High-risk Periods for Adult Traumatic Brain Injuries – a Nationwide Population-based Study

Jussi P. Posti, MD, PhD

Neurocenter, Department of Neurosurgery and Turku Brain Injury Centre, Turku University Hospital and University of Turku, Finland

Ville Kytö, MD, PhD

Heart Centre and Center for Population Health Research, Turku University Hospital and University of Turku, Turku, Finland; Research Center of Applied and Preventive Cardiovascular Medicine, University of Turku, Turku, Finland; Center for Population Health Research, Turku University Hospital and University of Turku, Turku, Finland; Administative Center, Hospital District of Southwest Finland, Turku, Finland

Jussi O.T. Sipilä, MD, PhD

Neurocenter, Department of Neurology, Turku University Hospital and University of Turku, Finland; Department of Neurology, Siun sote, North Karelia Central Hospital, Joensuu, Finland

Päivi Rautava, MD, PhD

Clinical Research Center, Turku University Hospital and University of Turku, Turku, Finland

Teemu M. Luoto, MD, PhD

Department of Neurosurgery, Tampere University Hospital and Tampere University, Tampere, Finland

Corresponding author: Jussi Posti, Neurocenter, Department of Neurosurgery and Turku Brain Injury Centre, Turku University Hospital, P.O. Box 52, FI-20521 Turku, Finland

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Abstract

Introduction: There is minimal existing available information on nationwide seasonal peaks in traumatic brain injuries (TBI). This lack of information is an impediment to the effective development of prevention programs, societal policies, and hinders the resourcing of medical emergency services. Our current aim is to study nationwide population-based high-risk periods TBI over a 15-year study period in Finland.

Methods: Nationwide databases were searched for all admissions with a TBI diagnosis and later for deaths of persons ≥16 years of age during 2004–2018. The search included all hospitals that provide acute TBI care in Finland.

Results: The study period included 69,231 TBI-related hospital admissions (men=62%). We found that for men, the highest rate of TBIs occurred on Saturdays, whereas women experience the highest rate of TBIs on Mondays. We also found that the highest rate of TBIs in men occurred in July, while women experienced the highest rate of TBIs in January. TBI-related hospital admissions [incidence risk ratio (IRR) 1.090, 95%CI 1.07–1.11, p<0.0001] and mortality within 30 days after TBI [hazard ratio (HR) 1.057, 95%CI 1.001–1.116, p=0.0455] were more common on public holidays and weekends than on weekdays. There was an increasing trend in the proportion of TBI-related hospital admissions occurring on public holidays and weekends from 2004 (31.5%) to 2018 (33.4%) (p for trend = 0.0007). In summer months, TBI-related hospital admissions (IRR 1.10, 95%CI 1.08–1.12, p<0.0001) and 30-day mortality (HR 1.069, 95%CI 1.010–1.131, p=0.0211) were more common than in other months. TBIs occurred more often in younger and healthier individuals on these index days and times. In terms of specific public holidays, the TBI risk was overall higher on New Year's Eves and Days (IRR 1.40, 95%CI 1.25–1.58, p<0.0001) and Midsummer's Eves and Days (IRR 1.36, 95%CI 1.20–1.54, p<0.0001), compared to non-working days. This finding was significant in both genders.

Conclusions: TBI-related hospital admissions and mortality were more common on public holidays, weekends, and in summer months in Finland. People who sustained TBIs on these days were on average younger and healthier. The occurrence of TBIs on public holidays and weekends is increasing at an alarming rate over time.

Introduction

The World Health Organization (WHO) estimated that traumatic brain injury (TBI) is the third most common cause of death in the world, as TBIs account for nearly half of all injury-related deaths globally. [1] Accidents and injuries that lead to TBI have become more preventable as epidemiological knowledge increases. Finnish [2], European [3], and global longitudinal studies [4] have also illuminated the ongoing changes in the worldwide incidence of TBI in different age groups: the most significant change is the increase in mild TBIs and their accumulation in older age groups.

