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Original Research

All-cause mortality and suicide after pediatric traumatic brain injury: a 20-year nationwide study in Finland

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ABSTRACT

Objectives: To assess all-cause mortality and suicides after pediatric traumatic brain injury (pTBI).
Study design: We conducted population-based historical cohort study using three nationwide registers from 1998 to 2018 in Finland. All patients that were the age of 0–17 at the time of the pTBI were included. The reference group consisted of children with ankle or wrist fractures. We used Kaplan–Meier and restricted mean survival time (RMST) analysis with 95% confidence intervals (CI) to compare all-cause mortality and suicides between groups.
Results: After 20 years of follow-up, there were 479 deaths in the pTBI group (0.67% of 71,963) and 306 deaths in the reference group (0.47% of 64,848). In the pTBI group, 28.6% of the deaths occurred after the first follow-up year, compared to 2.6% in the reference group. In all-cause mortality, survival time was slightly less in the pTBI group with age and gender adjustment throughout the follow-up period [20-year RMST ratio: 0.995; CI (0.994–0.996)]. The leading manners of death were suicides (pTBI group = 28.4%; reference group = 45.5%) and traffic collisions (pTBI group = 37.4%; reference group = 20.8%). Age and gender-adjusted survival time was slightly less for those with suicide as a manner of death in the pTBI group [10-year RMST ratio: 0.999; CI (0.999–0.999); 20-year RMST ratio: 0.999; CI (0.998–0.999)].
Conclusions: Children and adolescents who sustained a TBI have slightly lower long-term survival time for all-cause mortality, most of which occurs during the first year following injury. There is no clinically meaningful difference in deaths by suicide between the two injury groups.
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Introduction

Pediatric traumatic brain injury (pTBI) is associated with considerable mortality and morbidity.[1–4] In a global review, 47 to 280 per 100,000 children experience a pTBI annually and the incidence appears to be increasing in Finland.[2,5] Most youth hospitalized for pTBIs sustain an injury classified as mild (ca. 81%).[2] PTBI is the leading cause of death for children in most high-income countries, occurring most frequently between the ages 0–2 and 15–18 years.[2] Direct mortality after pTBI varies between 2.8 and 3.8 per 100,000 children and the most common causes of pTBI are road and traffic collisions and falls.[2,6–10]

One previous study examined all-cause mortality and found that those who sustained a pTBI had a greater risk of premature death during 41 years of follow-up compared to the general population who did not sustain TBIs.[11] However, the study lacks detailed information on the mortality.[11] Some studies have reported a greater risk for suicide after TBI in all ages, and these studies speculate that the risk for suicide could arise from preinjury factors and from TBI

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predisposing to disability, anxiety, and depression, with associated increasing self-destructive thoughts and behavior.[12–15] A registry based study from Canada reported that pTBI was associated with increased risk for suicide, and the risk increased after more severe or multiple TBIs.[16] On the other hand, the risk for suicide also increased after musculoskeletal injuries, even when adjusted with pTBIs.[16] In a study of youth with moderate or severe TBIs, almost 50% of cases had unfavorable outcomes, such as lower quality of life and need for rehabilitation.[17] Pediatric TBI is associated with increased utilization of mental health services, depression, anxiety, and suicidal behavior.[18,19] In a recent study, risk for suicide attempt was greater in adolescents, 12–17 years of age, after TBI compared to general population. That study also reported more severe TBIs and multiple TBIs, female gender, younger age at the time of injury, and preinjury psychiatric conditions were associated with increased risk for suicide attempts.[20]

Detailed information on mortality after pTBI is lacking. The purpose of this study was to thoroughly examine all-cause mortality and suicide after pTBI, and the time interval between pTBI and suicide.

