24-hour pattern of falls in hospitalized and long-term care institutionalized elderly persons: A systematic review of the published literature

Pablo Jesús López-Soto¹, Roberto Manfredini², Michael H. Smolensky³, and María Aurora Rodríguez-Borrego⁴

¹Department of Nursing, Maimonides Institute for Biomedical Research in Córdoba, University of Córdoba, Córdoba, Spain, ²Department of Medical Sciences, University of Ferrara, Ferrara, Italy, ³Department of Biomedical Engineering, Cockrell School of Engineering, The University of Texas at Austin, Austin, TX, USA, and ⁴Department of Nursing, Maimonides Institute for Biomedical Research in Córdoba, University of Córdoba, Córdoba, Spain

Falls are common among the elderly >65 years of age and can result in both serious trauma and costly medical care. The epidemiology of falls in the elderly typically focuses on identifying contributory exogenous environmental and endogenous age-related physical, cognitive and other health status factors; however, one potentially important variable seldom considered is time of fall. We sought to determine if falls in hospitalized/institutionalized elderly persons exhibit 24 h and other temporal patterns, since knowledge of such could be useful in their prevention. We conducted a systematic review of the published literature to critically appraise and synthesize the methods and findings of previous reports addressing clock-time, day-of-week and month-of-year fall patterns of institutionalized elderly cohorts. Medline, SCOPUS, Ovid SP and Web of Knowledge were systematically assessed, entering search terms of “accidental fall”, “circadian rhythm”, “biological clocks”, “circadian clocks”, “activity cycles”, “periodicity”, and with databases accepting an age limiter, “age of 65+ years”. Methodological quality was assessed by STROBE and CONSORT checklists, respectively, in observational and clinical studies. Publications were reviewed if meeting inclusion criteria of: (i) being an empirical study, (ii) adopting circadian and/or other period rhythmicity as a fall risk, and (iii) focusing on hospitalized/institutionalized falls in those ≥65 years of age; plus exclusion criteria of: (i) cohort <65 years of age and (ii) reports as dissertations or editorials. The search retrieved 170 publications; however, only nine met all inclusion/exclusion criteria. Typically, past studies disregarded the temporal aspects of fall incidents; the few that did varied in quality, institutional setting, and patient type, i.e. medical diagnoses. Overall, findings suggest a single or double-peak 24 h pattern of fall incidence, with time of greatest incidence seemingly associated with circadian rhythm-dependent differences in the symptom intensity of dominating medical diagnoses (e.g. heart failure versus Alzheimer syndrome) among sample cohorts plus location (e.g. bathroom versus hallway) of occurrence. Future research is urgently required to define temporal patterns in falls and their etiology, e.g. relative to circadian and other rhythms in both the manifestation and intensity of medical conditions and adverse effects of medications according to scheduling, plus staff personnel number and work schedules as it affects patient oversight, and cyclic environmental conditions (e.g. light intensity exposure) to best design preventive measures.

Keywords: Elderly, hospital falls, institutional falls, 24-hour pattern

INTRODUCTION

An important achievement of modern civilization is enhanced longevity of people. This plus decline in fertility and enhanced migration are causing remarkable changes in the demographics of most countries. According to a United Nations report (Kalache & Gatti, 2003), worldwide by the year 2050 the number of older people (defined as ≥65 years of age in developed countries and >60 years of age in underdeveloped countries) for first time in history will exceed the number of younger people. Indeed, the report predicts the proportion of individuals >65 years of age will increase substantially, from 17% in 2010, to 23% in 2030, and to 30% in 2060. The increased population of the elderly will constitute significant challenges because of anticipated consequent medical, economic and social implications.
From a biological perspective, aging entails cell, organ and system deficits that compromise adaptive functions and alter physical, cognitive and/or affective capabilities, manifesting as sensory, musculoskeletal, neurological and metabolic disorders (WHO, 2007) that decrease and limit independence. Moreover, the elderly are subjected to significant social and economic transformations. Overall, the elderly are more vulnerable to stressors and degradation of functional capabilities than younger persons (Rockwood & Mitnitski, 2011), and because cognitive competence and bipedal ambulation are often the processes initially most compromised, risk of falls and fall-related injuries is markedly increased (Collard et al., 2012; Fried et al., 2001; Sydenham, 2008).

