day to perform their activities of daily living. The remaining did find a link, in some way, to seasonal changes affecting fall rates in older adults. However, the findings were not the same. One study (Kim *et al.*, 2020) found that falls increased during warmer months. This study took place in Korea and examined the difference in fall characteristics between older adults in rural and urban areas. Peak fall numbers were reported in spring and summer for urban areas and summer and autumn for rural areas. The remaining nine studies found a link between cooler temperatures and a higher prevalence of falls.

While the majority (75%) of studies did find a link between cooler, winter months/ temperatures and an increased incidence of falls it should be noted that the cause could be seen as different between studies. Parker and Martin (1994) found that fall rates remain relatively consistent throughout the year however they noted a relationship between the presence of ground frost and an increase in older adults presenting to the ED for treatment of fall related injuries. In contrast to this, an increase in the incidence of falls among older adults has also been noted the study conducted by Xing Xing *et al.* (2020). However, the authors note that it does not snow in Hong Kong and write that the risk of slipping on snow or frost is not applicable to the population studied. The researchers suggest that physiological, mental or behavioral changes linked with seasonality may be the cause. Following this mindset, Bird *et al.* (2013) examined the relationship between seasonal changes in serum vitamin D levels and the incidence of falls. The researchers found that serum vitamin D levels in older adults are at their lowest during the winter (15% lower than the peak levels observed during the summer). Interestingly, the majority of falls were in autumn and winter. It might be noted that a link between postural sway and vitamin D levels was not found. Early winter mornings were found to be peak times for falls among older adults by two studies (Molés Julio *et al.*, 2020; Magota *et al.*, 2017). Molés Julio *et al.* (2020) also noted that the use of slippers can contribute to the fall risk, this was reiterated by Kim *et al.* (2020).

The EBL checklist was used to evaluate the methodological quality of the 12 studies. Only one study, 8.33%, (Ashley *et al.*, 1977) was not valid for study design as it was unclear if ethics approval was sought prior to undertaking the study. A further two studies, 16.66% (Stevens *et al.*, 2007; Mamdani and Upshur, 2001), did not state inclusion or exclusion criteria. This is an important aspect of study design as the population being studied needs to be clear to those using the study results for informing policy and practice. This is also important for ensuring replicability in the future. The populations studied by Magota *et al.* (2017) were not bias free and therefore also not representative of all older adults. The population studied by Xing Xing *et al.* (2020) was also not representative of all older adults as it only focused on those about to enter long-term care. Five studies (41.66%) failed to address seeking consent (Magota *et al.*, 2017; Stevens *et al.*, 2007; Mamdani and Upshur, 2001; Parker and Martin, 1994; Ashley *et al.*, 1977). However, these were retrospective studies using recorded data.

Research methodology is important as it allows one to assess a study's validity, reliability and accuracy. In short, it allows researchers to know if a study, and the subsequent results, can be trusted to inform practice and further research. Despite the above limitations, the studies chosen allow for a well-rounded view of the impact of seasonal changes on older adults' risk of falling.

5. Conclusion

The present study was designed to determine the effect of seasonal ambient changes on the incidence of falls in older adults. This study has found that generally, the season of winter, and the weeks leading up to it, appear to carry an increased risk of falling for older adults. This may be due to lower temperatures that bring increased causative factors such as frost, ice or snow, or behavioral changes such as moving less that lead to muscle loss. It is unlikely that intrinsic factors, such as a loss of serum vitamin D, lead to an increase in the incidence of falls among older adults; however, oral supplementation should be taken to prevent bone density loss. Further research is needed in this area, likely examining the climate one lives in as opposed to seasonal changes. However, the learning from this SR can be used to inform health-care providers and older adults about the increased risk of falling during winter.

References

Ashley, M.J., Gryfe, C.I. and Amies, A. (1977), "A longitudinal study of falls in an elderly population II. Some circumstances of falling", *Age and Ageing*, Vol. 6 No. 4, pp. 211-220.

Bird, M.-L., Hill, K.D., Robertson, I., Ball, M.J., Pittaway, J.K. and Williams, A.D. (2013), "The association between seasonal variation in vitamin D, postural sway, and falls risk: an observational cohort study", *Journal of Aging Research*, Vol. 2013, p. 751310.

Bulajic-Kopjar, M. (2000), "Seasonal variations in incidence of fractures among elderly people", *Injury Prevention*, Vol. 6 No. 1, pp. 16-19.

Centers for Disease Control and Prevention (2017), "Important facts about falls", available at: www.cdc.gov/homeandrecreationalsafety/Falls/adultfalls.html (accessed 29 October 2021).

Dent, E., Ambagtsheer, R.C., Beilby, J. and Stewart, S. (2020), "Editorial: frailty and seasonality", *The Journal of Nutrition, Health & Aging*, Vol. 24 No. 6, pp. 547-549.

Enderlin, C., Rooker, J., Ball, S., Hippensteel, D., Alderman, J., Fisher, S.J., McLeskey, N. and Jordan, K. (2015), "Summary of factors contributing to falls in older adults and nursing implications", *Geriatric Nursing*, Vol. 36 No. 5, pp. 397-406.

Ersoy, N., Taşçi, İ., Özgürtaş, T., Salih, B., Doruk, H. and Rakicioğlu, N. (2018), "Effect of seasonal changes on nutritional status and biochemical parameters in Turkish older adults", *Nutrition Research and Practice*, Vol. 12 No. 4, pp. 315-323.

Glynn, L. (2006), "A critical appraisal tool for library and information research", *Library Hi Tech*, Vol. 24 No. 3, pp. 387-399.

Health Service Executive (2020), "Falls 2020", available at: www.hse.ie/eng/about/who/qid/nationalsafetyprogrammes/falls-2020.html (accessed 2 March 2022).

Higgins, JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (Eds) (2021), "Cochrane handbook for systematic reviews of interventions version 6.2 (updated February 2021)", *Cochrane*, available at: www.training.cochrane.org/handbook

Iwamoto, J., Saeki, K., Kobayashi, M., Yamagami, Y., Yoshida, O., Kurumatani, N. and Obayashi, K. (2020), "Lower incidence of in-Hospital falls in patients hospitalized in window beds than nonwindow beds", *Journal of the American Medical Directors Association*, Vol. 21 No. 4, pp. 476-480.