The information on nationwide seasonal TBI peaks in Finland is minimal. Lack of information on seasonal peaks of TBIs is an impediment to the effective development of prevention programs and societal policies. Research data on high-risk periods for TBI would also assist in planning medical emergency service resourcing. The available information on the seasonality of TBIs is scarce and most of the existing studies are based on regional data [5–8], which makes it difficult to generalize the findings.

The age-standardized incidence of TBIs in Finland is one of the highest in Western Europe, along with that in Belgium. On the other hand, the incidence is only half of the figures in Eastern and Central Europe. [4] To provide data for clinical practice and societal decision-making, we used national databases to conduct a nationwide population-based study investigating adult TBI seasonality over a 15-year study period in Finland. We hypothesize that there are seasonal peaks in hospital admissions and mortality.

Materials and Methods

Study population and data search

For this study, we searched the Care Register for Health Care [held by the National Institute for Health and Welfare (THL), Helsinki, Finland], a mandatory database for all public healthcare hospital discharges in mainland Finland, for all admissions with a TBI diagnosis (ICD-10 codes S06.*) for

patients ≥16 years of age between January 1, 2004 and December 31, 2018. Information on injury dates and patient demographics [here: gender, age and co-morbidities] are included in the register's discharge data. The Charlson Comorbidity Index (CCI) scores were calculated as described elsewhere. [9]

All hospitals in Finland that provide care for acute TBIs necessitating acute head computed tomography imaging were included in the search. Hospital transfers related to a particular episode of a hospitalization were combined as one admission. One admission per patient per calendar year was included. 30-day mortality data of admitted patients was obtained from the mandated-by-law Statistics Finland database covering all deaths of Finnish citizens (mortality data was available until December 31, 2018). Patients lost to follow-up (0.9% of patients) were excluded from the mortality analysis.

Injury dates

The index injury dates were classified as follows: i) summer months (June–August, including weekends and Midsummer's Eve and Day), ii) weekdays (Monday–Friday, all months), iii) public holidays [New Year's Eve and Day, Epiphany, Easter (Thursday–Monday), May Day Eve and Day, Ascension Day, Midsummer's Eve and Day, Independence Day, Christmas (Eve–Boxing Day)] and weekends (Saturdays and Sundays, all months). Public holidays that have fixed dates in Finland are: New Year's Day (1st January), Epiphany (6th January), Independence Day (6th December), Christmas Eve (24th December), Christmas Day (25th December), and Boxing Day (26th December). New Year's Eve (31st December) is not a paid holiday in the public sector, but many people both in the municipal and business sectors take the day off work. The leap years (2004, 2008, 2012, and 2016) were taken into account in the month analyses. During the 15 study years, there were 1380 days in summer months (4099 days in non-summer months), 255 days public holiday days (5224 non-public holiday days), and 1096 weekend days (4383 weekdays).

Statistical analysis

The Wilcoxon-Mann-Whitney test was used to analyze the differences in patient age and the CCI scores between the different index dates. Negative binomial regression was used to analyze incidence risk ratios (IRR) for TBI-related hospital admissions and Cox regression was used to analyze hazard ratios (HR) for 30-day mortality when comparing different index dates. The trends in TBI-related hospital admission percentages on different index dates were analyzed with the Cochran-Armitage Trend Test. Significance was inferred at 5%. The SAS system version 9.4 (SAS Institute Inc., NC, USA) and GraphPad Prism version 8.0 (Graphpad Software, CA, USA) were used for the statistical analyses.

Results

During the 15 study years, there were 69,231 TBI-related hospital admissions among adults (men=62%). The 30-day mortality in the total study population was 8.9% (6,131 deaths, 63% men). Across different weekdays, the highest rate of TBIs among men occurred on Saturdays, while women experienced the highest rate of TBIs on Mondays (Table 1A). Moreover, the highest rate of TBIs occurred in July for men and in January for women (Table 1B).