Methods

We conducted a population-based, historical cohort study using nationwide Finnish health registries for the study period from January 1998 to December 2018. The registries used were the Finnish Care Register for Healthcare, Population Information Register, and Cause of Death Register.[21–23] The Finnish Care Register includes information on all specialized health care (secondary and tertiary level units) visits, procedures, and hospitalizations in Finland. The register has been shown to have excellent coverage and validity.[24]

Patients

We included all pediatric (age 0–17 years) patients with emergency department (ED) visits from the Finnish Care Register. The patient group (referred to as the pTBI group) included all ED visits and hospitalizations with ICD-10 diagnostic codes referring to a TBI. A reference group was formed from children of the same age who had ED visits regarding wrist or ankle fractures. The complete list of diagnosis codes used in both groups are shown in the appendix (Appendix 1). Our hypothesis was that fracture patients would be more likely to have similar risk-taking behavior as the patients with pTBIs and that both these groups might display more risk-taking behaviors than the general population. The reference group and pTBI group were similar in size regarding the number of cases during the follow-up. If a patient experienced multiple TBIs or extremity injuries during the follow-up period, only the first injury was noted because the register does not differentiate new injuries and control visits in specialized health care. Patients that experienced both TBI and extremity injury during the follow-up were included in pTBI group.

Procedures

The data from the Finnish Care Register for Healthcare was received in May 2022, and it was gathered by the register keeper according to our request. It included all diagnose codes, sex, pseudonymized identification number, age, and date of the initial visit to the hospital. The selected exposures were visits regarding traumatic brain injury in the pTBI group and ankle/wrist fractures in the reference group. Information on emigration and immigration dates were gathered from the Statistics Finland Population Information Register. These dates were used as endpoints for the survival time analyses. The manners and time of deaths were retrieved from the Cause of Death Register, which is maintained by the Finnish Institute of Health and Welfare. This registry contains information on the date of death, and it stratifies causes of death into three categories with three possible postmortem clarification routes: direct cause of death, underlying cause of death, and contributing factors of a death.[23] According to Finnish legislation, the underlying cause of death must always be filled in the death certificate and is considered the main cause of death. We used the underlying cause of death in our analyses as an endpoint.

The pTBI group was further divided into concussions (S06.0) and 'other pTBIs' (S06.1–S06.9) to perform secondary analyses. The other pTBI group included TBIs with structural imagining findings. These secondary analyses were performed to evaluate the impact between specific and possibly more serious TBIs and concussions to all-cause mortality and suicides.

Statistical analyses

In main analyses, we used the Kaplan–Meier (K–M) method and restricted mean survival time (RMST) to estimate the association of pTBI with all-cause mortality and suicide as the manner of death and compared the results with the reference group. In secondary analyses, we used the same analytical methods to compare concussions to other pTBIs within the pTBI group. Results from secondary analyses are presented in Appendix 2 and are cited in the text as eTables and eFigures.

RMST can be interpreted as the average survival time in years of subjects at risk for an event. The RMST ratios are adjusted with age and gender, and they are presented with their 95% CIs to compare outcomes between the exposure groups. To evaluate the proportional hazards assumption, we inspected log–log plots and Schoenfeld residuals. The RMST was used instead of Cox regression because the data did not meet the proportional hazards assumption.[25] Subject follow-up ended and observations were censored either at the date of death, date of emigration, or December 31, 2018, whichever came first. To focus more on suicide, we calculated the mean with standard deviation (SD) or median with interquartile range (IQR) for the time interval from injury to suicide for both groups and for boys and girls separately. All statistical analyses were done using R version 4.0.5, with the dplyr and survival packages.[26]

Results

There were a total of 71,972 children in the pTBI group (4531 other pTBIs; 67,441 concussions) and 64,856 in the wrist and ankle fracture reference group at the beginning of the follow-up period. The median age at the time of the injury in the pTBI group was 7 years and 11 years in the reference group (Table 1). In the pTBI group, 57.7% were boys compared to 61.9% in the reference group. The most common diagnosis in the pTBI group was concussion (Table 2).

There was a total of 479 deaths in the pTBI group and 308 deaths in the reference group during the 20-year follow-up period (Table 1). Of these 479 deaths in the pTBI group, 268 were diagnosed with prior concussions and 211 with other pTBIs (eTable 1 in Appendix 2). The most frequent manner of death was suicide (n = 276, 35.1%), followed by traffic collisions (n = 243, 30.9%) (Table 3).

All-cause mortality was highest during the first year following the pTBI (Figs. 1, 2, Tables 1, 4). Of note, 30-day mortality was high in the pTBI group with 74 deaths vs 2 deaths in the reference group. In the pTBI group, 28.6% of deaths and in the reference group, 2.6% of deaths were recorded during the first year following

Table 1
Summary of findings.