Kihara, Y., Yamaguchi, R., Makino, K., Shimizu, K., Ito, K. and Furuna, T. (2019), "Relationship between the occurrence of falls by season and physical functions of community-dwelling old-old people living in cold, snowy areas", *Geriatrics & Gerontology International*, Vol. 19 No. 2, pp. 124-129.

Kim, M., Chang, M., Nam, E., Kim, S.G., Cho, S.-I., Ryu, D.H., Kam, S., Choi, B.Y. and Kim, M.J. (2020), "Fall characteristics among elderly populations in urban and rural areas in Korea", *Medicine*, Vol. 99 No. 46, p. e23106.

Kojima, S., Furuna, T., Ikeda, N., Nakamura, M. and Sawada, Y. (2008), "Falls among community-dwelling elderly people of Hokkaido, Japan", *Geriatrics & Gerontology International*, Vol. 8 No. 4, pp. 272-277.

Lach, H.W., Harrison, B.E. and Phongphanngam, S. (2017), "Falls and fall prevention in older adults with Early-Stage dementia: an integrative review", *Research in Gerontological Nursing*, Vol. 10 No. 3, pp. 139-148.

Lee, S.B., Oh, J.H., Park, J.H., Choi, S.P. and Wee, J.H. (2018), "Differences in youngest-old, Middle-old, and oldest-old patients who visit the emergency department", *Clinical and Experimental Emergency Medicine*, Vol. 5 No. 4, pp. 249-255.

Magota, C., Sawatari, H., Ando, S.-I., Nishizaka, M.K., Tanaka, K., Horikoshi, K., Hoashi, I., Nobuko, H., Ohkusa, T. and Chishaki, A. (2017), "Seasonal ambient changes influence inpatient falls", *Age and Ageing*, Vol. 46, pp. 513-517.

Mamdani, M.M. and Upshur, R.E. (2001), "Fall-related hospitalizations: what's in season?", *Canadian Journal of Public Health*, Vol. 92 No. 2, pp. 113-116.

Molés Julio, M.P., Lavedán Santamaría, A., Botigué Satorra, T., Masot Ariño, O., Esteve Clavero, A. and Maciá Soler, M.L. (2020), "Characteristics and circumstances of falls in the Community-Dwelling older adult population", *Journal of Primary Care & Community Health*, Vol. 11, p. 2150132720940508.

Morley, J.E. (2010), "Hip fractures", *Journal of the American Medical Directors Association*, Vol. 11 No. 2, pp. 81-83.

Morris, R. and O'Riordan, S. (2017), "Prevention of falls in hospital", *Clinical Medicine*, Vol. 17 No. 4, p. 360.

Munn, Z., Peters, M.D.J., Stern, C., Tufanaru, C., Mcarthur, A. and Aromataris, E. (2018), "Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach", *BMC Medical Research Methodology*, Vol. 18 No. 1, p. 143.

National Health Service (2021), "Falls", available at: www.nhs.uk/conditions/falls/ (accessed 2 March 2022).

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P. and Moher, D. (2021), "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews", *BMJ*, Vol. 372, p. n71, doi: 10.1136/bmj.n71.

Parker, M.J. and Martin, S. (1994), "Falls, hip fractures and the weather", *European Journal of Epidemiology*, Vol. 10 No. 4, pp. 441-442.

Peel, N.M. (2011), "Epidemiology of falls in older age", *Canadian Journal on Aging/La Revue Canadienne du Vieillissement*, Vol. 30 No. 1, pp. 7-19.

Petry, N.M. (2002), "A comparison of young, Middle-Aged, and older adult Treatment-Seeking pathological gamblers", *The Gerontologist*, Vol. 42 No. 1, pp. 92-99.

Stevens, J.A., Thomas, K.E. and Sogolow, E.D. (2007), "Seasonal patterns of fatal and nonfatal falls among older adults in the U.S", *Accident Analysis & Prevention*, Vol. 39 No. 6, pp. 1239-1244.

Taylor, K.S., Mahtani, K.R. and Aronson, J.K. (2021), "Summarising good practice guidelines for data extraction for systematic reviews and meta-analysis", *BMJ Evidence-Based Medicine*, Vol. 26 No. 3, p. 88.

Trevisan, C., Noale, M., Mazzochin, M., Greco, G.I., Imoscopi, A., Maggi, S., Spinella, P., Manzato, E., Welmer, A.K. and Sergi, G. (2021), "Falls may trigger body weight decline in nursing home residents", *Nutrition*, Vol. 90, p. 111429.

Virginia Commonwealth University (2022), "Virginia commonwealth university", available at: https://guides.library.vcu.edu/health-sciences-lit-review/question#:~:text=in%20recurrence%20rate-,PEO,3)%20Outcome(s)

Vu, M.Q., Weintraub, N. and Rubenstein, L.Z. (2004), "Falls in the nursing home: are they preventable?", *Journal of the American Medical Directors Association*, Vol. 5 No. 6, pp. 401-406.

World Health Organization (WHO) (2021), "Falls", available at: www.who.int/news-room/fact-sheets/detail/falls (accessed 2 March 2022).

Xing Xing, Q., Pui Hing, C., Chiwai, K., Vivian Wq, L., Leung, A.Y.M., Mandy, H., Fong, D.Y.T. and Chi, I. (2020), "Seasonal pattern of single falls and recurrent falls amongst community-dwelling older adults first applying for long-term care services in Hong Kong", *Age & Ageing*, Vol. 49, pp. 125-129.

Further reading

Buccheri, R.K. and Sharifi, C. (2017), "Critical appraisal tools and reporting guidelines for Evidence-based practice", *Worldviews on Evidence-Based Nursing*, Vol. 14 No. 6, pp. 463-472.