Falls constitute a common and serious problem for the elderly, posing significant medical, social and economic burdens for them and their family members (Roudsari et al., 2005). According to Chang & Ganz (2007), the risk of falling increases with age, with one-third of those aged ≥ 65 of years experiencing a fall at least once a year. As summarized by the recent review article of Hester & Wei (2013), (i) in 2008 nearly 20 000 people aged ≥ 65 of age died of fall-related injuries, (ii) in 2009, 2.1 million such elderly persons were treated for falls in emergency medical departments with > 581 000 of them requiring hospitalization, and (iii) in 2000, fall-associated health expenditures amounted to approximately 19 billion USD (equal to 28.2 billion USD in 2010). Although on an individual case basis, fall-related costs in the USA tend to be higher than in Europe and Australia, such annual costs range between 0.85 and 1.5% of the total healthcare expenditures within the 15 European Union member states (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden and the UK), Australia and the USA (Heinrich et al., 2010).

A fall is the consequence of a complex interaction between multiple risk factors (WHO, 2007). Over the past decade or so, efforts have been devoted to identifying the extrinsic and intrinsic risk factors involved in causing falls (American Geriatrics Society, 2001; Todd & Skelton, 2004). Intrinsic risk factors are specific to the individual and include (i) biological factors, such as age, sex, chronic diseases, and emotional, neurocognitive and physical abilities, and (ii) behavioral factors, such as medication use, alcohol consumption, and activity/fitness, and footwear. Extrinsic factors are specific to (i) socioeconomic factors, such as income, education, housing quality, social interaction level, health status, social care access and community resources, and (ii) environmental factors, such as building design, flooring condition, and lighting. Knowledge of the contribution of these and other risk factors informs fall and fall-injury preventative strategies (Costello & Edelstein, 2008), as control of even a single one can result in meaningful impact on the frequency and morbidity of falls (Tinetti, 2003; Yates & Dumnagan, 2001).

Although considerable effort has been extended to identify the potential causality of falls, the clock time of their occurrence is often disregarded. It is well-documented that the manifestation of many acute life-threatening and life-ending diseases events, such as myocardial infarction, stroke, aortic diseases and pulmonary embolism, plus the exacerbation of a multitude of chronic medical conditions, such as peptic ulcer disease, asthma, osteoarthritis and rheumatoid arthritis (Casetta et al., 2002; Manfredini et al., 2004; Mehta et al., 2002; Smolensky et al., 2014a, b) exhibit profound predictable-in-time diurnal or 24 h variation. Although anecdotal evidence and clinical experience suggest a nocturnal preference for falls in the elderly, appropriate chronoepidemiology studies, i.e. ones that specifically address the clock time of their occurrence, relative to the sleep–wake routine and circadian rhythm determinants, and/or according to day of week and month or season of year, have yet to be conducted.

The aim of this article is the systematic review and synthesis of the published research on falls in hospitalized and long-term care institutionalized elderly (≥ 65 years of age) persons in which the influence of the circadian time structure (CTS) is taken into account through the reporting of the number falls per hour or specified span of the entire 24 h as well as day of week and month of year.

METHODS

The review was conducted in a series of steps: (i) database search of the published literature, (ii) quality assessment of each retrieved investigation, (iii) data extraction from tables and graphs, and (iv) summary and interpretation of findings (Khan et al., 2011). Meta-analysis of the obtained data was not feasible because of the great diversity of settings and extensive heterogeneity of findings between investigations. Therefore, the findings and synthesis of our review are provided as a narrative summary.

