

Seasonality of child and adolescent injury mortality in Japan, 2000–2010

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Received: 7 July 2014 / Accepted: 11 October 2014 / Published online: 31 October 2014
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Abstract

Objective Injury is the leading cause of death among children and adolescents in Japan. Despite this, until now there has been comparatively little research on this phenomenon. The purpose of this study was to examine if there was seasonal variation in child and adolescent injury mortality in Japan in 2000–2010.

Methods Vital statistics injury mortality data were obtained from the Ministry of Health, Labour and Welfare of Japan. The seasonality of the major causes of unintentional injury (transport accidents, drowning and suffocation) and intentional injury (suicide and homicide) mortality was examined for children and adolescents aged 0–19. Incidence ratios (IR) with 95 % confidence intervals (CI) were calculated to determine the difference between the numbers of observed and expected seasonal deaths.

Results The annual average injury mortality rate among children and adolescents was 9.0 per 100,000. Deaths from transport accidents, drowning, suffocation and suicide had a significant seasonality. There was a summer peak for transport accidents (IR 1.15, 95 % CI 1.10–1.19) and drowning (IR 2.00, 95 % CI 1.88–2.11), a spring peak for suicide (IR 1.09, 95 % CI 1.04–1.14), while the incidence of suffocation was higher in winter (IR 1.12, 95 % CI 1.03–1.21).

Conclusion Child and adolescent injury mortality from transport accidents, drowning, suffocation and suicide has a

pronounced seasonality in Japan. More research is now needed to find the circumstances underpinning different forms of injury mortality in different periods of the year so that effective interventions can be designed and implemented to reduce the burden of injury mortality among Japanese children.

Keywords Season · Unintentional injury · Suicide · Epidemiology · Japan

Introduction

Japanese child mortality has decreased dramatically since the 1950s due to the development of health care infrastructure and the establishment of an emergency health system [1, 2]. Nonetheless, ‘unintentional injuries’ continue to be the leading cause of death among children aged 1 year and above in Japan as they have been since the 1960s [2, 3]. Most injury deaths such as those resulting from transport accidents, drowning, and suffocation are unintentional [3, 4]. However, the growing death toll from suicide among Japanese adolescents in recent years [5] has meant that deaths from intentional injuries, that is, from suicide and homicide, have now become increasingly important.

Given the four distinct seasons in Japan, one factor that might be associated with child injury mortality in this setting is the time of the year when death occurs, i.e., its seasonality. A previous study has suggested that there were seasonal differences in mortality among children and adolescents in Japan in the 1957–1960 period. During those years children aged 0–4 years experienced a high degree of seasonal variation in their mortality with a “winter” peak, while children and adolescents aged 5–19 years had a

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“summer” peak mainly due to deaths from road transport accidents [6]. Excess winter deaths from accidents, as well as a large spring peak and a small autumn peak in deaths from suicide, were also reported among the Japanese population in 1970–1999 [7].

Despite the potential importance of season for child and adolescent injury mortality, there has been little research on this phenomenon to date in Japan. This is an important research gap. As most injury deaths are preventable [8–10], understanding when deaths occur may have important public health implications. Given this, while defining injurious death as being both unintentional (e.g., accidents) and intentional (e.g., homicide) in form, this study uses data from Chapter XX (external causes of morbidity and mortality) of the International Statistical Classification of Diseases 10th Revision (ICD-10; V01–Y98) with the aim of determining the seasonality of childhood injury deaths in Japan in the period from 2000 to 2010.

Methods

Vital statistics injury mortality data for the period 2000–2010 were obtained from the Ministry of Health, Labour and Welfare of Japan. These mortality data were classified in accordance with ICD-10 which was adopted in Japan in 1995. All injury deaths (V01–Y98) were included in the analysis, i.e., deaths from unintentional injury [or accidents (V01–X59); transport accidents (V01–V99), drowning (W65–W74) and suffocation (W75–W84)], deaths from intentional injury [suicide (X60–X84) and homicide (X85–Y09)] and deaths from injury of undetermined intent (Y10–Y34). The focus of the current study was Japanese children and adolescents who were younger than 20 years of age (i.e., infants less than 1 year old, young children aged 1–4 years, children aged 5–9 years, older children aged 10–14 years and adolescents aged 15–19 years), who died in the period from 1 January 2000 to 31 December 2010. Data were used to determine the mortality resulting from the main forms of unintentional (transport accidents, drowning and suffocation) and intentional (suicide, homicide) injury among boys and girls in this age range, and whether these causes of death varied in their occurrence across the seasons of the year.