Majid, U. and Vanstone, M. (2018), "Appraising qualitative research for evidence syntheses: a compendium of quality appraisal tools", *Qualitative Health Research*, Vol. 28 No. 13, pp. 2115-2131.

Appendix 1

Table A1 Data extraction table

Author and date	*Ashley* et al. *(1977)*	*Parker and Martin (1994)*
Title	A longitudinal study of falls in an elderly population	Falls, hip fractures and the weather
Country	Canada	Birmingham, UK
Aims/Purpose	To explore the aetiology and circumstances of falls in older adults and the relationship between intrinsic factors and falls	To investigate a relationship between sub-clinical hypothermia which impairs coordination in older adults and hip fracture prevalence
Design	Longitudinal observational cohort study Using a standard report form, data was collected on falls experienced by the JHA residents	Prospective study of older adults coming to ED with hip fracture
Setting	Aged care home	Data collected at ED, location of falls not documented
Participants	441 residents of the Jewish Home for the Aged (JHA) 68.7% were female and between the ages of 75 and 90 years	Older adults treated at ED for hip fracture. 429 patients met criteria and 85% were female. Average age was 81 years and 72% were living in their own home
Inclusion/Exclusion Criteria	No specific inclusion or exclusion criteria are listed The author does not state whether cognitive or physical ability excluded a resident as a participant	No inclusion criteria were specifically stated however the following exclusion criteria were noted: Under 60 years of age Fell in hospital No history of fall
Duration	5 years (average period of observation was 2.2 years)	One year
Primary outcome	Incidence of falls (not explicitly stated)	Relationship between weather and hip fractures (not explicitly stated)
Secondary outcome	Injury (not explicitly stated)	Fall rates (not explicitly stated)
Results	Falls occurred during all hours of the day and no pattern was found to be concentrated around any specific time periods. The severity of falls occurring during the active (07.00-22.00) and inactive (22.00-07.00) times of day did not significantly vary A lower percentage of falls occurred on Saturday (the Sabbath) than on other days, however this decrease was minor. There was no evidence, however, of seasonal variation, with falls being fairly evenly distributed both by month and by season The majority of falls in winter and summer took place in the resident's own area. A higher number of outdoor falls took place in the summer (as expected) The percentage of falls occurring in elevators or elsewhere inside the unit varied but decreased with the increasing age of residents Severity of injury varied according to the location of the fall. There was a higher percentage (21.6%) of severe injuries sustained outside or in the resident's own room (21%) Returning from the toilet is the activity linked with the highest incidence of falls. 186 of 651 falls (28.6%) were associated with this and it became more marked with increasing age Almost as many falls occurred in association with sitting in a chair or with lying in bed as occurred in association with getting into or out of bed. Over 33% of falls were associated with a resting posture	Results proved a constant rate of falls throughout the year and no relationship between falls and season was found. A slight link between day of fall and presence of ground frost ($p = 0.04$) was found. Yet no significant statistical evidence for air frost ($p = 0.08$) or minimum daily temperature ($p = 0.15$) were found

(*continued*)

Table A1

Author and date	Ashley et al. (1977)	Parker and Martin (1994)
Study limitations	The author does not note any limitations and the absence of inclusion/exclusion criteria does not help However, I note the lack of a second study site as a limitation. Data collected at this study site may be particularly relevant to the extrinsic environment	The study did not determine the location of where falls occurred which could have been done as it was prospective
Conclusions and recommendations	This study showed little seasonal variation among falls for nursing home residents however the author notes the unique living arrangements may assist with this finding	This study demonstrates that slipping on ice is more significant (in the context of falls) than hypothermia. The authors note that data may be diminished as older adults may elect to stay indoors when visible frost is on the ground
Author and date	Bulajic-Kopjar (2000)	Mamdani and Upshur (2001)
Title	Seasonal variations in incidence of fractures among elderly people	Fall-Related Hospitalizations: What's in Season?
Country	Oslo, Norway	Ontario, Canada
Aims/Purpose	To investigate seasonal variations in the incidence of fractures secondary to falls among older adults aged 65 and greater	To explore temporal patterns of fall-related hospitalizations in different age groups
Design	Prospective observational population based cohort study	Retrospective, population-based study Data was collected using the Canadian Institute for Health Information Discharge Abstract Database. This was used to find information related to falls and patient demographic Data was collected at monthly intervals Time series analysis was used to collect data on seasonal variations and trends
Setting	Three urban areas of Norway: Stavanger, Trondheim and Harstad)	Hospitals
Participants	10,992 older adults	Approx. 14 million residents of Ontario. 455,103 fall-related hospitalizations occurred in the time period Age groups were: 0–9 10–29 30–59 60+
Inclusion/Exclusion Criteria	*Inclusion:* Minimum age of 65 years Living in one of the three studied areas *Exclusion:* Fractures caused by motor injury or occupational injury Multiple fractures from the one fall were counted as a singular case (fracture) and there was an order of preference for choosing category	Not specifically stated
Duration	January 1, 1990–December 31, 1997	April 1, 1988, to February 28, 1999
Primary outcome	Fall-related fractures and seasonal variation	Temporal patterns of fall-related hospitalizations (not explicitly stated)
Secondary outcome	Falls (not explicitly stated)	Injury (not explicitly stated)
Results	10,992 fall related fractures observed in the 7 years among 65+ year olds: 75% were from falls at the same level 14% were from a level less than 1.5m high Fewer than 1% were from a height of over 1.5m 8% had missing information Statistical difference was found in incidence rate of injuries occurring during colder seasons for sex and	455,103 fall-related hospitalizations occurred in the study period: Complimentary seasonal patterns were seen for the 0-9 year (FK = 44.8, $p < 0.01$, BK = 0.64, $p < 0.01$, m-1 = 58) and 30–59 year (FK = 28.9, $p < 0.01$, BK = 0.50, $p < 0.01$, m-1 = 58) age groups 0–9 year age groups saw more hospital

(*continued*)