Literature search strategy
Between 25/10/2013 and 31/10/2013, the first author undertook a computerized search of all the published literature, without language restriction, of the following databases: Medline, SCOPUS, Ovid SP and Web of Knowledge. These databases were chosen because they best cover the medical resources relevant to the topic. The Cochrane database was checked for reviews on the topic; however, because none were located, the other databases were pursued. The search terms were the Medical Subject Headings of “accidental fall”, “circadian rhythm”, “biological clocks”, “circadian clocks”, “activity cycles”, “periodicity”, and for databases in which an age limiter is a feature, the age group of
Therefore, the search strategy entailed the following: [“accidental fall”] AND [“circadian rhythm” OR “biological clocks” OR “circadian clocks” OR “activity cycles” OR “periodicity”] without restriction of language and date of publication.

Inclusion/exclusion criteria
The retrieved publications were screened based on meeting the a priori established inclusion criteria of: (i) constituting an empirical study conducted in a hospital or long-term nursing home or healthcare institution; (ii) adopting a circadian rhythm or clock-time, day-of-week and/or month-of-year approach to the study of falls, fall trauma or fall risk; (iii) addressing falls of older people, commonly defined in developed countries as age ≥ 65 years (WHO, 2012), and exclusion criteria of: (i) pertaining to fall data of cohorts < 65 years and (ii) reporting of findings in dissertations and editorials. Our search returned 169 articles, and 1 additional relevant article was added from the reference list of one of the primary articles, 170 in total. As illustrated in Figure 1, of the total number of retired citations, 97 duplicate ones were excluded, leaving 72 articles. Further, examination of the title and abstract of these latter ones according to the inclusion and exclusion criteria resulted in the elimination of an additional 50 publications, leaving 22 articles. Thorough reading of the full content of the latter number of papers culminated in the exclusion of an additional 10 of them, because fall data were not recorded according to clock time or selected time spans of the 24 h, i.e. not related to circadian rhythm dependencies, and three other articles were removed because the study population was inappropriate, thus, leaving nine published studies for consideration.

Quality appraisal of publications
Assessment of the quality of each published investigations was conducted by one of the authors (PJLS). There is no universally accepted gold standard for evaluating and interpreting the quality of published research articles. Thus, we choose to assess the quality of the methods and research of articles meeting our inclusion and exclusion criteria using approaches commonly applied in the field of epidemiology, i.e. STrengthening the Reporting of OBservational (STROBE) checklist in the case of observational studies (cross-sectional, case-control and cohort studies) and CONsolidated Standards of Reporting Trials (CONSORT) checklist in the case of clinical trial-type studies. The STROBE checklist (Version 4 published in October/November 2007; von Elm et al., 2007) is not intended to serve as a tool to determine methodological quality, but rather a statement list of 22 recommendations for the design and implementation of an observational study. The CONSORT checklist that was developed in February 2006 (Boutron et al., 2008) for non-pharmacologic treatment trials also consists of 22 recommendations.

Data abstraction and synthesis
The nine studies were classified according to year/author, sample cohort, country/setting, study type, and clock-time and/or other temporal patterning of falls (Table 1).
RESULTS

Investigative methods

Nine studies, eight published in English and one in German (von Renteln-Kruse & Krause, 2004), met all inclusion/exclusion criteria. Two were descriptive and retrospective research letters to the editor (Manfredini et al., 2011; von Renteln-Kruse et al., 2013), six descriptive (prospective or retrospective), and one compact randomized clinical trial (Bouwen et al., 2008). The sample size of the databases and/or the elderly cohorts varied greatly between studies, from only \(N=160\) in Pellfolk et al. (2009) to \(N=40\,755\) (out of \(N=137\,521\) representative of all ages) in McMahon et al. (2012).

Temporal patterning in falls was explored both according to time of day, day of week, and month of year as summarized in Table 1. The research setting was well defined in all publications, except for the research letters to the editor (Manfredini et al., 2011; von Renteln-Kruse et al., 2013). Thus, in Table 1, the research setting is classified as hospital (utilizing hospital recordings) and long-term care institutions (utilizing nursing home and psychogeriatric residence recordings). No study was specifically conducted in a community venue. Only one study (Manfredini et al.,

TABLE 1. Detailed summary of findings per qualifying investigation.