Characteristic	Pediatric TBI			Ankle or wrist fractures		
	Total	Boys	Girls	Total	Boys	Girls
Total sample	71,972	41,498	30,474	64,856	40,111	24,745
Age at injury (median)	7	8	6	11	12	10
Age at injury (M, SD)	7.7, 5.5	7.9, 5.4	7.4, 5.7	10.8, 3.8	11.3, 3.7	9.9, 3.7
Total number of deaths	479	341	148	306	254	57
Age at death (median)	19.3	19.6	17.3	21.7	22.1	20.2
Age at death (M; SD)	18.6; 7.5	19.1; 7.2	17.6; 8.0	22.3; 5.6	22.6; 5.4	20.9; 6.3
% of sample that died	0.67%	0.82%	0.49%	0.47%	0.63%	0.23%
% of total deaths in first year	28.6%	25.8%	33.1%	2.6%	2.4%	3.5%
% of deaths in patients with concussion in first year	9.49%	11.4%	6.12%	NA	NA	NA
% of deaths in patients with other pTBI in first year	90.5%	88.6%	93.9%	NA	NA	NA
% of total deaths in first 5 years	44.9%	41.9%	48.6%	24.0%	21.7%	33.3%
% of deaths in patients with concussion in first 5 years	34.0%	35.7%	30.6%	NA	NA	NA
% of deaths in patients with other pTBI in first 5 years	66.0%	64.3%	69.4%	NA	NA	NA
Number with suicide as manner of death	136	100	36	140	119	21
% of cohort who completed suicide	0.19%	0.24%	0.12%	0.22%	0.30%	0.08%
% of deaths with suicide the manner of death	28.4%	29.3%	24.3%	45.5%	46.9%	36.8%
Age at time of suicide (median)	22.3	22.5	20.4	23.3	23.3	23.1
Years between injury and suicide (median)	8.2	9.1	6.3	11.2	11.6	10.8
% of total deaths by suicide in first year	6.6%	4.0%	10.2%	0%	0%	0%
% of suicides in patients with concussion in first year	11.1%	33.3%	0%	NA	NA	NA
% of suicides in patients with other pTBI in first year	88.9%	66.7%	100%	NA	NA	NA
% of total deaths by suicide in first 5 years	27.2%	22.0%	41.7%	11.4%	10.9%	14.3%
% of suicides in patients with concussion in first 5 years	73.0%	81.8%	60.0%	NA	NA	NA
% of suicides in patients with other pTBI in first 5 years	27.0%	18.2%	40.0%	NA	NA	NA

Table 2
Total number of different TBI diagnoses in the Pediatric TBI group.

Diagnosis code	*n*	Percentage of all TBI diagnosis codes
S06.0 Concussion	67,441	93.7%
S06.1 Traumatic cerebral edema	188	0.26%
S06.2 Diffuse traumatic brain injury	1209	1.68%
S06.3 Focal traumatic brain injury	774	1.08%
S06.4 Epidural hemorrhage	307	0.43%
S06.5 Traumatic subdural hemorrhage	634	0.88%
S06.6 Traumatic subdural hemorrhage	357	0.50%
S06.7 Intracranial injury and prolonged concussion	23	0.03%
S06.8 & S06.9 Other/unspecified intracranial injury	1039	1.44%
Total	71,972	

Note: TBI = traumatic brain injury.

injury (Table 1). Of these first-year deaths in the pTBI group, 90.5% were in the other pTBI group— TBIs with structural imagining findings (Table 1). In visual inspection of the K–M curve, all-cause mortality was higher during most of the 20-year follow-up period in the pTBI group (Fig. 2). Survival time was less in the pTBI group in all-cause mortality in all selected time periods in RMST-analyses (Table 4). In the age and gender-adjusted RMST-ratio analyses, the survival time of pTBI patients was lower in all selected time periods compared to the reference group, and the difference was greatest after 20 years of follow up (Table 2). In secondary analyses, all-cause mortality was higher and survival time lower in other pTBIs throughout the follow-up period in K–M curve and RMST analyses (eTable 1, eFigs. 1, 2 in Appendix 2).