Table A1

Author and date	Ashley et al. (1977)	Parker and Martin (1994)
	age subgroups: The difference was larger among people aged 65–79 years (RR = 1.39) compared to people aged 80 years and older (RR = 1.17). It was similar for men and women in the respective age subgroups. Approximately 16% of cases in those aged 65-79 and 8% of cases among the older age group can be linked to the effects of a colder season The difference between warm and cold seasons can be seen by examining the incidence of arm fractures. Among people aged 65–79 years, the incidence rate of arm fractures was 69% (95% CI = 56% to 83%) higher during colder seasons compared with milder seasons with this pattern being similar for women and men. The incidence rate of arm fractures was 30% (95% CI = 13% to 43%) higher during the colder compared with the milder season among those aged 80 years and older. The effect was higher among men (RR = 1.52) than women (RR = 1.24) More hip fractures (27% more) were observed in colder seasons than warmer seasons. 12% of all hip fractures occurring among people aged 65–79 years were linked to season effects. Among people aged 80 years and older, the seasonal pattern in occurrence of hip fractures was moderate (RR = 1.08, 95% CI 1.00 to 1.15). Only 4% of hip fractures were due to the effects of seasonal changes	admissions due to falling during the warmer months (May–November) and a downward trend over time 30–59 year age group saw a higher rate of hospital admissions from falls during colder months (December–April) and neutral trend over time 10–29 year age group experienced changes in seasonal admission peaks with higher rates of admissions at extreme temperatures and a downward trend over time In the 60 and over age group the seasonal variation in admissions secondary to falls were weaker however peak admission numbers occurred in colder months (December–April) and there was an upward trend over time. Hospitalization rate for the 60+ age group was 4–10 fold higher than the other age groups
Study limitations	Cases of fractures from falls not studied if they occurred outside of the registration system catchment area People are more likely to travel to a location during warmer seasons National hospital discharge statistics show that approximately 1%–2% of hip fractures in the study population are treated in hospitals that are not represented on the injury register Information bias is possible with under reporting being more likely than over reporting	Causative factors did not appear to be considered, e.g. slipping, tripping etc. Falls that did not lead to a presentation to a hospital were not factored in
Conclusions and recommendations	The study shows the need for extra vigilance during colder seasons for older adults This information can be used for the creation of preventative measures to safeguard the older adult population	Different seasonal patterns were observed for different age groups More details study of this is needed Data has good use for prevention programs
Author and date	Stevens *et al.* (2007)	Kojima *et al.* (2008)
Title	Seasonal patterns of fatal and nonfatal falls among older adults in the U.S.	Falls among community-dwelling elderly people of Hokkaido, Japan
Country	USA	Japan
Aims/Purpose	Examine unintentional fall rates among older adults by season and climate and nonfatal fall rates by season	To determine why few falls are reported by older adults living in Hokkaido, where there is a severe winter with heavy snow
Design	Data on fatal falls among the US adults aged 65 years and older were studied via the retrospective collection of data from annual mortality tapes of the National Centre for Health Statistics (NCHS). Cause of death data is taken from information on death certificates completed by doctors and coded	Questionnaire by post – retrospective

(*continued*)

Table A1

Author and date	Ashley et al. (1977)	Parker and Martin (1994)
	according to the ICD-10 which allows for categorizing the circumstance or extrinsic cause of injury. Unintentional falls were found using the code W00-W19 Data on nonfatal fall-related injuries was taken from the National Electronic Injury Surveillance System All Injury Program (NEISS-AIP) which is controlled by the U.S. Consumer Product Safety Commission. It collects information on types and causes of injuries across the USA The study found that there was no definite definition of "climate" and as such climate categories were determined by each state's average temperature on January 1, 2001. The average temperature of states classified as having a "colder climate" was $\leq$ 32˚F and the states with an average temperature of $>$32˚F were deemed to have a "warmer climate" Season of injury was determined based on the date of death for fatal falls and date of ED treatment for nonfatal falls Separate analysis was done for men and women as fall fall-related injuries differ greatly between the two	
Setting	Varied – community based but ED used in data capture	Own home
Participants	12,700 deaths were observed from fall-related injuries in the selected timeframe 1.63 million older adults (65+ years) were treated in EDs for non-fatal falls	Residents of Hokkaido living in their own home aged 65 years and older 1,000 subjects were randomly contacted and agreed to participate. 849 (436 men, 413 women) of these completed the survey which obtained information on histories of falls, the number of falls experienced, the season the falls took place in, place of occurrence and the cause of the falls (all in the past 12 months) Mean age was 73.0 $\pm$ 5.2 years
Inclusion/Exclusion Criteria	No inclusion or exclusion criteria were specifically listed by the study authors however they note using specific codes from the ICD-10 for fatal falls and using the NEISS-AIP data to search for "fall" listed under causes of injury. This was looked at further to see if the fall was "unintentional/undetermined." The study also notes only examining cases of older adults aged 65 years and above living in the USA	*Exclusion:* People aged 64 and under People not living in their own home People who could not answer the questionnaire for the themselves
Duration	December 2001–November 2002	Questionnaire asked about the past year (12 months)
Primary outcome	No primary outcome is explicitly listed however the study notes the use of the collected data is to examine seasonal patterns of both fatal and nonfatal fall-related injury rates among people aged 65 years and older by gender and age and to assess the effect of climate on these fall rates	Falls (not explicitly stated)
Secondary outcome	Assess the effect of climate on fall rates (not specifically stated)	Injury (not explicitly stated)
Results	The authors categorized results into seasonal patterns and climate *Seasonal patterns:* 12,700 older adults died in the USA of falls in the examined timeframe which leaves an overall rate of	849 subjects returned a completed questionnaire 694 (81.7%) of these reported having a medical problem Those aged 75+ had a higher prevalence of having a medical problem than those aged 65-74.