| Author (year)        | Sample (events) | Country and setting | Type of study (study period) | Time to fall and main outcomes | Checklist (quality) |
|----------------------|-----------------|---------------------|-----------------------------|--------------------------------|--------------------|
| Gurwitz et al. (1994)| 703 (3390)      | USA Nursing home    | Retrospective descriptive (1 yr) | Falls classified by care level. For semi-dependent residents (SMD), incidence higher 06:00–08:00 h. Peak incidence for SDR and independent residents 06:00–08:00 h and independent residents 00:00–14:00 h | 17 STROBE |
| Parker et al. (1996) | 787 (564)       | UK Hospital records (all settings) | Prospective descriptive (3 yrs) | Higher incidence of falls 09:00–12:00 h | 11 STROBE |
| von Renteln-Kruse et al. (2004) | 5,946 (1596) | Germany Nursing home | Prospective descriptive (3 yrs) | Time of fall varies per patient diagnosis group | 15 STROBE |
| Bouwen et al. (2008) | 369 (64)        | The Netherlands Nursing homes (7 centers) | Compact Randomized clinical trial | Higher incidence of falls 17:00–20:00 h; peak incidence 18:00 h | 19 CONSORT |
| Eriksson et al. (2009) | 191 (229)      | Sweden Psychogeriatric Institution | Prospective descriptive (2 yrs) | No difference between day and night (Higher incidence overnight is highlighted) | 20 STROBE |
| Pellfolk et al. (2009) | 160 (191)     | Sweden Psychogeriatric Institution | Retrospective descriptive (6 mos) | 35% of falls occurs 21:00–06:00 h; peak incidence 17:00–18:00 h | 20 STROBE |
| Manfredini et al. (2011) | No data (371) | Italy Hospital | Retrospective descriptive (1 yr) | Main peak of incidence ~10:30 h; variation in incidence according to patient characteristics, fall modalities and fall consequences | Research letter to editor (no quality assessment) |
| McMahon et al. (2012) | 137,521 [≥65 yrs: 40,755] (161) | UK Hospital records (community setting) | Prospective descriptive (18 yrs) | During the night, number of deaths double that during the day following a low velocity fall of <2 m | 19 STROBE |
| von Renteln-Kruse et al. (2013) | No data (3401) | Germany Hospital | Retrospective descriptive (11 yrs) | Majority of falls occurred 06:00–00:00 h and ~25% 00:00–06:00 h; ~50% occurred 09:00–21:00 h with variation by diagnosis | Research letter to editor (no quality assessment) |
2011) utilized statistical methods routinely used in the field of chronobiology to analyze time series data to objectively identify and quantify temporal patterns. Of the remaining eight studies, six relied on a descriptive approach to report time patterning of falls (Bouwen et al., 2008; Gurwitz et al., 1994; Parker et al., 1996; Pelfolk et al., 2009; von Renteln-Kruse & Krause, 2004; von Renteln-Kruse et al., 2013), and in two (Eriksson et al., 2009; McMahon et al., 2012) data were reported for time spans of the day and night rather than individual clock times.

Quality of investigative methods
Although all of the papers comprising this review were published in peer-review journals, we, nonetheless, examined their methodological quality using STROBE and CONSORT recommendations as criteria. The nine qualifying reports differed rather substantially in the quality of the research method, reflecting the varied nature of the studies, some being descriptive, some gray literature-type, and one randomized clinical trial. One was of very low methodological quality (Parker et al., 1996), four moderate quality (Bouwen et al., 2008; Gurwitz et al., 1994; McMahon et al., 2012; von Renteln-Kruse & Krause, 2004), and two good quality (Eriksson et al., 2009; Pelfolk et al., 2009). Methodological quality of the research letters to the editor was not evaluated because of absence of specific criteria for judging such publications. Overall, the methodological quality of articles improved by year of publication, being higher for the more recently than earlier published papers (Supplementary Tables 1 and 2).