Statistical analysis

The SAS statistical software package (version 9.3; SAS Institute Inc., Cary, NC, USA) was used to analyze the injury mortality data. Crude mortality rates (per 100,000) which were used to show seasonal monthly mortality trends by sex were calculated for the period from 2000 to 2010 using population data from the 2005 census as the

denominator. For the analysis the spring season was defined as running from March through to the end of May; summer as June to August; autumn as September to November; and winter as December to February. Using the methodology employed in earlier studies as a guide [11, 12], to test the seasonal variation in the number of injury deaths statistically, we used incidence ratios (IR—defined as the ratio between the observed and expected numbers of injury deaths in each time interval) and 95 % confidential intervals (CI), the calculation of which is based on a normal approximation as $\pi/\pi_0 \pm 1.96\sqrt{\pi(1-\pi)/n}/\pi_0$, where π is the observed proportion of injury deaths in a season, π_0 is the expected proportion of injury deaths when the null hypothesis is true, and n is the total number of injury deaths for the entire study period. We calculated the number of deaths that would be expected if the total number of injury deaths that occurred was distributed evenly across the seasons of the year while taking leap years into account. These numbers were then compared with the number of injury deaths that actually occurred in each season. These comparisons were made for all injury deaths, unintentional injury deaths from transport accidents, drowning and suffocation, for intentional injury deaths from suicide and homicide, and for deaths from injury of undetermined intent. The null hypothesis for this study was that there would be no discernible seasonal variation in the mortality of children and adolescents in Japan from different forms of injury. Ethical approval was not sought for this study as it made use of secondary data.

Results

A total of 23,662 children and adolescents aged 0–19 years died as a result of injuries in Japan in the period between 2000 and 2010. Specifically, 16,099 (68.0 %) boys and 7,563 (32.0 %) girls died during these years. The average annual crude injury mortality rate among children and adolescents aged 0–19 years was 9.0 per 100,000 (11.9 for boys and 5.9 for girls).

Table 1 presents details of injury deaths for children and adolescents aged 0–19 in the 11 years period (2000–2010) and the annual average mortality rate per 100,000. Among all injury deaths, 65.3 % were deaths from unintentional injury, 24.8 % from suicide, 4.7 % from homicide and 3.9 % were deaths of undetermined intent among children and adolescents aged 0–19 years. Infants less than 1 year old and adolescents aged 15–19 years old had the highest injury mortality rates (19.0 and 18.9 per 100,000, respectively). Unintentional injury deaths comprised the majority of all injury deaths for all age categories (78.8 % for infants less than 1 year old, 82.6 % for young children

Table 1 Total injury deaths and the annual average injury mortality rate per 100,000 children aged 0–19 years by selected causes in Japan, 2000–2010 (*N* = 23,662)

Cause of death	ICD10	<1		1–4		5–9		10–14		15–19		0–19	
		<i>N</i> (%)	Rate	<i>N</i> (%)	Rate								
All injury	V01–Y98	2,193 (100)	19.0	3,052 (100)	6.2	2,518 (100)	3.9	2,371 (100)	3.6	13,528 (100)	18.9	23,662 (100)	9.0
Unintentional injury	V01–X59	1,728 (78.8)	15.0	2,522 (82.6)	5.1	2,135 (84.8)	3.3	1,487 (62.7)	2.3	7,582 (56.0)	10.6	15,454 (65.3)	5.9
Transport accidents	V01–Y99	140 (6.4)	1.2	864 (28.3)	1.7	1,087 (43.2)	1.7	703 (29.6)	1.1	5,939 (43.9)	8.3	8,733 (36.9)	3.3
Drowning	W65–W74	103 (4.7)	0.9	610 (20.0)	1.2	530 (21.0)	0.8	317 (13.4)	0.5	636 (4.7)	0.9	2,196 (9.3)	0.8
Suffocation	W75–W84	1,261 (57.5)	10.9	428 (14.0)	0.9	134 (5.3)	0.2	118 (5.0)	0.2	164 (1.2)	0.2	2,105 (8.9)	0.8
Suicide	X60–X84	0 (0)	0	0 (0)	0	5 (0.2)	0.0	627 (26.4)	1.0	5,248 (38.8)	7.3	5,880 (24.8)	2.2
Homicide	X85–Y09	253 (11.5)	2.2	309 (10.1)	0.6	234 (9.3)	0.4	111 (4.7)	0.2	194 (1.4)	0.3	1,101 (4.7)	0.4
Undetermined intent	Y10–Y34	178 (8.1)	1.5	137 (4.5)	0.3	81 (3.2)	0.1	96 (4.0)	0.1	428 (3.2)	0.6	920 (3.9)	0.3