At 20 years, there were 136 deaths from suicide in the pTBI group and 140 deaths from suicide in the reference group (Tables 1 and 3). Considering all youth who died, 45.5% of those in the ankle and wrist fracture group had suicide as their manner of death compared to 28.4% in the pTBI group (Table 1). Of all pTBI group suicides, 112 (82.4%) had prior concussions and 24 (17.6%) had other pTBIs (eTable 2 in Appendix 2). Up to 7 years after the injury, the cumulative suicide rate was higher in the pTBI group based on visual inspection of the K–M curve (Fig. 3). The survival time relating to suicide was less in the pTBI group than in the reference group 1 and 10 years after the injury in RMST analyses (Table 5). Survival time was less in the pTBI group 10 and 20 years after the injury in the age and gender adjusted analyses (Table 5). The effect sizes for these differences are very small. Survival times relating to suicides were lower 5–20 years after the injury in other pTBIs compared to concussions in RMST analyses (eTable 2 in Appendix 2). No notable difference was seen in survival time between concussions and other pTBIs in age and gender adjusted RMST-ratio (eTable 2 in Appendix 2).

Boys were overrepresented with suicide as a manner of death in both the pTBI group and the reference group (Table 6). In the total

Table 3
Number and manner of death.

Manner of death	Pediatric TBI	Percentage	Ankle and wrist fractures	Percentage	Total	Percentage of all deaths
Suicide	136	28.4%	140	45.5%	276	35.1%
Traffic collisions	179	37.4%	64	20.8%	243	30.9%
Disease related	64	13.4%	46	14.9%	110	14.0%
Other accidents	54	11.3%	27	8.8%	81	10.3%
Cancer	29	6.1%	16	5.2%	45	5.7%
Violent cause	11	2.3%	8	2.6%	19	2.4%
Uncertain	6	1.3%	7	2.3%	13	1.7%
Total	479		308		787	

Note: TBI = traumatic brain injury.

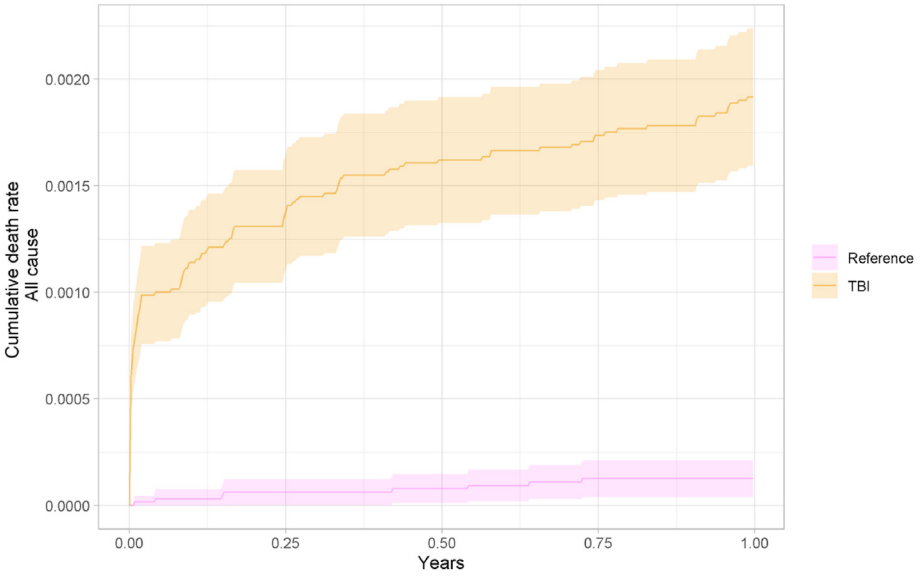

Fig. 1. Cumulative death rate for all-cause mortality between the pTBI group and the reference group (ankle and wrist fractures) during the first year after injury. pTBI, pediatric traumatic brain injury.