Falls occurring in hospitals
Four studies were conducted in a hospital setting with the data of two of them (McMahon et al., 2012; Parker et al., 1996) obtained through hospital records of emergency units, and the data of the remaining two (Manfredini et al., 2011; von Renteln-Kruse et al., 2013) collected from general hospital records. The study by Parker et al. (1996) focused on falls related to environmental hazards that resulted in hip fracture. The majority, i.e. 71%, of the falls of this investigation occurred in the community, while only 6% in the hospital and 23% in other institutions. McMahon et al. (2012) examined the independent effects of age, time of arrival to the hospital for medical care, and mechanism of injury in trauma survival at 30 days following the fall. Information was extracted from the database of the Trauma Audit and Research Network, representative of a large number of participating hospitals, that included details on injured patients of all ages who required hospitalization for 72 h, who were admitted to intensive care or high-dependency units, who required hospital transfer for specialist trauma treatment, or hospital death within 3 months of injury (regardless of cause). Only this study included patients of all ages because the investigators were interested in learning the effect of age on trauma survival, and specific statistical analysis of the data pertaining to the elderly was done.

The clock time during the 24 h of the greatest number of hospital falls across the four different studies is inconsistent. Parker et al. (1996) found an elevated incidence of falls in the morning between 09:00 and 12:00 h and reduced incidence overnight between 23:00 and 07:00 h. McMahon et al. (2012) analyzed their prospectively collected data for mortality at 30 days following hospital admission. The odds ratio (OR) of mortality independent of age for all injury severity levels was higher in persons admitted to the hospital between 00:00 and 08:00 h than between 08:00 and 16:00 h (OR = 1.5). The OR of mortality of those >65 years of age injured in a low-velocity fall of <2 m that were admitted to the hospital between 00:00 and 08:00 h was double that of those admitted between 08:00 and 16:00 h. The findings of the study by von Renteln-Kruse et al. (2013) differ; in this study the majority of falls, i.e. 73–75%, occurred during the day between 06:00 and 12:00 h and only ~25% overnight between 12:00 and 06:00 h. Although one-half of the falls occurred between 09:00 and 21:00 h, there was no obvious peak in incidence during the day, although 24 h patterns with a distinguishable peak time were detected in cohorts defined by certain specific dominant diagnoses. The authors of this study also found the incidence of falls exhibited a clear day-of-week difference. Finally, Manfredini et al. (2011), who used Cosinor time series analysis to objectively substantiate 24 h patterning and precisely derive the peak time of falls, reported biphasic 24 h variation in hospital falls with one peak in the morning and the other in late afternoon, the main peak being ~10:30 h. When the data were analyzed according to sex of those that fell and circumstances of the falls, the main peak for men was ~10:45 h, for subjects who fell alone anduntended ~11:00 h, for falls due to loss of consciousness ~10:30 h, for falls occurring in the bathroom ~09:15 h, for falls caused by slippery wet floors ~03:50 h, for falls caused by non-wearing of footwear ~00:30 h, and for falls from beds outfitted with bedrails ~12:30 h. The peak time of falls resulting in minor trauma without significant bruise was ~11:10 h and ones resulting in fracture ~13:05 h.

Falls occurring in long-term healthcare institutions
Five studies addressed temporal patterning of falls in long-term healthcare institutions. Three of them (Bouwen et al., 2008; Eriksson et al., 2009; von Renteln-Kruse & Krause, 2004) further examined the circumstances of falls in long-stay or geriatric/psychogeriatric institutions, and the remaining two by Pelfolk et al. (2009) and Gurwitz et al. (1994), respectively, assessed fall risk factors and unexpected and adverse events occurring in a long-term residence setting. The publications by Bouwen et al. (2008) and Pelfolk et al. (2009) both state a peak incidence of falls at 18:00 h. However, Gurwitz et al. (1994) reported the peak incidence of falls varies with
patient care level, while von Renteln-Kruse & Krause (2004) detected statistically significant day–night variation only when events were pooled into 3 h intervals, and Eriksson et al. (2009) found no day-night differences.

DISCUSSION
The main finding of this systematic review is the scientific literature pertaining to falls in the elderly in which an influence of biological rhythms is taken into consideration is sparse. In fact, lack of interest in the time of falls has been highlighted previously by one of us authors (Manfredini et al., 2012); <50% of the most recently published fall studies have included an examination of the time of their occurrence. A notable finding of this review is the disparity between published studies in the time of the peak incidence of falls, varying in particular according to the study setting, dominant diagnosis of the examined cohort, and place of fall occurrence. Nonetheless, the results of our review reveal 24 h or other temporal patterns in falls in different groups and specific hospital and long-term care residential settings in those > 65 years of age.