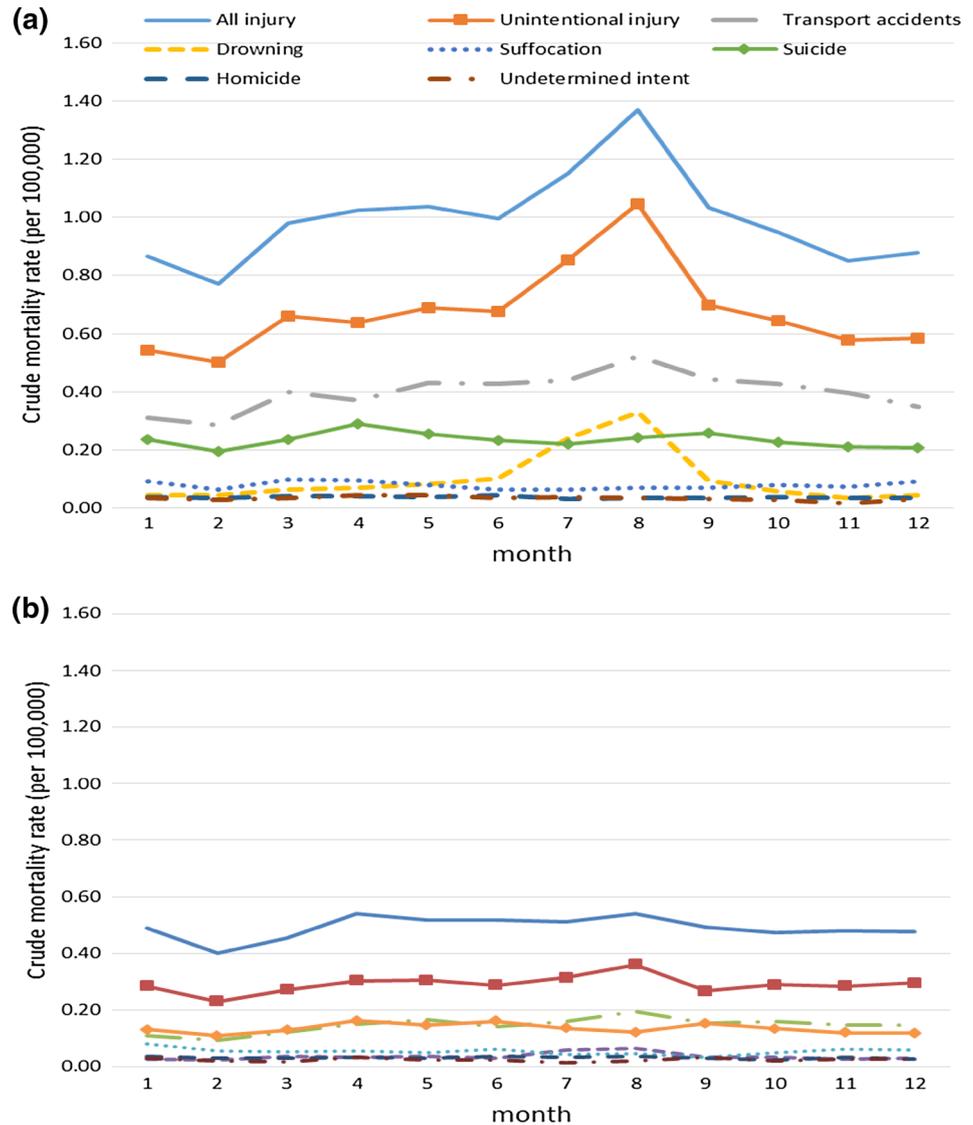
aged 1–4 years, 84.8 % for children aged 5–9 years, 62.7 % for older children aged 10–14 years and 56.0 % for adolescents aged 15–19 years). As regards the three causes of unintentional injury mortality detailed in the table, there was an exceptionally high annual average mortality rate from suffocation among children aged less than 1 year old (10.9 per 100,000) which was mirrored by a high mortality rate from transport accidents among adolescents aged 15–19 (8.3 per 100,000). The mortality rate from drowning was low among all age groups, ranging from 0.5 to 1.2 per 100,000, with the lowest rate among those aged 10–14. In terms of intentional injuries, for suicide there were very few deaths (*N* = 5) before the age of 10 while the highest mortality rate was in the 15–19 age group (7.3 per 100,000). The homicide rate was highest among infants aged 0–1 (2.2 per 100,000) and ranged between 0.2 (10–14 years old) and 0.6 (1–4 years old) for the other age groups. The highest rate of undetermined death was in the 0–1 age group (1.5 per 100,000).