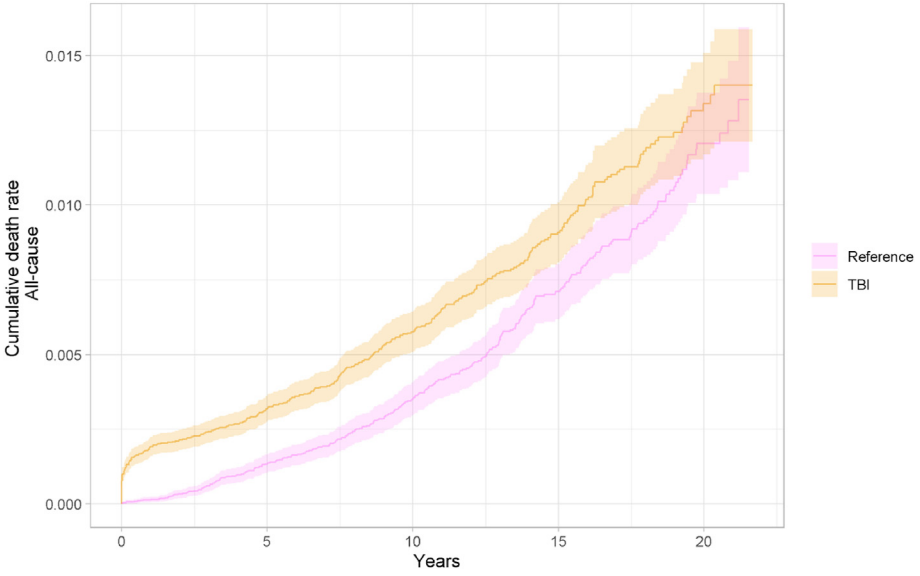

Fig. 2. Cumulative death rate for all-cause mortality between the pTBI group and the reference (ankle and wrist fractures) group for the 20-year follow-up period. pTBI, pediatric traumatic brain injury.

Table 4
All-cause mortality after pediatric traumatic brain injury.

Time	Pediatric traumatic brain injury				Ankle and wrist fractures (reference)				PTBI/reference	
	Events	At risk	RMST (years)	95% CI	Events	At risk	RMST (years)	95% CI	RMST ratio	95% CI
1 year	137	66,597	0.998	(0.998–0.999)	8	61,412	1.000	(1.000–1.000)	0.998	(0.998–0.998)
5 years	215	46,939	4.988	(4.987–4.990)	74	48,136	4.997	(4.997–4.998)	0.997	(0.997–0.998)
10 years	326	29,611	9.964	(9.960–9.969)	160	33,263	9.986	(9.983–9.988)	0.997	(0.996–0.997)
20 years	479	3961	19.858	(19.845–19.871)	308	4575	19.912	(19.903–19.922)	0.995	(0.994–0.996)

Note: Restricted mean survival time estimated in years and RMST ratio with age and gender adjustment with 95% confidence intervals in selected time periods. Ankle and wrist fracture patients as reference group. RMST = Restricted mean survival time. Events refer to the number of deaths. CI = confidence interval. PTBI = pediatric traumatic brain injury.

sample, as well as in the subgroups of boys and girls, the mean age at the time of injury was higher in the pTBI group, but the mean age at the time of suicide was lower (Table 6). The time interval between the injury and suicide was also shorter in the pTBI group than the reference group in the total sample and in boys and girls (Table 6). The difference was more notable in girls (Table 6). When