Temporal patterning of falls according to patient diagnosis and place of occurrence
Two studies from the group of von Renteln-Kruse were included in our systematic review (von Renteln-Kruse & Krause, 2004; von Renteln-Kruse et al., 2013). In these two studies, one addressing nursing home falls and the other hospital falls, there was no difference in the recorded occurrence of falls between the day and night spans, though no obvious peak incidence. However, in both studies the temporal pattern of fall occurrence was found to be related to certain specific dominant diagnoses. The two studies are consistent in finding highest incidence of falls in stroke and Parkinson patients between 09:00 and 12:00 h and in cardiovascular (congestive heart failure) patients between 03:00 and 06:00 h. Interestingly, the reported elevated morning incidence of falls of stroke patients coincides in time to the greatest incidence of stroke events during the 24 h in the population at large (Casetta et al., 2002); moreover, the reported elevated nocturnal incidence of falls of heart failure patients coincides in time to when the symptoms of this heart condition are worst during the 24 h (Smolensky et al., 2014a). These same two studies also report more serious falls, ones that result in significant injury and fracture, are most frequent between 00:00 and 03:00 h. However, these latter findings are not substantiated in studies conducted by others (Manfredini et al., 2011; Parker et al., 1996). Parker et al. (1996) utilizing UK hospital data reported increased morning (09:00–12:00 h) occurrence of falls that resulted in hip fracture, while Manfredini et al. (2011) utilizing Italian hospital data reported peak incidence of such falls ~13:00 h and peak incidence for falls with minor trauma without significant bruise ~11:00 h. Although it is also true that the setting and place of where the fall occurred differ between the studies.

von Renteln-Kruse & Krause (2004) specifically investigated the temporal pattern of falls according to the places where they occurred. Bathroom falls exhibited bimodal 24 h variation with one peak between 06:00 and 09:00 h and the other between 18:00 and 21:00 h. This finding to some extent was verified by Manfredini et al. (2011), who based upon Cosinor analysis of their time series data found a morning main peak of ~09:00 h in bathroom falls. von Renteln-Kruse & Krause (2004) additionally reported falls that occurred in corridors also displayed a differently phased bimodal 24 h variation with one peak between 00:00–03:00 h and the other between 06:00–09:00 h. The consequent severity and medical outcomes of falls experienced by the elderly according to either the time or place of their occurrence were not explored in most studies, in spite of the fact that McMahon et al. (2012) found falls in those > 65 years of age admitted to hospitals between 00:00 and 08:00 h were two-fold more likely to result in death than those who were admitted between 08:00 and 16:00 h.

Occurrence relative to circadian time of falls related to Sundowning syndrome
Two studies (Bouwen et al., 2008; Pellfolk et al., 2009) addressed the temporal specificity of falls in elderly institutionalized Alzheimer individuals, finding peak incidence of falls between 17:00 and 20:00 h. The authors of both publications related this peak incidence to the time span, afternoon–evening, when Sundowning syndrome, i.e. exacerbation of behavioral symptoms of Alzheimer’s disease, is dominant (Volicer et al., 2001). Sundowning syndrome is perhaps an expression, at least in part, of the circadian time structure that is synchronized by the natural or artificial light/dark 24 h cycle to which the institutionalized patients are exposed (Arend, 1998).

Occurrence of falls according to day of week and season
Three studies (McMahon et al., 2012; Parker et al., 1996; von Renteln-Kruse et al., 2013) examined the pattern of falls in institutionalized elderly persons according to day of week and season. Parker et al. (1996) and von Renteln-Kruse et al. (2013) detected day-of-week differences in falls, although McMahon et al. (2012) did not. The study by von Renteln-Kruse et al. (2013) identified monthly differences, with falls being more common in winter (HR = 1.91, 95% CI: 1.32–2.75) than spring. A possible explanation for these findings could be seasonal variation in delirium; in hospitalized medical patients, Gallerani & Manfredini (2013) found delirium to be significantly greater in autumn–winter than other times of the year.
Occurrence of falls according to activities of daily living and medications and their scheduling