To determine whether there are noticeable differences in the occurrence of different causes of death at specific time points across the year, monthly trends in the annual average injury mortality rate in 2000–2010 by cause of death and sex are shown in Fig. 1a (boys), b (girls). Among boys, the highest mortality rate for all injuries and from unintentional injuries occurred in August, while the lowest rates for these causes of death were in February. From June to August, the overall injury mortality rate (comprising mostly deaths from unintentional injury) increased and then fell until November. Suicide was slightly higher among boys in April than in the other months. Among girls, against a backdrop of lower injury mortality rates, there were two small seasonal peaks in all injury mortality in April and August, while the lowest rate was observed in February (as with boys). We noted, however, that this August peak did not occur every year throughout the study period (data not shown). Mortality from unintentional injury for both boys and girls exhibited a declining trend after August.

The comparison between the observed and expected number of injury deaths among Japanese children and adolescents aged 0–19 years old in each season is shown in Table 2. There were significant differences between the observed and expected number of injury deaths across the seasons for both sexes. All injury mortality was significantly higher during summer (IR 1.14, 95 % CI 1.11–1.16), and lower during winter (IR 0.88, 95 % CI 0.86–0.90), when compared with the expected number of deaths in each season.

The number of children and adolescents dying as a result of transport accidents was significantly higher during summer and autumn, but lower during winter (IR 1.15, 95 % CI 1.10–1.19; IR 1.06, 95 % CI 1.02–1.10; IR 0.80, 95 % CI 0.76–0.84, respectively). A summer peak in

Fig. 1 Monthly trends in the annual average injury mortality rate by cause of death per 100,000 among children and adolescents aged 0–19 years in Japan, 2000–2010 **a** boys, **b** girls



transport accident mortality was observed for both sexes. This peak was also observed for injury deaths due to drowning. Both boys and girls were significantly more likely to drown during summer (IR 2.00, 95 % CI 1.88–2.11). The reverse was observed in the other seasons, which registered a lower number of drowning deaths, particularly among boys. For deaths due to suffocation, boys experienced a significant elevation in cases during spring; in contrast, this number was significantly lower in the summer that followed (IR 1.15, 95 % CI 1.03–1.26; IR 0.84, 95 % CI 0.74–0.94, respectively). For girls, a significantly higher number of suffocation deaths were observed during winter (IR 1.21, 95 % CI 1.06–1.35). As regards suicide mortality, significantly more suicide deaths were observed among children and adolescents in spring (IR 1.09, 95 % CI 1.04–1.14), though this was less apparent in girls. The trend in suicide deaths reversed in

winter for both genders (IR 0.91, 95 % CI 0.86–0.96). There was no seasonal variation in deaths due to homicide. Deaths of undetermined intent were more common in spring among boys (IR 1.25, 95 % CI 1.06–1.44).

Discussion

This study examined the seasonality of injury deaths among children and adolescents aged 0–19 years in Japan in 2000–2010. The annual average mortality rate of injury deaths among Japanese children was 9.0 per 100,000 (Table 1). We found that there were significant seasonal variations in some forms of injury mortality among boys and girls. Specifically, transport accidents, drowning, suffocation, suicide and deaths of undetermined intent all had a seasonal component.