Traumatic brain injury-related admissions on public holidays and weekends throughout the year

There were 23,281 TBI-related hospital admissions on public holidays and weekends and 45,950 on weekdays. The patients who sustained TBIs on public holidays and weekends were on average younger and healthier than those who suffered TBIs on weekdays (Table 2). TBI-related hospital admissions were more common on public holidays and weekends than on weekdays in men (IRR 1.16, 95%CI 1.13–1.18, $p<0.0001$) and overall (IRR 1.09, 95%CI 1.07–1.11, $p<0.0001$), while in women, no difference was observed (interaction $p<0.0001$) when adjusted for study year. There was no change in the significance when adjusted for both study year and summer months. There was an annual increasing trend for TBI-related admissions on public holidays and weekends compared to

weekdays in men (from 32.2% to 35.1%, p for trend = 0.0005) and overall (from 31.5% to 33.4%, p for trend = 0.0007), but in women, no change was observed (Figure 1).

The risk of TBI-related admissions was higher on the New Year's Eves and Days and Midsummer's Eves and Days while the risk was lower on Easter weekends, Christmas holidays, and Epiphanies, although the results indicated gender differences between specific holidays (Table 3).

Traumatic brain injury-related deaths on public holidays and weekends around the year

Death occurred within 30 days in 1,917 patients who sustained TBI on public holidays and weekends (8.32%) and in 4214 patients on weekdays (9.25%). Mortality was more common on public holidays and weekends in men (HR 1.084, 95%CI 1.013–1.160, p=0.0203) and overall (HR 1.057, 95%CI 1.001–1.116, p=0.0455) when adjusted for study year, age, gender, CCI score and summer holiday season. No significant differences were observed in women. In terms of specific dates, no public holiday was associated with a particularly high 30-day mortality.

Traumatic brain injury-related admissions in summer months

There were 18,677 TBI-related hospital admissions in summer months and 50,554 in other months. Again, the patients who sustained TBIs in summer months were on average younger and healthier than those who suffered TBIs in other months (Table 2). TBI-related hospital admissions were more common in summer months than in other months among men (IRR 1.15, 95%CI 1.12–1.18, p<0.0001) and overall (IRR 1.10, 95%CI 1.08–1.12, p<0.0001), while in women, no difference was observed (interaction p<0.0001) when adjusted for study year. There was no change in significance when adjusted for both study year, public holidays, and weekends.

The results also indicated an annual decreasing trend for TBI-related admissions in summer months compared to other months overall (p=0.0146). Additionally, when the genders were studied separately, no trends were observed (Figure 2).

Traumatic brain injury-related deaths in summer months

The 30-day TBI-related mortality figures were distributed as follows: 1,645 patients in summer months (8.92%) and 4,486 patients in other months (8.94%). Mortality was more common in summer months overall (HR 1.069, 95%CI 1.010–1.131, p=0.0211) when the analysis was adjusted for study year, age, gender, CCI score, weekends, and public holidays.

Discussion

In this nationwide population-based study, we examined the seasonality of adult TBIs in Finland over a 15-year time period. The main finding is that the incidence of TBI-related hospital admissions and 30-day mortality are higher in summer months and on holidays and weekends. It was also found that the occurrence of TBIs is increasing on public holidays and weekends. Compared to other days, TBIs sustained on these index days appear to occur more often in younger and healthier individuals.

There is a call for global efforts to reduce the burden of TBIs through better prevention policies and timely resourcing of emergency healthcare services. This kind of initiative requires rigorous epidemiological studies to identify groups at risk of TBI and the certain times and events that increase the risk. [10] Knowledge of the seasonal nature of TBIs at the national levels is scarce. Robust research results on this issue could be applied nationally and internationally. [11,12] The current study is the first to examine this subject in Finland and found that nationwide, TBI occurrence peaks in January, July, and August, while the occurrence is lowest in February. These patterns observed in the current study were driven by men. Conversely, the peak in female TBI occurrence was more modest in summer and was more clearly concentrated around the turn of the year, specifically in December and January. The occurrence of TBIs on different days of the week was also driven by men, since the highest rate occurred on Saturdays overall and in men, while in women, the highest rate occurred on Mondays. Furthermore, TBI-related hospital admissions were more common on public holidays and weekends than on weekdays in men and overall, while this was not the case for women. TBIs were also more common in summer in men and overall but not in women.