The etiology of the 24 h and other time patterns of falls by the elderly have thus far been little studied. Parker et al. (1996) attributed the morning-time (09:00–12:00 h) high incidence of falls that they found in their investigation to the “hangover” effect of long-acting benzodiazepines plus high number of ADL, i.e. arising, getting dressed, etc., in the morning at the start of the day. McMahon et al. (2012), on the other hand, cited several endogenous and exogenous factors—disruption of biological rhythms, poor lighting and psychotropic medication—as contributing to the higher mortality overnight of falls occurring in the elderly. Pellfolk et al. (2009), who in their study found the peak incidence of falls in the late afternoon, associated with inappropriate behaviors in activities of daily living (ADL) connected with Sundowning syndrome. The temporal patterning of falls in elderly persons with significantly compromised ADL seems to differ according to level of independence. In this regard, Gurwitz et al. (1994) reported that compared to independent patients, who as a group exhibited highest incidence of falls between 00:00 and 02:00 h, semi-dependent patients experienced elevated incidence of falls at two spans of the 24 h, between 06:00–08:00 h and 18:00–20:00 h, while dependent patients experienced such at one span of the 24 h, between 18:00 and 20:00 h.

Limitations

The specific focus of this review is temporal patterns of hospitalized and long-term institutionalized elderly persons. In spite of the fact that reference lists of the retrieved articles were integrated into the search and no language restrictions were imposed, the search may not have been entirely comprehensive since a detailed manual search of the literature was not performed. The methodological quality of all the published studies, assessed by STROBE and CONSORT criteria, was not uniformly high even through each underwent peer review, thereby compromising, at least to some extent, certain reported findings. Nevertheless, this review describes the current state of research and provides certain evidence of biological rhythm and/or cyclic environmental influences upon the occurrence of falls in the elderly.

Surprisingly, only a small number of publications were retrieved in our search of the literature for temporal patterns in the falls of hospitalized and institutionalized elderly, indicating the general disregard of the potential relevance of time of day, day of week, and month of year in past epidemiologic and other investigations. Moreover, the findings of the retrieved studies could be specific, at least to some extent, to the structural, environmental, staffing and/or administrative features of each individual setting. Overall, this review reveals how little is known about temporal patterns in falls of the elderly and associated underlying endogenous and exogenous causal factors, and it additionally reveals several significant deficiencies in study methods.

All of the retrospective investigations included in this review reported only the total number of falls per time interval, i.e. hour, span of day, day of week or month of year. It is possible minor falls that were not witnessed or did not require staff response or medical care went unrecorded, and it is possible that the occurrence of such minor events, themselves, may show time-of-day patterning. None of the review papers examined temporal differences in the relative risk of falls in elderly institutionalized cohorts, for example, by examining per clock hour the number of falls detected relative to the number of persons who were ambulatory or otherwise at risk to falls, and in the case of falls in specific places, such as the bathroom, for example, by examining per clock hour the number of falls by elderly in bathrooms relative to the number elderly exposed to bathroom use. Expectations are that bathroom use to urinate by a large proportion of both elderly men and women is highly common at night and for defecation most common in the morning (Smolensky et al., 2014b). Relative risk is an important concept in (chrono) epidemiology, even though it is often ignored, as illustrated by the recent study by Riedel et al. (2011). They found the actual number of accidental trauma incidents of fire fighters to be greatest in the afternoon, but when the data were re-expressed in terms of the per clock-hour number of fire fighters exposed to accidental trauma, the peak of the 24 h pattern of relative risk does not occur during the day but at night, when fatigue and various cognitive, attention, performance and decision making circadian rhythms, based upon laboratory research and field studies primarily entailing those <65 years of age, attain their trough (e.g. Åkerstedt et al., 2008; Bjerner et al., 1955; Browne, 1949; Colquhoun, 1971; Marek et al., 2010; Shub et al., 1997; Valdez et al., 2010). Thus, the role of these and other circadian rhythms, or of disruption of key circadian rhythms due to absence of strong synchronizing time cues as a consequence of abnormal day and nighttime lighting and lack of sufficient diurnal socializing common in many nursing homes and other long-term healthcare institutions that may exacerbate already compromised behavior and ADL capability of the elderly (Forbes et al., 2014; Martin et al., 2006, 2007), also deserves examination.