(*continued*)

Table A1

Author and date	Ashley et al. (1977)	Parker and Martin (1994)
	35.7 per 100,000 (95% CI 35.1–36.3). 5,795 of these deaths were men (39.3. per 100,000 [95% CI 38.3–33.9]) and 6,905 were women (33.1 per 100,000 [95% CI 32.4-33.9]). Rates were significantly higher in men overall and rose sharply with increasing age and no seasonal effect was observed for men or woman A difference was observed between races with the fatal fall rate of white people being 2.4 times higher than that of black people. Within each race category, men were higher than women for both races 1.63 million older adults were treated in EDs for fall related injuries. Overall rate = 4,589 per 100,000 (95% CI 3804–5375). Overall rates for men were 3,222 per 100,000 and 5,557 per 100,000 for women. Again, rates increased sharply with age but were significantly higher for women compared to men in all age groups except in 85 and older No seasonal pattern was observed *Climate:* Annual fatal fall rate was 9.1% higher in colder climates compared to warmer climates (37.2 per 100,00 versus 34.1 per 100,000, $P < 0.001$) This difference was also observed when stratified by sex: annual rate in colder climates is 8.8% higher than warmer climates for men and 9.8% higher for women. For both sexes combined, colder climates had a higher number of deaths compared to those with warmer climates for winter, spring and autumn	For activities of daily living: over 80% of the respondents stated that "they performed each task." The percentage of people who performed each task was higher among those aged 65–74 years than people aged 75 years and over (82.8% versus 74.3% for the use of public transportation, 94.4% versus 84.6% for shopping for daily necessities and 87.5% versus 82.5% for handling bank accounts, $P < 0.001$). More women shopped for daily items and managed banking than men In the previous year, 277 subjects had fallen at least once and the % of those who had fallen was higher for those aged 75+. The percentage was higher for women than men in both age groups ($P = 0.019$) 56% of the 277 fallers reported two or more falls in the past year and no significant differences were seen between age groups or sexes Of the fallers, 61% reported the falls to have taken place during winter and a significant difference in the distribution of falls by season and age groups. In winter the percentage of falls was lower for those aged 75+ and higher for those aged 65-74. No significant difference between sexes observed Subjects most commonly fell on roads or paths and 87.9% of these falls were in winter. People aged 75+ fell more in their own home compared to 65–74 year olds Slipping (48.0%) was the most prevalent cause of falling, followed by tripping (31.8%), misstep (4.0%) and loss of balance (4.7%). For slip related falls, 88% were in winter
Study limitations	No inclusion/exclusion criteria listed Primary and secondary outcomes not explained	Subjects may have difficult recalling the past year and circumstances surrounding falls For subjects who experienced two or more falls, they were only asked to discuss the most severe fall
Conclusions and recommendations	The authors note that the differences in sex are unclear and state that differences in risk taking behavior may play a part as well as circumstances and deconditioning The authors note that including a date of injury instead of date of death would have given a clearer indication of seasonal pattern however they explain this was not done as the records did not include date of injury, only date of death The authors note the impact climate has on fall rates and outcomes. They make the observation that those in cold climates may be indoors more, less active and not exposed to vitamin D in comparison to those in warmer climates. They say more research in this regard is needed	The findings showed a significant seasonal variation in falls. Winter falls accounted for 61% of falls in Hokkaido. The authors suggest climate factors may play a part (icy terrain, fewer daylight hours, low temperature)

(*continued*)

Table A1

Author and date	Ashley et al. (1977)	Parker and Martin (1994)
Author and date	Bird *et al.* (2013)	Magota *et al.* (2017)
Title	The Association between Seasonal Variation in Vitamin D, Postural Sway, and Falls Risk: An Observational Cohort Study	Seasonal ambient changes influence inpatient falls
Country	Australia	Fukuoka City, Japan
Aims/Purpose	To investigate whether postural sway varies seasonally and is associated with serum vitamin D and falls	To investigate the influence of behavioral and ambient factors on inpatient falls, focusing on seasonal and diurnal variations
Design	Longitudinal observational cohort study Participants found via local print media and community clubs. Participants were tested for postural sway, serum vitamin D levels over a three week period in each season. Participants also had a calendar to mark falls in	Retrospective study Incident reports used to identify falls and collect data on date, time, location, triggering circumstances, contributing factors, detailed behaviors, the site and severity of injury and patient demographics Meteorological data was obtained from the Japan Meteorological Agency
Setting	Community	Hospital
Participants	88 community-dwelling older adults Average age was 69.2 years 70% were female, 30% were male Mean BMI was 27.4 kgm2 Living independently in own home (10% were sole occupants)	Inpatients in a secondary emergency medical facility with 260 beds. 464 total Average age = 76.4 years ± 11.0 years 263 were male, 201 were female
Inclusion/Exclusion Criteria	*Inclusion:* Aged between 85 and 85 Able to ambulate independently *Exclusion:* Recent or current acute medical issues Uncontrolled chronic condition Aged below 65 or older than 85 Daily intake of over 800iU of vitamin D History of neurological disease Liver and Kidney disease patients Participants were forced to withdraw if they experienced any medical condition during the study that would impact their ability to perform physical tests	41 falls excluded as patients were in emergent/unstable conditions in OPD, ED, ICU or dialysis unit 11 falls excluded as they were considered to be a result of patient's medical conditions
Duration	End of Spring 2009 to end of Spring 2010	April 2010–March 2014
Primary outcome	Postural sway, serum vitamin D and falls (not explicitly stated)	Impact of behavioral and ambient factors on falls (not explicitly stated)
Secondary outcome	Fall injuries (not explicitly stated)	Injury (not explicitly stated)
Results	All balance measures had the highest sway scores (poor balance) at the first end of spring measurement. All other seasonal measures were significantly different but not significant difference was found which indicates a lack of seasonal variation No association between postural sway and vitamin D was observed Vitamin D levels showed a 15% variation across the year with a peak at the end of summer and lowest levels being observed in the winter 33% of the participants (29 people) fell at least once and 10% of the group had multiple falls. 48 falls were recorded and 14 of these occurred inside the house, and 34 occurred outside. Six falls were due to	464 patients included in analysis Most prevalent comorbidity was hypertension (40.5%) Most frequent fall-related injury was toileting (56.9%) Fall rate at night was significantly higher than day (1.6 ± 0.8 vs 1.2 ± 0.7/1,000 OBDs, P = 0.001) In November, January and February had particularly higher fall rate at night compared to day (2.4 ± 0.7 vs 1.4 ± 0.2/1,000, 1.9 ± 0.6 vs 1.1 ± 1.3/1,000 and 2.2 ± 0.7 vs 1.0 ± 0.4/1,000 OBDs; respectively) It was noted that a high number of night and dawn falls happen in winter with most falls occurring at 07.00am in February (6.7/1,000 OBDs)