Table 2 Observed versus expected injury deaths by season among children aged 0–19 years in Japan, 2000–2010 ($N = 23,662$)

	Total			Boys			Girls		
	Obs	Exp	IR (95 % CI)	Obs	Exp	IR (95 % CI)	Obs	Exp	IR (95 % CI)
All injury									
Spring	6,053	5,960	1.02 (0.99–1.04)	4,114	4,055	1.01 (0.99–1.04)	1,939	1,905	1.02 (0.97–1.06)
Summer	6,769	5,960	1.14 (1.11–1.16)	4,754	4,055	1.17 (1.14–1.20)	2,015	1,905	1.06 (1.01–1.10)
Autumn	5,681	5,895	0.96 (0.94–0.99)	3,825	4,011	0.95 (0.93–0.98)	1,856	1,884	0.99 (0.94–1.03)
Winter	5,159	5,848	0.88 (0.86–0.90)	3,406	3,979	0.86 (0.83–0.88)	1,753	1,869	0.94 (0.90–0.98)
Transport accidents									
Spring	2,183	2,200	0.99 (0.95–1.03)	1,619	1,634	0.99 (0.94–1.04)	564	565	1.00 (0.92–1.08)
Summer	2,520	2,200	1.15 (1.10–1.19)	1,882	1,634	1.15 (1.10–1.20)	638	565	1.13 (1.04–1.21)
Autumn	2,302	2,176	1.06 (1.02–1.10)	1,709	1,616	1.06 (1.01–1.11)	593	559	1.06 (0.98–1.14)
Winter	1,728	2,158	0.80 (0.76–0.84)	1,278	1,603	0.80 (0.75–0.84)	450	555	0.81 (0.74–0.89)
Drowning									
Spring	427	553	0.77 (0.70–0.84)	291	412	0.71 (0.63–0.79)	136	142	0.96 (0.80–1.12)
Summer	1,105	553	2.00 (1.88–2.11)	906	412	2.20 (2.06–2.34)	199	142	1.41 (1.21–1.60)
Autumn	376	547	0.69 (0.62–0.76)	255	407	0.63 (0.55–0.70)	121	140	0.86 (0.71–1.02)
Winter	288	543	0.53 (0.47–0.59)	182	404	0.45 (0.39–0.52)	106	139	0.76 (0.62–0.91)
Suffocation									
Spring	570	530	1.08 (0.99–1.16)	367	320	1.15 (1.03–1.26)	203	211	0.96 (0.83–1.10)
Summer	462	530	0.87 (0.79–0.95)	267	320	0.84 (0.74–0.94)	195	211	0.93 (0.80–1.06)
Autumn	488	524	0.93 (0.85–1.01)	299	316	0.95 (0.84–1.05)	189	208	0.91 (0.78–1.04)
Winter	585	520	1.12 (1.03–1.21)	336	314	1.07 (0.96–1.19)	249	207	1.21 (1.06–1.35)
Suicide									
Spring	1,617	1,481	1.09 (1.04–1.14)	1,055	957	1.10 (1.04–1.17)	562	524	1.07 (0.99–1.16)
Summer	1,479	1,481	1.00 (0.95–1.05)	943	957	0.99 (0.92–1.05)	536	524	1.02 (0.94–1.11)
Autumn	1,462	1,465	1.00 (0.95–1.05)	939	947	0.99 (0.93–1.05)	523	518	1.01 (0.92–1.09)
Winter	1,322	1,453	0.91 (0.86–0.96)	863	939	0.92 (0.86–0.98)	459	514	0.89 (0.81–0.97)
Homicide									
Spring	289	277	1.04 (0.92–1.16)	165	154	1.07 (0.91–1.23)	124	123	1.01 (0.83–1.18)
Summer	287	277	1.03 (0.92–1.15)	153	154	0.99 (0.84–1.15)	134	123	1.09 (0.90–1.27)
Autumn	257	274	0.94 (0.82–1.05)	146	152	0.96 (0.80–1.11)	111	122	0.91 (0.74–1.08)
Winter	268	272	0.98 (0.87–1.10)	148	151	0.98 (0.82–1.14)	120	121	0.99 (0.82–1.17)
Undetermined									
Spring	268	232	1.16 (1.02–1.29)	171	137	1.25 (1.06–1.44)	97	95	1.02 (0.82–1.22)
Summer	222	232	0.96 (0.83–1.08)	145	137	1.06 (0.89–1.23)	77	95	0.81 (0.63–0.99)
Autumn	207	229	0.90 (0.78–1.03)	102	135	0.75 (0.61–0.90)	105	94	1.12 (0.90–1.33)
Winter	223	227	0.98 (0.85–1.11)	125	134	0.93 (0.77–1.09)	98	93	1.05 (0.84–1.26)