These results are relatively similar to those of previous Norwegian and Finnish studies that also suggest a possible explanation for the occurrence of TBIs. A study on moderate to severe TBIs from Norway's Trondheim region demonstrated that there was no difference between TBI-related admissions on weekends and weekdays in sober patients, whereas the difference was significant in patients under the influence of alcohol. The rate of TBIs was highest in June, July, and December, while it was low in the first five months of the year. In December, TBIs were most common in patients with a positive alcohol test. The authors linked the peak times to cultural factors and the celebration of holidays. [13] An earlier regional study from Northern Finland also reported that alcohol-associated head injuries peaked on weekends and in July, but in sober patients there were no temporal variations. TBI occurrence was lowest in February, while in the current study comprising the whole country, the occurrence was lowest in April. This particular study differs from ours as all kinds of head injuries from scalp wounds to severe TBIs were included. [5] The current observations of TBI seasonality differ from the Canadian study, which reported that TBIs occurred most commonly in fall and winter. [14]

Injury mechanisms seem to affect the seasonality of TBI incidence. In a Slovakian study investigating traffic-related fatal TBIs, pedestrians sustained more fatal TBIs during winter months, while cyclists and motorcyclists experienced more fatal TBIs in spring and summer. [15] The findings of the present study warrant more research, and the seasonal nature of injury mechanisms should be studied in nationwide settings in Finland. In this study, only adults were examined, although the seasonality of pediatric TBIs appear to follow the adult counterpart. Danish [16], British [17], and Japanese [18] studies showed that pediatric TBIs are more common in summer, although the methods of inclusion in these studies vary.

The data on the association of alcohol consumption and TBIs is abundant. Alcohol intoxication strongly increases the risk of accidents and accidental deaths. Various studies have previously reported that nearly half of those who sustain a TBI are under the influence of alcohol in the event of

the accident. [19,20] A recent American multicenter study reported that fall-related emergency department visits with indication of alcohol use were more frequent on weekends and in summer months. The percentage of falls under the influence of alcohol that resulted in a head injury was 50%, compared with 25% for patients who were sober. [21] In Finnish culture, alcohol consumption increases on weekends and public holidays while it is not as common on weekdays. Alcohol is consumed on weekends and in larger quantities per occasion in Finland in contrast to southern European countries. [22,23] Consequently, there is a clear peak in intoxication-related deaths on public holidays and weekends in all age groups in Finland. Alcohol-related deaths have been reported to be most common on Midsummer's Eve and Day followed by May Day and Christmas. [24] Direct causal associations with the current results cannot be drawn, but the earlier findings help contextualize the findings of our study. Since both alcohol consumption and abuse are much more common among men in Finland [25], this might also explain the sex differences we observed.

In the current study, it was observed that mortality after TBI is more common on weekends, public holidays, and in summer months. This suggests that there may be a TBI-related "weekend effect" in a similar way as proposed in stroke. This suggests that patients with acute ischemic stroke, who are admitted outside routine working hours, are in higher risk of in-hospital mortality than patients who are admitted during routine working hours. The effect may depend on factors related to either the healthcare system [26] or more serious cases of illness [27], or both. Patients with TBIs may also experience delays in accessing emergency departments on weekends.

Children, adolescents, and young adults constitute the majority of patients who suffer TBIs. [3,28] We observed that TBIs tend to occur in younger and heathier patients on weekends, public holidays, and in summer months. The finding may partly explain the lower mortality seen before adjusting the mortality analyses. Above all, however, it reflects the fact that younger people are at higher risk of accidents in their spare time. An increasing trend in TBIs on weekends and public holidays was also observed in the entire population, but not in women.

The strengths of the study are the population-based design, 15 year-long study period, and the robust Finnish obligatory databases. To our knowledge, this is the first study reporting nationwide high-risk periods for TBI. This was a retrospective registry study based on administrative data. Therefore, there are certain weaknesses that must be acknowledged. Since the data search was based on the ICD-10 coding, we were unable to individually study varying severities of TBI. It is also known that most patients with mild head injuries do not seek medical attention, so this part of the population could not be analyzed in this study, which results in an underestimation of the actual number of TBIs. In addition, it should be emphasized that we only included patients in the study whose TBI required hospital admission. A limitation in terms of the 30-day mortality is that we have included patients who died within 30 days from injury—no death certificates were reviewed for underlying causes of death.