Additionally, certain patient characteristics, such as the number and type of prominent medical conditions, can be influential. With aging there is decline in autonomic function, giving rise to an altered circadian rhythm of blood pressure plus time-of-day patterns of abnormal arterial baroreflex and orthostatic and carotid sinus syndrome events (Mulcahy et al., 2003; Tan & Kenny, 2006), all of which can be predisposing to falls and affect physiologic response to fall-induced injuries (Bliwise, 2004; Volcier et al., 2001). In some elderly individuals, syncope, which often is causal of a fall, is circadian time-dependent, with heightened incidence in
the morning. In addition, syncope in the elderly may sometimes be precipitated by urination and bowel movement; thus, time patterns of such (Smolensky et al., 2014b) during the 24 h may play a significant role in the observed day–night patterns of falls in the various publications reviewed herein. The symptom intensity of many common morbid conditions of the elderly, such as rheumatoid arthritis, osteoarthritis, congestive heart failure, transient ischemia attack, gastroesophageal reflux, peptic ulcer, certain chest diseases, and various pain syndromes, among many others, undergoes marked circadian rhythmicity (Smolensky et al., 2014a, b), and directly or indirectly they may contribute to the reported time-of-day major and minor peaks in fall frequency when data of hospitals or nursing homes or other long-term care facilities were pooled by clock hour.

Finally, temporal patterns of healthcare staff, i.e. number of qualified workers, conduct of their patient care tasks, and attributes of their work schedule constitute other very important aspects of the observed time-of-day, day-of-week and month-of-year patterns. Thus, the potential role of such temporal patterns in healthcare staff, number and level according to training/expertise, to provide safe oversight of institutionalized elderly residents during the daytime versus nighttime additionally requires assessment in future investigations. Typically, the staffing of nursing homes, long-term institutions, and other healthcare facilities for the elderly is reduced overnight, over the weekends, and during seasonal holidays. Furthermore, since the institutional time schedule of certain tasks and patient care activities, e.g. linen changes, bathing, patient transfers, and meal servings, may be influential or causal, the potential contribution of such ought to be assessed in future studies. Moreover, the role of circadian rhythms in fatigue/sleepiness, mood and cognitive functionality of the healthcare staff, themselves, and of desynchronization of the circadian time structure of shift-working day and night staff, in particular, as it affects their vigilance and oversight at different times of the day and night, also awaits evaluation.

CONCLUSIONS

Falls of the elderly are likely to result from multiple intrinsic and extrinsic causal factors. Evidence shows it is important to conduct studies whereby falls in this population are analyzed in a chronobiological perspective and using appropriate investigative and time series analytical methods to derive a comprehensive perspective upon which to construct optimal preventive counter-measures. Our review of the published literature suggests temporal patterns of falls in the elderly > 65 years of age are characteristic at least of certain cohorts residing in hospitals and nursing and other types of long-term healthcare institutions. This is particularly the case of Alzheimer disease patient cohorts prone to Sundowning syndrome, for which peak incidence of falls ~ 18:00 h is reported. In hospital settings, it is suspected that more falls occur at night and also during the late-morning. Moreover, falls of the elderly that occur in the morning, rather than other times of the day, are more likely to result in fracture. However, falls that occur during the overnight hours in this age group show twice the mortality than ones that occur during the day. The major conclusion form our review is that much additional study is required, first to substantiate the thus far reported temporal patterns in incident events and to explore the relative risk of falls and fall-induced trauma in the geriatric population of the elderly and, additionally, for specific cohorts according to medical diagnosis taking into consideration those common morbid conditions that are likely to be predisposing. Such information is urgently required to effectively and comprehensively define the etiology of falls and, of utmost importance, design meaningful preventive strategies.

DECLARATION OF INTEREST

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