Spring: March–May, Summer: June–August, Autumn: September–November, Winter: December–February

Obs observed, *Exp* expected, *CI* confidence interval, *IR* incidence ratio, the observed number of injury deaths divided by the expected number of deaths assuming the null hypothesis of no seasonality is true

Unintentional injuries (or accidents) constituted 65.3 % of all injury deaths with transport accidents, followed by drowning and suffocation being the main causes of this form of death among children younger than 20 years of age in Japan, although the relative contribution of each cause varied between the age groups which corresponds with the

findings from previous studies undertaken in Canada and the European region [9, 13, 14]. A seasonal trend was observed for all injury mortality, and for unintentional injury mortality, especially among boys (Fig. 1). The finding that injury deaths are more likely to happen in summer in Japan corresponds with the findings from an

Italian study where, for children aged 1–13 years, there were more hospital injury cases in summer compared to winter in 2000–2009. This was linked to the fact that not only were children more likely to engage in a greater range of activities for longer periods of time in summer, but also that some of these activities might be riskier and thus increase the possibility of injury [15].

The summer peak in injury mortality in Japanese children and adolescents aged 0–19 years contrasts, however, with the finding of an earlier study from Canada which showed that there was an autumn peak in school injuries among children aged 5–19 years in 2002. In that study, the higher level of mortality in autumn was attributed to it being the most suitable season to undertake activities in school playgrounds in Canada [16]. In Japan, however, activities for children such as swimming in rivers and the sea or going on trips and school outings tend to mostly occur in summer [17] which might increase the subsequent risk of injury and possible death. Excessive sports activity in summer in Japan has also been previously linked to child mortality as a result of heatstroke [18].

About one-third of all injury deaths were from transport accidents (8,733/23,662), which is similar to in Europe where transport accidents are the single largest cause of childhood deaths among children aged 1–14 years [8]. However, transport accident mortality among children and adolescents in Japan is comparatively low when compared to that in some other countries in Europe. Transport accident mortality among Lithuanian adolescents aged 15–19 years in 2003–2005 for example, was about 3 times higher than among Japanese adolescents in the same age range in the current study [19]. We found that there was significant seasonal variation in transport accident mortality with a comparatively high risk of mortality in summer. Research suggests that most of these deaths will come in the form of injuries to pedestrians and cyclists, which constituted more than 76 % of transport accident deaths among children under 15 years old in Japan in 2009 [3]. If this summer excess does principally concern pedestrians then our results correspond with those from an earlier study from the USA where the risk of pedestrian injury among urban children aged 5–14 years was higher in summer [20]. Although it is uncertain what specific factors underlie this upsurge in transport accident mortality in summer, it can be speculated that it might be due to a combination of factors, including the possibility that there may be more cars on the road, that children spend more time on or around roads and/or engage in riskier behaviours when there. Irrespective of the particular causes, these findings suggest that emergency systems that deal with paediatric injuries should be strengthened during the summer vacation period so that injury mortality from various road-centred summer activities can be better prevented.