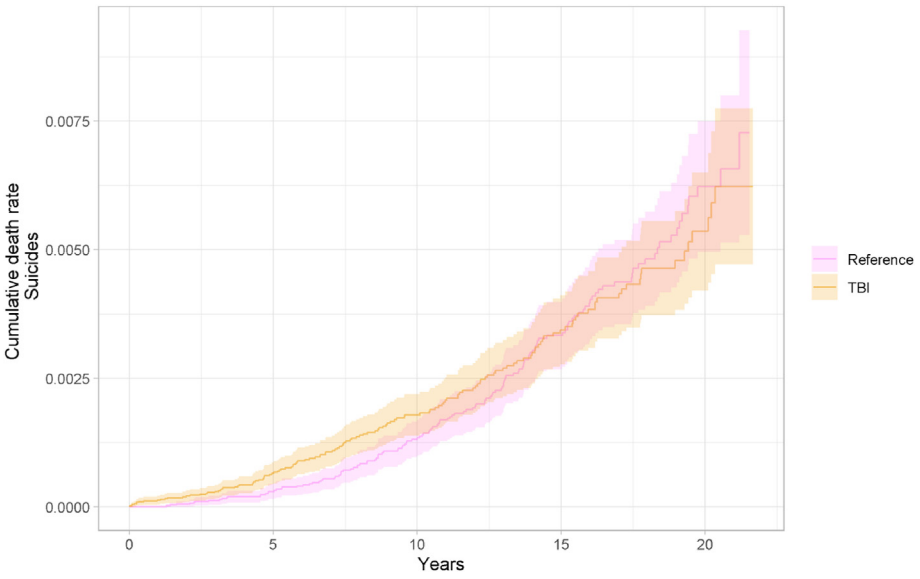

Fig. 3. Cumulative death rate by suicide during the 20-year follow-up period between the pTBI group and the reference (ankle and wrist fractures) group. pTBI, pediatric traumatic brain injury.

Table 5
Suicides after pediatric traumatic brain injury.

Time	Pediatric traumatic brain injury				Ankle and wrist fractures (Reference)				PTBI/Reference	
	Suicides	At risk	RMST (years)	95% CI	Suicides	At risk	RMST (years)	95% CI	RMST ratio	95% CI
1 year	9	66,597	0.999	(0.999–0.999)	0	61,412	1.000	(1.000–1.000)	1.000	(1.000–1.000)
5 years	37	46,939	4.999	(4.998–4.999)	16	48,136	4.999	(4.999–5.000)	1.000	(0.999–1.000)
10 years	80	29,611	9.992	(9.991–9.994)	57	33,263	9.996	(9.995–9.997)	0.999	(0.999–0.999)
20 years	136	3961	19.958	(19.951–19.965)	140	4575	19.961	(19.954–19.968)	0.999	(0.998–0.999)

Note: Restricted mean survival time estimated in years and RMST ratio with age and gender adjustment with 95% confidence intervals in selected time periods. Ankle and wrist fracture patients as reference group. RMST = Restricted mean survival time. CI = confidence interval. PTBI = pediatric traumatic brain injury.

Table 6
Comparing groups on age at the time of injury, age at the time of suicide, and time interval between injury and suicide.

	Pediatric TBI						Ankle and wrist fractures					
	n	M	Md	SD	IQR	Range	*n*	M	Md	SD	IQR	Range
Total sample	136						140					
Age at injury		13.5	15.0	3.9	12.8–16.0	0.0–17.0		13.0	14.0	2.9	11.0–15.0	4.0–17.0
Age at suicide		22.3	22.3	4.6	19.3–25.1	13.6–33.8		24.0	23.3	4.8	20.4–27.6	13.4–36.1
Interval between injury and suicide		8.8	8.2	5.2	4.7–12.8	0.1–19.6		11.0	11.2	4.6	7.8–14.2	1.3–19.5
Boys	100						119					
Age at injury		13.4	14.5	3.9	11.8–16.0	2.0–17.0		13.0	13.0	3.0	11.0–15.0	4.0–17.0
Age at suicide		22.9	22.5	4.3	19.7–25.4	14.1–33.8		24.1	23.3	4.9	20.6–27.9	13.4–36.1
Interval between injury and suicide		9.7	9.1	5.0	5.3–14.0	0.1–19.6		11.2	11.6	4.7	7.9–14.4	1.4–19.8
Girls	36						21					
Age at injury		14.0	15.0	3.9	13.0–16.0	0.0–17.0		13.1	14.0	2.5	12.0–15.0	7.0–16.0
Age at suicide		20.6	20.4	4.0	17.3–22.8	13.6–28.9		23.4	23.1	4.5	19.7–25.6	15.6–32.5
Interval between injury and suicide		6.6	6.3	4.9	2.4–9.8	0.1–17.7		10.2	10.8	4.3	6.7–13.3	1.3–17.5

Note: The mean (M), median (Md), standard deviation (SD), and interquartile range (IQR) for age at injury, age at suicide, and the time-interval in years from injury to suicide for both groups as well as for boys and girls separately are presented. Note: TBI = traumatic brain injury.

comparing boys and girls, girls were, on average, older in both the pTBI and the reference groups at the time of the injury, but were younger at the time of suicide, and the time interval between the injury and suicide was shorter (Table 6).