(*continued*)

Table A1

Author and date	*Ashley et al. (1977)*	*Parker and Martin (1994)*
	fainting or dizziness and 40 falls were due to trip-related events, with one categorized as being pushed over by an animal and one not able to be categorized. Twenty-eight falls led to injury but only four needed medical attention (one was a fracture) Most falls occurred in May. When falls data were combined from autumn and winter seasons and compared to the combined spring and summer seasons, there were more falls reported in the combined autumn and winter seasons (30 compared to 18). The least amount of falls were recorded in spring than any other season ($P = 0.02$) and no other seasonal differences recorded	The number of falls at 02.00am and 07.00am were significantly higher than at other times of the day ($P = 0.02$) For daytime falls, female sex was also associated with an increase of falls in the multivariate analysis ($\beta = 0.35$, $P = 0.01$; both). A longer night-time was associated with an increased number of night-time falls in both the univariate and multivariate analyses ($\beta = 0.32$, $P = 0.03$ and $\beta = 0.27$, $P = 0.047$; respectively)
Study limitations	The recruitment of participants may have led to more robust people taking part. There are no frail subgroups The test-retest method of data collection may have led to test-retest learning which would have affected postural sway results	The study did not address cognitive status of patients The authors note their inability to determine the specific cause of falls or determine the severity of them due to the retrospective nature of the study
Conclusions and recommendations	This study proved that postural sway does not vary seasonally meaning that falls prevention education should focus on extrinsic, controllable factors	It was found that 62.6% of nocturnal falls are associated with toileting but also early morning hours combined with lower temperatures
Author and date	Kihara *et al.* (2019)	Molés Julio *et al.* (2020)
Title	Relationship between the occurrence of falls by season and physical functions of community-dwelling old-old people living in cold, snowy areas	Characteristics and Circumstances of Falls in the Community-Dwelling Older Adult Population
Country	Japan	Spain
Aims/Purpose	Investigate functional characteristics of older adults who fall in the winter season and other seasons	To describe the characteristics and circumstances of falls in community-dwelling older adults
Design	Prospective cohort study People aged 75 and above were enrolled in “Population-Based and Inspiring Potential Activity for Old-old Inhabitants” (a project) in November 2012 and 2013. They participated in a survey and also had an in-person interview and measures of physical and cognitive function were taken	Cross-sectional observational and descriptive study that involved primary health-care centers The study took place in the cities of Lleida and Castellon de la Plana
Setting	Participants lived in their own home	Family homes and data collection was done at primary health-care centers
Participants	403 people were included for analysis (269 in 2012 and 134 in 2013)	Older adults aged 75 years and above A total of 966 older adults were included: 57.5% were women and 42.5% were men Mean age was 81.4 ± 4.8 years
Inclusion/Exclusion Criteria	*Inclusion:* Aged >75 years at examination in 2012 or 2013 Resident of Bibai City *Exclusion:* Diagnosis of dementia Those with deficient falls data	*Inclusion:* Age of 75 years or above at time of interview Resident in family homes in the community Possessed a health-care card *Exclusion:* Terminal illness Showed cognitive impairment (Pfeiffer scale used) without caregivers or family members to respond on their behalf Under institutional care at time of study
Duration	November 2012 and November 2013	At the time of questioning, participants were asked about the past 12 months
Primary outcome	Falls (not explicitly stated)	Description of characteristics and circumstances of falls

(*continued*)

Table A1

Author and date	Ashley et al. (1977)	Parker and Martin (1994)
Secondary outcome	Injuries (not explicitly stated)	Injuries (not explicitly stated)
Results	31.5% of participants had fallen in the past year (35.4% of these were men and 63% of the falls were in non-winter months) (non-winter = April to November) The fall group had a significantly lower maximum walking speed ($P < 0.01$), TUG ($P < 0.01$) and grip power ($P < 0.01$). They also had significantly lower Activity SE ($P < 0.001$) and continuous walking distance ($P < 0.001$) than the non-fall group In non-winter months, the number of falls was higher than the fall in winter group ($P < 0.05$). The fall in non-winter group had a much lower maximum walking speed ($P < 0.01$), TUG ($P < 0.05$), hip walking distance ($P < 0.05$) and knee extensor strength ($P < 0.05$) than the fall in winter group among physical functions. the fall in non-winter group had significantly lower WHO-5-J ($P < 0.05$), exercise self-efficacy ($P < 0.01$), Activity SE ($P < 0.01$) and continuous walking distance ($P < 0.01$) than the fall group among health-related indicators Physical function was not associated with any model in comparison between fall and non-fall groups in winter. It should be noted though that for the non-fall and the fall in the non-winter groups, the maximum walking speed, TUG, hip walking distance and knee extensor strength were significantly associated. maximum walking speed was recognized as a significantly related variable in model 2 (OR 0.98, 95% CI 0.96–1.00, $P = 0.03$) During the winter, the fall in non-winter group had lower levels of activity than the fall in winter group	Prevalence of falls in prior year was 25.9% ($N =$ 249; 95% CI 20.5–31.3) with no significant difference between locations (Lleida and Castellon de la Plana) 249 participants (25.9%) reported falling in the past year. The researchers explored the characteristics of each person's most recent fall and the circumstances surrounding it, searching for associations by age and sex: Almost 70% had experienced multiple falls and it was found that falls were more common in the colder seasons and in the morning in over half of falls Accident was found to be the most common cause of falling No major difference between age and sex was observed for the aforementioned However, a difference between ages was seen in relation to falling flat on the ground and also women needing more assistance after falling flat Over half of all falls occurred within the home above all in those aged 85+ and most commonly in the bedroom. Interestingly, location of falls is mostly named as a familiar, well-lit area. Adverse conditions were rarely reported in falls occurring outside the home. It is interesting to note that women aged 85+ fell more when wearing slippers while men, and those aged under 85, fell more while wearing actual shoes
Study limitations	No information relating to place or the environment or the time of falls was collected This study only looked at cold, snowy areas so results should not be generalized Participants had to be 75 or older but falls prevention should start a decade (if not more) before this	The participants were only asked the circumstances and characteristics of their most recent fall, even if they had had multiple in the past 12 months Sampling was carried out differently in the two locations, one was randomized and one was intentional which did not allow the entire population to be covered Individuals may have had difficulty remembering the specifics of falls the experienced
Conclusions and recommendations	The results of this study can be used in prevention programs to highlight the importance of maintaining functional abilities to prevent future injury from falling This study shows that one should not just look at the presence or absence of falls when considering intervention but also seasons	The authors note that fall rates are not showing a downward trend despite the fall prevention efforts made The authors note the need to further examine seasonal trends that may be linked to fall rates
Author and date	Kim *et al.* (2020)	Xing *et al.* (2019)
Title	Fall characteristics among elderly populations in urban and rural areas on Korea	Seasonal pattern of single falls and recurrent falls among community-dwelling older adults first applying for long-term care services in Hong Kong