Conclusion

Public holidays, weekends, and summer months were identified as times of increased adult TBI occurrence in Finland. Furthermore, TBI occurrence alarmingly increased on public holidays and weekends and patients were on average younger and healthier. These results should be considered when planning emergency medical and healthcare services and TBI prevention policies. This is especially crucial because TBIs during these times caused more immediate mortality.

Statements

Conflict of interest statement

Dr. Posti has received speaker's fees from the Finnish Medical Association. Dr. Kytö has no financial disclosures. Dr. Sipilä has received honoraria (Merck, Pfizer, Sanofi), consultancy fees (Rinnekoti Foundation, Medaffcon), travel grants and congress sponsorship (Abbvie, Orion Pharma, Merck Serono, Sanquin, Lundbeck, Novartis), and holds shares (Orion Corporation). Dr. Rautava has no financial disclosures. Dr. Luoto has no financial disclosures.

Statement of ethics

The study was approved by THL (permission no. THL/2245/5.05.00/2019) and Statistics Finland (TK-53-484-20). This was a retrospective register study, and thus no informed consent was required, and the participants were not contacted. The legal basis for the processing of personal data is public interest and scientific research (EU General Data Protection Regulation 2016/679 (GDPR), Article 6(1)(e) and Article 9(2)(j); Data Protection Act, Sections 4 and 6).

Data availability statement

Due to national data protection legislation, the register data used in this study cannot be shared without applying for permission to use the data with a specific study protocol and scientifically justified study questions.

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Author contributions

Name	Location	Role	Contribution
Jussi P. Posti, MD, PhD	Turku University Hospital and University of Turku, Turku, Finland	Author	Conceived and designed the study, drafted the manuscript, prepared the figures, interpreted the results, revised the manuscript for intellectual content
Ville Kytö, MD, PhD	Turku University Hospital and University of Turku, Turku, Finland	Author	Co-designed the study, curated the data, conducted statistical analyses, provided critical contribution to manuscript drafting, interpreted the results, revised the manuscript for intellectual content
Jussi Sipilä, MD, PhD	North Karelia Central Hospital, Joensuu, Finland; Turku University Hospital and University of Turku, Turku, Finland	Author	Co-designed the study, curated the data, provided critical contribution to manuscript drafting, interpreted the results, revised the manuscript for intellectual content
Päivi Rautava, MD, PhD	Turku University Hospital and University of Turku, Turku, Finland	Author	Curated the data, interpreted the results, revised the manuscript for intellectual content
Teemu Luoto, MD, PhD	Tampere University Hospital and Tampere University	Author	Co-designed the study, provided critical contribution to manuscript drafting, interpreted the results, revised the manuscript for intellectual content

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Fig. 1. Trends in percentage of traumatic brain injuries occurred on weekends and public holidays compared to weekdays during 2004–2018