Discussion

Children and adolescents who sustained a TBI have slightly lower long-term survival time for all-cause mortality, most of which occurs during the first year following injury, yet the small findings extended through the 20-year observation period. Suicide was a rare event in both groups. Pediatric TBI was associated with slightly higher cumulative rates of suicide as a manner of death up to 7 years after the injury. However, the effect sizes were negligible. The time interval between injury and suicide was slightly shorter in the pTBI group. Overall, boys were more likely to have suicide as a manner of death than girls.

A Swedish cohort study from 2016, where the population was slightly older (0–26 years of age), reported that TBI was associated with increased risk for premature mortality compared to people without TBI during a 41-year follow-up period. The risk for premature death increased as age of injury increased as well as with

multiple TBIs.[11] We had similar results, with pTBI being associated with a small greater risk for premature all-cause mortality. Our reference group consisted of people who had suffered an ankle or wrist fracture instead of the general population, so our groups are likely more similar in their risk-taking behavior and in their reasons for going to the emergency department, such as accidents. Importantly, however, the greater mortality in our study is mostly attributable to differences in deaths occurring in the initial weeks and months following injury.

The death rate was higher immediately after the injury in the pTBI group in all-cause mortality. Within the first 30 days, the mortality was substantially greater than in the reference group. This greater mortality might be due to cases with more severe TBIs who died within days or weeks of injury.[27] In the pTBI group, a notable amount of the deaths occurred during the first year following injury compared to the extremity injury group. Most of these deaths occurred to children/adolescents with specific brain injury diagnosis. This indicates that most people who died during the first year had moderate or severe pTBIs. The increase could be caused from severe pTBI itself or additional injuries and medical problems associated with the incident in which the pTBI occurred. Most severe pTBIs likely happen as a result of high impact collisions such as traffic collisions, falls, and violence.[2] These high-impact injury mechanisms are likely to cause additional injuries, such as visceral injuries that could have a major impact on survival rate during the first few days and months after the injury.[28–30] According to Statistics Finland, all-cause mortality in people aged 0–30 years is highest at age 0 and lowest at ages 1 to 17.[31] People in the pTBI group were on average 3.1 years younger than the reference group at the time of the injury. Along with the fact that a considerable portion of the deaths occurred during the first months after the initial injury, this indicates that there were more deaths at 0–1 years of age in the pTBI group than the reference group.

When analyses were adjusted with age and gender, mean survival time was slightly lower with suicide as a manner of death in the pTBI group than the reference group 10 and 20 years after the injury. Other published studies have reported that pTBI is associated with an increased risk for suicide.[16,20] The risk seems to increase as the severity of the pTBI has increased.[16] In our secondary analysis, there were no differences in suicide rate between other/specific, possibly more severe, pTBIs than concussions. Overall, the risk estimates generated in our study are extremely small and not practically meaningful. Considering the entire cohorts, at 20 years, there were slightly more suicide-related deaths in the fracture group than in the pTBI group, and considering all youth who died, a greater proportion in the fracture group had suicide as their manner of death compared to the pTBI group.

We found that the time interval between injury and suicide was shorter in the pTBI group than in the reference group, and this has also been reported in a recent study.[20] The girls were, on average, somewhat older than boys at the time of the injury, but their time interval between injury and suicide was shorter than in boys. According to Statistics Finland, suicides are rare in children 0–14 years old, and they get increasingly more common after the age of 15–19.[32] The majority who died by suicide were boys and young men. In the pTBI group, about 27% of the deaths by suicide occurred in the first 5 years following injury, compared to 11% of the deaths in the fracture group occurring during the same period. In general, suicide ideation and attempts are more common in girls and young women, but the completion of suicide is more common in boys and young men, which is supported by our study.[33]