(*continued*)

Table A1

Author and date	Ashley et al. (1977)	Parker and Martin (1994)
Country	Korea	Hong Kong
Aims/Purpose	To research fall characteristics and compare same between rural and urban areas	Examine the seasonal patterns of single and recurrent falls of older adults in Hong Kong that are applying for long-term care (LTC)
Design	Retrospective and cross-sectional Survey of 2,012 participants aged over 60	Retrospective data was collected from the database of Hong Kong based community dwelling older adults who had taken the validated Chinese version of the Minimum Data Set-Home Care (MDS-HC) assessment when first applying for LTC services between 2005 and 2014
Setting	Urban and Rural areas. Participants had visited a public health center in their district	Own home in Hong Kong
Participants	2,012 participants in total. 807 lived between 2 rural areas. 1,205 lived between 3 urban areas All participants were over 60. Among urban and rural residents, respectively, 36.0% and 23.4% were in their 60s, 46.1% and 52.4% were in their 70s and 17.9% and 24.2% were 80 or over Rural participants were much older than their urban counterparts and the majority for both urban and rural were women (63.4% and 67.0% respectively)	89,100 people met the inclusion criteria
Inclusion/Exclusion Criteria	Participants had to be over 60, live in one of the selected areas and have visited a public health center	People aged 65 years and older, living in their own home in Hong King, had underwent the validated Chinese version of the Minimum Data Set-Home Care (MDS-HC) assessment when initially applying for publicly funded LTC The only exclusion criteria listed is if information pertaining to fall outcomes
Duration	September 1, 2015–October 12, 2015	2005–2014
Primary outcome	Fall characteristics (not explicitly stated)	Self-reported fall episodes in the past 90 days (of taking the assessment)
Secondary outcome	Injury (not explicitly stated)	No secondary outcome is listed
Results	Results were categorized as follows: *Demographic characteristics:* As above with the addition of lifetime fall history being significantly higher in rural areas (78.9%) than in urban areas (69.3%; P < 0.001). However when fall history for just the past 12 months was similar between the two areas (P = 0.693). 80.1% of older adults in urban areas had undergone falls prevention education but only 0.5% of those in rural areas had done this, a significant difference *Causes of falls:* 663 of respondents had fallen in the past year and for both areas the most common reason slippery surfaces (32.6% urban, 42.1% rural). The next most common causes differ – for urban areas, it was stumbling on a door sill (14.0%) and ankle sprain (13.6%). For rural areas it was ankle sprain (11.6%), dizziness (10.6%) and steep slopes (7.7%) *Season and time of fall:* Participants were asked about the month and time of their fall. Falls occurred most frequently in summer (June to August) (29.8%) and spring (March to May) (29%) in urban areas. In rural areas it was summer (27.8%) and autumn (26.3%). Seasonal fall rates	Of the 89,100 subjects, 23,396 (31.9%) were classed as "fallers," i.e. had experienced at least one fall in the past 90 days. 9,536 (33.6%) of these had fallen recurrently, i.e. had fallen twice or more within the past 90 days *Single falls:* Logistic regression model did not show significant interaction between month and gender (P-value = 0.870), age and month (P-value = 0.063), year and month (P-value = 0.125) or gender and age (*P*-value = 0.393). Insignificant interaction terms were removed and main effects of age, month and year were kept in the model. Compared with those aged 85 or above (oldest-old), those aged 65–74 (young-old) were at lower risk of falling (odds ratio [OR] for young-old: 0.81, 95% confidence interval [CI], 0.77–0.85; OR for those aged 75–84 [middle-old]: 0.90, 95% CI, 0.86–0.93) Females were more likely to fall than males (OR 1.08, 95% CI, 1.04–1.12). The risk of falling peaked in February when the months of November to February were examined with a OR of 1.29 (95% CI, 1.19–1.41) as compared with