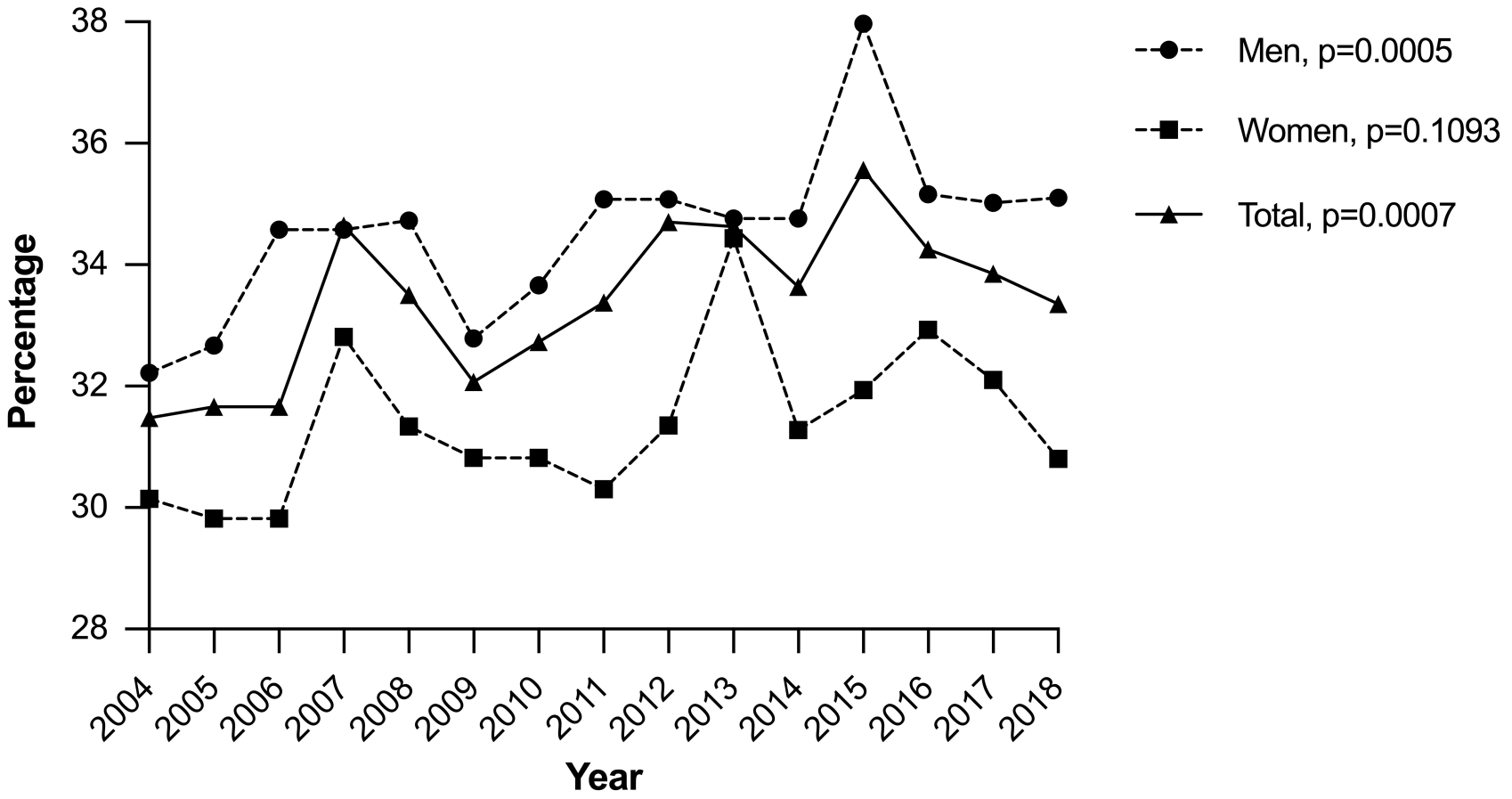

Fig. 2. Trends in percentage of traumatic brain injuries occurred in summer months compared to other months during 2004–2018