A Swedish nation-wide cohort study reported that pTBI was associated with lower education, welfare recipiency, and psychiatric disorders, all of which might contribute to the increase in premature mortality and possible suicidal behavior after pTBI.[11] There is an extensive literature relating to factors that are associated with suicidality and suicide during childhood and adolescence in youth from the general population, and none of these factors could be considered or adjusted for in our study. Childhood adversity (such as abuse, neglect, and family violence) is associated with greater overall mortality and increased risk for suicide.[34] Having a parent commit suicide is associated with greater risk for suicide.[35] Many factors are also associated with suicidal ideation or attempts in youth and young adults, such as (i) mental disorders, including depression and anxiety; (ii) sexual abuse, physical abuse, emotional abuse, emotional neglect, and physical neglect; (iii) cannabis smoking; (iv) bullying; (v) identifying as gay, lesbian, or bisexual; (vi) stressful life events; and (vii) legal problems.[33,36–43] Among adolescents and young adults who are hospitalized for a mental health disorder, predictors of suicide attempts included having a depressive disorder, being the victim of bullying, family history of suicide, emotional traumas, and other traumatic experiences.[44]

Strengths and limitations

A major strength of our study is that it is population-based and includes all hospitalized, incident cases of pTBI in Finland. The included registers are excellent in coverage, and the quality of these registers has been shown to be consistently high.[24] The ICD-10 classification has stayed similar in Finland throughout the study period, and the frequency of using these codes in registers is excellent. Our cohorts are large and that is reflected in our narrow confidence intervals. Weaknesses in our study are the lack of detailed pTBI characteristics as well as the lack of preinjury medical history. Follow-up times varied in both groups because the occurrence of injuries spans throughout the follow-up period and only a small portion of patients in both groups were followed for 20 years. We also could not reliably identify people with multiple TBIs. The RMST ratios were adjusted for age and gender, but we were not able to adjust for any other confounding factors such as preinjury medical history in general or psychiatric comorbidities. We had no reliable information on possible additional injuries in the pTBI group that could have had an impact on their survival. It is also possible that there were a few cases that sustained severe TBIs during a suicide attempt, died within days or weeks, and then were coded as having suicide as a manner of death. It is not possible using the registries to reliably determine if there were such cases.

Conclusion

Patients who suffered a pTBI had greater one-year all-cause mortality rates, and survival time stayed lower in the pTBI group than reference group through the follow-up period in age and gender-adjusted analysis. Those who sustained a pTBI had a slightly lower survival time for suicide as a manner of death in age and gender-adjusted RMST-ratios at 10 and 20 years after the TBI. However, our risk estimates are small. There was no clinically meaningful difference in suicide-related mortality between those who sustained pTBIs and those who sustained ankle and wrist fractures. There is a need for more population-based, incident cohort studies with good control of potential confounding factors to quantify or refute this risk.

Author statements

Ethical approval

According to the Finnish research legislation, ethical committee evaluation is not required for register-based retrospective studies. We received permission to access the Care Register for Health Care

from Findata (the Finnish data authority; permission number: THL/2058/14.02.00/2020). Permission to use Population Information Register and Cause of Death Register was acquired from Statistics Finland (Permission number: TK/380/07.03.00/2020). Pseudonymized register-based retrospective studies do not require written or oral informed consent from participants in Finland.

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Competing interests

Grant Iverson, PhD serves as a scientific advisor for NanoDX®, Sway Operations, LLC, and Highmark, Inc. He has a clinical and consulting practice in forensic neuropsychology, including expert testimony, involving individuals who have sustained mild TBIs, and on the topic of suicide. He has received past research support or funding from several test publishing companies, including ImPACT Applications, Inc., CNS Vital Signs, and Psychological Assessment Resources (PAR, Inc.). He has received research funding as a principal investigator from the National Football League, and subcontract grant funding as a collaborator from the Harvard Integrated Program to Protect and Improve the Health of National Football League Players Association Members. He has received research funding from the Wounded Warrior Project™. He acknowledges unrestricted philanthropic support from ImPACT Applications, Inc., the Mooney-Reed Charitable Foundation, the National Rugby League, Boston Bolts, and the Schoen Adams Research Institute at Spaulding Rehabilitation. J. David Cassidy, PhD, DrMedSc has provided expert testimony on the long-term effects of sports concussions for the National Hockey League (Canada and USA) and the National Collegiate Athletic Association (USA). He has also received grants from various stakeholders and agencies in Canada, the USA, Sweden, and Denmark to study prognosis after traffic injuries, including MT.

Availability of data and materials

Due to the law of secondary use of patient information in Finland, none of our data can be made available for researchers living outside of Finland. Finnish researchers can access the data by applying permission to access the Care Register for Health Care from Findata.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2024.07.025.

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