A total of 2,196 Japanese children younger than 20 years old died as a result of drowning in 2000–2010. Based on WHO health statistics in 2005, the drowning death rate among children aged 0–14 years in Japan was 4.7 times higher than the average of 13 developed countries [4]. As with the current study, an earlier study which looked at drowning among Japanese children aged 0–14 years in 1991 also found that children and adolescents were more likely to drown in summer [21]. This might be related to the fact that children and adolescents are more likely to play in rivers or the sea during the summer vacation, and that rivers in Japan are fast flowing [22, 23]. Indeed, previous research has shown that drowning deaths among school students in Japan occur overwhelmingly in rivers and in the sea but rarely in swimming pools [22, 23]. The large mortality ratio (2.20) that we found for boys suggests that risk behaviour around water might be especially prevalent in this group in the summer. Having said this, a recent study reported that about 40 % of accidental drowning deaths among children aged under 15 years old in 2009 had occurred in bath tubs [3], which also accords with the results from earlier studies in Japan [21, 22]. However, despite the large proportion of bath tub deaths that seemingly occur across all seasons, it is not clear if this type of mortality contributed to the surge of drowning deaths during the summer months. It does emphasize, however, that parental monitoring of children's bathing might be one way of preventing home injuries such as infant drowning as was shown in a recent study [24].

More than half of all deaths among those aged less than 1 year old were due to suffocation, which accords with the finding from an earlier study that focused on Estonian infants [13]. Inhalation of gastric contents and ingestion of food causing obstruction of the respiratory tract were the main causes of suffocation among infants and young children in Japan in 2011 [25]. Suffocation deaths were less likely to happen in summer than in spring and winter. The specific mechanisms underpinning this seasonal variability have yet to be determined. Previous studies in other settings have shown, however, that mother–infant bed sharing can sometimes occur due to cold conditions, breastfeeding or where children are ill [26, 27], while a study from Japan highlighted that mother–infant bed sharing is sometimes associated with infant suffocation during sleep [28]. Given this, it can be hypothesized that bed sharing due to these factors may be more common in winter and thus be linked to an increased risk of infant mortality from accidental smothering, although further research employing both quantitative and qualitative methods will be needed to confirm this supposition.

The annual average suicide mortality rate among Japanese children and adolescents was 1.0 per 100,000 for those aged 10–14 years old and 7.3 for 15–19 year olds in

2000–2010. Hanging and jumping from high places and in front of moving objects constituted about 90 % of all suicide deaths among children aged 10–19 years in 2003 [29, 30]. The high proportion of jumping deaths in this age range might highlight the impulsive nature of these deaths which have been linked to phenomena such as school bullying [30]. Children and adolescents were more likely to commit suicide in spring than in winter. This “spring peak” in young people’s suicide corresponds with that seen in the general Japanese population [7, 31]. Indeed, worse mood in spring, i.e., ‘spring blues’, has been reported among the Japanese population since the 1950s [31–34]. Among adolescents these spring blues might emanate from seasonal events such as the start of the academic year and ‘exam hell’ which have been previously linked to adolescent suicide [35]. The detrimental effects from the stress of these events might also be exacerbated by the fact that young people are in a developmentally sensitive stage of life and can easily be affected negatively by a variety of social and psychological factors [29, 36].

There are a couple of limitations that should be considered when interpreting the results of this study. First, due to the small numbers for some causes of death, we used seasons rather than months as the time unit of analysis. Although annual average mortality for 11 years is acceptable to test seasonal variations statistically, for some causes of death seasonal numbers were still small, especially for girls. Second, the coverage and accuracy of the registration of injury deaths might be another limitation. Previous studies in other settings have highlighted how there is misclassification of injury deaths and an underestimation of intentional deaths among infants [8, 13]. This might also be a problem in Japan as there was a high mortality rate for deaths of undetermined intent among infants (1.5 per 100,000) in the current study.

This study examined the seasonality of child and adolescent injury mortality in Japan in 2000–2010. It showed that injury mortality resulting from transport accidents, drowning, suffocation and suicide had a significant seasonality. Given this, more research is now needed to find the exact circumstances that underpin different forms of injury mortality at different time points in the year, so that specific interventions can be designed and implemented to reduce the burden of child and adolescent injury mortality in Japan. As a more general first step, however, public health campaigns to educate both parents and children about the dangers of childhood injury and how different types of fatal injury are more likely to occur at different times of the year might be important in helping to modify/reduce children’s engagement in some forms of risk behaviour (e.g., summer swimming in fast-flowing streams) and thus lower the overall level of childhood injury mortality in Japan.

Acknowledgments This study was a part of the project entitled Development of a Seamless Chemical Assimilation System and its Application for Atmospheric Environmental Materials (SALSA). The views expressed in this article are those of the authors and do not necessarily represent the views and policies of the funding organizations.

Conflict of interest None of the authors had any conflicts of interest.

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