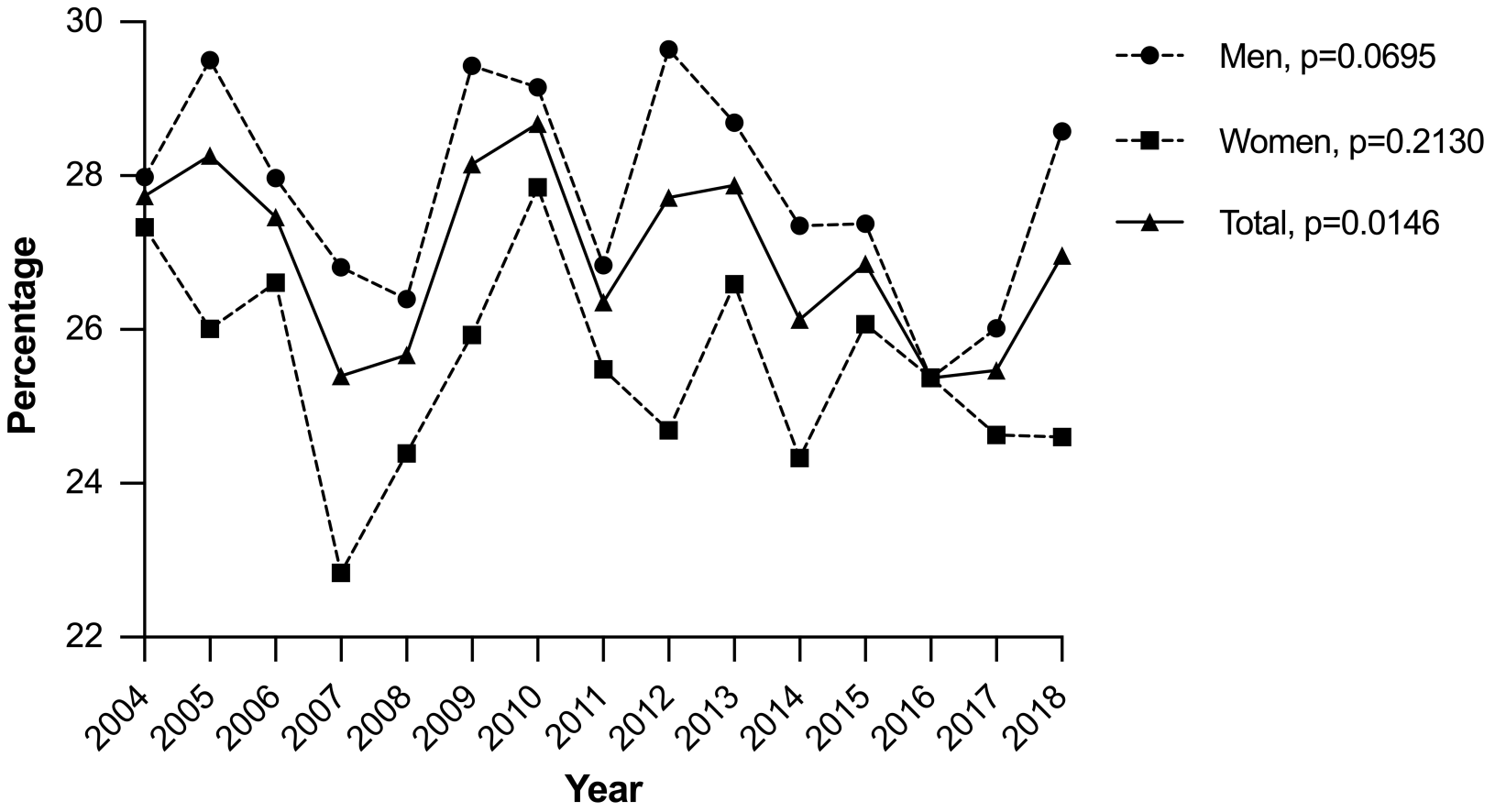

Table 1A. Rates of traumatic brain injury-related hospital admissions on different weekdays during 2004–2018

Weekday	Men			Women			Total		
	n	% of days	rank	n	% of days	rank	n	% of days	rank
Monday	6055	14.12	3	3892	14.77	1	9947	14.37	3
Tuesday	5741	13.39	6	3802	14.43	3	9543	13.78	6
Wednesday	5642	13.16	7	3695	14.02	6	9337	13.49	7
Thursday	5882	13.72	5	3734	14.17	4	9616	13.89	4
Friday	5906	13.77	4	3682	13.97	7	9588	13.85	5
Saturday	7031	16.40	1	3827	14.52	2	10858	15.68	1
Sunday	6625	15.44	2	3717	14.11	5	10342	14.94	2

Table 1B. Rates of traumatic brain injury-related hospital admissions in different months during 2004–2018