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Table A1

Author and date	*Ashley* et al. *(1977)*	*Parker and Martin (1994)*
	were statistically different between the two areas (P = 0.009). Re time of day: 55.2% of urban falls occurred between 12.00 p.m. and 18.00 p.m. while 45.9% of rural falls were between 06.00 a.m. and 12.00 p.m. Significant differences *Floor or ground material and footwear:* Roads made of cement or asphalt were the most common ground materials at the time of the fall in both urban (38.7%) and rural (37.8%) areas. Soil (20.1%), tile (15.3%), linoleum (13.7%) and ice (5.1%) were the next common materials in urban areas, while soil (30.0%), linoleum (13.0%), tile (10.0%) and ice (4.1%) were the next common in rural areas; the differences between urban and rural areas were significant (P = 0.008) 58.0% of urban and 45.2% of rural respondents reported wearing running shoes at the time of their fall. Other responses were barefoot (18.1%), slippers (11.2%) and dress shoes (4.6%) in urban areas, and slippers (22.6%), barefoot (16.3%) and dress shoes (3.3%) in rural areas, and the difference between urban and rural areas was significant (P < 0.001)	October when researchers examined July to October which had the lowest risk of falling *Recurrent falls:* The logistical regression model showed no significant interactions between gender and month (P-value = 0.200), age and month (P-value = 0.129), year and month (P-value = 0.344) or gender and age (P-value = 0.134). Only the main effects of age, gender, month and year were included in the final model. Females were found to be at a lower risk of recurrent falls (OR 0.80, 95% CI, 0.76–0.83) in comparison to males. Older age was also associated with a lower risk of falling recurrently. Compared with the oldest-old group, the OR for young-old was 1.14 (95% CI, 1.07–1.21), whereas for middle-old, it was 1.06 (95% CI, 1.01–1.11). The recurrent fall risk was the highest in February (representing fall occurrence from November to February) (OR 1.46, 95% CI, 1.31–1.64), when compared to the reference month October (representing fall occurrence from July to October) which had the lowest risk Study notes that is not easy to strictly categorize the seasons according to calendar months for Hong Kong. This is because of the subtropical climate but the study does note that June to September is considered the summer months and November to February is considered winter
Study limitations	Only older adults who attended public health centers were able to respond meaning those who were severely injured as a result of a fall (attended hospital) were not included Study design may lead to recall bias. Risk of this increases with number of falls experienced	No secondary outcome is clearly defined
Conclusions and recommendations	Data collected can be used to inform residents of different areas when they are more likely to fall. This can help form varying education/prevention programs (one size fits all approach will not work despite same country) Falls prevention education was low in both areas which can be addressed and assist in direction of funding	Fall risk (single and recurrent) peaked during coldest months. A similar pattern to the USA and Australia is noted however the cause is likely different as it never snows in Hong Kong so slipping on snow or ice is not a risk factor. The study notes that possible underlying causes could be physiological, mental or behavioral patterns that are subject to changes in climate Study notes that the population studied had a higher incidence of falls than general community dwelling adults and suggest this is because of age and their need for LTC. It is noted that older adults needing LTC generally have functional deficits

Source: Table by authors

Appendix 2

Table A2 Excluded studies

Author(s) and database	*Year*	*Title*
Yousef MEDLINE	1980	Case of the fall season
Aharonoff *et al.* MEDLINE and CINAHL Plus	1988	A longitudinal study of falls in an elderly population II. Some circumstances of falling
Bergland *et al.* MEDLINE and CINAHL Plus	1998	Falls reported among elderly Norwegians living at home
Boye *et al.* MEDLINE	2014	Circumstances leading to injurious falls in older men and women in the Netherlands
Caberlon and Bos MEDLINE	2015	Seasonal differences in falls and fractures among the elderly in the southern Brazilian state of Rio Grande do Sul
Campbell *et al.* MEDLINE	1988	Falls, elderly women and the cold
Duval *et al.* MEDLINE	2017	Vitamin D and the Mechanisms, Circumstances and Consequences of Falls in Older Adults: A Case-Control Study
Inderjeeth *et al.* MEDLINE	2002	Seasonal variation, hip fracture and vitamin D levels in Southern Tasmania
Leavy *et al.* MEDLINE	2013	When and where do hip fractures occur? A population-based study
Mondor *et al.* MEDLINE and CINAHL Plus	2015	Weather warnings predict fall-related injuries among older adults
Morency *et al.* MEDLINE and CINAHL Plus	2012	Outdoor falls in an urban context: winter weather impacts and geographical variations
Parker *et al.* MEDLINE and CINAHL Plus	1996	Environmental hazards and hip fractures
Ryynänen *et al.* MEDLINE	1991	Times, places, and mechanisms of falls among the elderly
Turner *et al.* MEDLINE	2011	Air temperature and the incidence of fall-related hip fracture hospitalisations in older people
An *et al.* Embase	2021	Non-Ground Level Fall-Related Injuries and Seasonality in Malawi
Boye *et al.* Embase	2014	Circumstances leading to injurious falls in older men and women in the Netherlands
Gökçek *et al.* Embase	2019	Investigation of Causes and Risk Factors for Falls of Patients over 65 years old who Applied with the Complaint of Fall to the Department of Emergency
Murphy *et al.* Embase	2013	Age related change in the supraspinatus tendon
Muthusamy *et al.* Embase	2014	Epidemiology, clinical characteristics, inpatient and intermediate outcomes, and seasonal variation in a large series of patients with stress cardiomyopathy
Mutlu and Lee Embase	2012	Airborne lead levels in the Korean peninsula: Characterization of temporal and spatial patterns and cancer risk analysis
Mwambelo *et al.* Embase	2013	Are geriatric giants a problem in older adults living in urban Malawi?
Myasoutava *et al.* Embase	2013	Risk assessment of falls in patients with osteoporosis and rheumatoid arthritis
O'Farrell and De La Harpe Embase	2012	Is the HSE prevention of falls strategy delivering results? the prevalence of accidental falls requiring hospital in-patient admission over a 6 year study period
Solanki *et al.* Embase	2014	Seasonal variation in falls: Can we do anything about it?
Unguryanu *et al.* Embase	2020	Weather conditions and outdoor fall injuries in Northwestern Russia

(*continued*)

Table A2

Author(s) and database	*Year*	*Title*
Vikman *et al.* Embase	2011	Falls among old people, living at latitude degrees 65 50 *n* in Sweden, receiving home-help services
Yoshimoto *et al.* Embase	2010	An analysis of fall accidents in ambulance service records of fire department in Japan: investigation of time and location
Bøkenes *et al.* CINAHL Plus	2011	Annual variations in indoor climate in the homes of elderly persons living in Dublin, Ireland and Tromsø, Norway
Fraenkel *et al.* CINAHL Plus	2017	Is the association between hip fractures and seasonality modified by influenza vaccination? An ecological study

Source: Table by authors

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