Month	Men			Women			Total		
	n	% of months	rank	n	% of months	rank	n	% of months	rank
January	3772	8.11	4	2426	5.22	1	6198	13.33	3
February	3118	7.35	8	1919	4.53	11	5037	11.88	11
March	3441	7.40	7	2224	4.78	7	5665	12.18	9
April	3276	7.28	11	1935	4.30	12	5211	11.58	12
May	3686	7.93	6	2152	4.63	10	5838	12.55	6
June	3803	8.45	3	2119	4.71	9	5922	13.16	4
July	4122	8.86	1	2300	4.95	5	6422	13.81	1
August	4023	8.65	2	2310	4.97	4	6333	13.62	2
September	3602	8.00	5	2125	4.72	8	5727	12.73	5
October	3388	7.29	10	2240	4.82	6	5628	12.10	10
November	3260	7.24	12	2248	5.00	3	5508	12.24	8
December	3391	7.29	9	2351	5.06	2	5742	12.35	7

Table 2. Cohort demographics

	Time period	Men				Women				Total			
		n	mean	SD	p	n	mean	SD	p	n	mean	SD	p
Age	Public holidays and weekends	14796	53.08	20.32	**<0.0001**	8252	63.388	22.11	**<0.0001**	23048	56.77	21.55	**<0.0001**
	Weekdays	27660	58.57	19.49		17902	66.60	20.79		45562	61.72	20.39	
	Summer months	11787	54.86	19.97	**<0.0001**	6654	64.66	21.82	**0.0011**	18441	58.39	21.18	**<0.0001**
	Other months	30669	57.34	57.34		19500	65.90	21.07		50169	60.67	20.79	
CCI	Public holidays and weekends	14796	0.80	1.37	**<0.0001**	8252	1.04	1.46	**<0.0001**	23048	0.89	1.41	**<0.0001**
	Weekdays	27660	1.03	1.49		17902	1.11	1.49		45562	1.06	1.49	
	Summer months	11787	0.89	1.42	**<0.0001**	6654	1.07	1.48	0.1679	18441	0.96	1.44	**<0.0001**
	Other months	30669	0.97	1.47		19500	1.09	1.09		50169	1.02	1.47	

CCI. Charlson Comorbidity Index; mean. mean age in years; SD. standard deviation in years; p. p value from the Wilcoxon-Mann-Whitney test; significant p values in bold

Table 3. Traumatic brain injuries on specific public holidays and comparison with other public holidays and weekends during 2004–2018

Public holiday	Men				Women				Total			
	cases/day	IRR	95%CI	p	cases/day	IRR	95%CI	p	cases/day	IRR	95%CI	p
New Year's Eve and Day	11.90	1.39	1.23–1.58	**<0.0001**	6.77	1.42	1.23–1.65	**<0.0001**	9.33	1.40	1.25–1.58	**0.0001**
Epiphany	7.13	0.83	0.67–1.02	0.074	3.73	0.78	0.59–1.02	0.0581	5.43	0.81	0.66–0.98	**0.0001**
Easter (whole weekend)	7.33	0.84	0.77–0.93	**0.0004**	4.72	0.98	0.88–1.10	0.7695	6.03	0.89	0.82–0.97	**0.0108**
May Day Eve and Day	9.13	1.06	0.92–1.22	0.4222	4.50	0.94	0.79–1.12	0.4824	6.82	1.02	0.89–1.16	0.7989
Ascension Day	7.73	0.90	0.73–1.10	0.2981	3.80	0.79	0.60–1.04	0.0774	5.77	0.86	0.71–1.04	0.124
Midsummer's Eve and Day	11.73	1.37	1.21–1.56	**<0.0001**	6.30	1.32	1.14–1.54	**0.0005**	9.02	1.36	1.20–1.54	**0.0001**
Independence Day	7.27	0.84	0.68–1.04	0.1087	4.60	0.96	0.75–1.23	0.731	5.93	0.88	0.73–1.07	0.2056
Christmas (Eve–Boxing Day)	5.84	0.67	0.59–0.77	**<0.0001**	4.29	0.89	0.77–1.04	0.132	5.07	0.75	0.67–0.84	**0.0001**

IRR. incidence rate ratio (comparison with other public holidays and weekends); 95%CI. 95% confidence interval; p value from incidence rate ratio test; significant p values in bold