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Associations between alcohol intake and hospital contacts due to alcohol and unintentional injuries in 71,025 Danish adolescents – a prospective cohort study

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Summary

Background Alcohol is a leading risk factor to adolescent health. However, it is unclear how associations between alcohol intake and injuries are shaped. We investigated the dose–response relationship between alcohol intake and risk of hospital contacts due to alcohol and unintentional injuries in adolescents.

Methods We conducted a prospective cohort study including 71,025 Danish students aged 15–24 years, followed up for five years from 2014 to 2019. The main outcome measures were hospital contacts due to alcohol and unintentional injuries (all injuries and head injuries), obtained from hospital registers.

Findings Approximately 90% of males and females reported drinking alcohol, and the median intake among those was 11 drinks/week in males and 8 drinks/week in females. During five years of follow-up, 1·3% had an alcohol-attributable hospital contact, the majority of which were due to acute intoxication (70%). Alcohol-attributable hospital contacts were equally frequent in males and females and between age groups (15–17-year-olds vs 18–24-year-olds). Compared with never drinking, the adjusted incidence rate ratios for weekly intake of <7, 7–13, 14–20, 21–27, and >27 drinks/week were 1.70 (95% confidence interval 1.23–2.34), 1.77 (1.27–2.46), 1.91 (1.35–2.70), 2.34 (1.59–3.46), and 3.25 (2.27–4.64) for having an alcohol-attributable hospital contact within five years of follow-up. Restricting follow-up to one year more than doubled risk estimates. During the five years of follow-up, 27% incurred an unintentional injury. The most frequent types of injury were to the wrist or hand (27.6%), ankle or foot (25.2%), or head (12.4%). Injuries were more frequent among males (first-time incidence rate 110 per 1000 person-years) compared to females (82 per 1000 person-years), with no differences between age groups. Compared with never drinking, the adjusted incidence rate ratios for weekly intake of <7, 7–13, 14–20, 21–27, and >27 drinks were 1.09 (1.03–1.15), 1.14 (1.07–1.20), 1.25 (1.17–1.33), 1.38 (1.28–1.49), and 1.58 (1.47–1.69) for having a hospital contact for any type of unintentional injury within five years of follow-up. Results for the one-year follow-up period were comparable. Separate analysis for head injuries showed similar results as the analysis on all injuries. Results were generally similar in males and females.

Interpretation Adolescents' drinking is associated with a higher risk of acute harm in terms of hospital contacts due to alcohol and unintentional injuries in a dose–response relationship. Thus, increased risk was apparent in those with low alcohol intake, suggesting a need for awareness of and initiatives to prevent youth drinking. Furthermore, initiatives should include a strengthened focus on people younger than 18 years.

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Keywords: Alcohol-attributable hospital contacts; Injuries; Intoxication; Adolescent health; Alcohol

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Research in context

Evidence before this study

We conducted an elaborate literature review in PubMed, with no language restrictions, on 15 June 2022, using the search terms: (adolescents OR youth OR young adults) AND (injury) AND (alcohol OR drinking). We identified articles assessing adolescents' alcohol intake and associated injuries. Cross-sectional and retrospective studies have shown that alcohol intake in adolescence is associated with a higher risk of unintentional injuries and poisonings. However, current evidence is based on self-reported information on injuries, implying the possibility of recall bias, and clinical studies on adolescents who are already injured, which prohibits risk assessment. Furthermore, it is unclear how associations are shaped.

Added value of this study

Our analysis was based on data from The Danish National Youth Study 2014, which is a large cohort of young people (n = 75,853). Undertaking a prospective study design using hospital register data, we found that alcohol intake is associated with hospital contacts due to alcohol and unintentional injuries in a dose-dependent shaped relationship.

Implications of all the available evidence

Since associations reflected a dose-dependent relationship in this study, all levels of alcohol intake were associated with heightened risk, adding important nuance to the existing body of evidence regarding alcohol-related harm in adolescents.

Introduction

In 2019, injuries were responsible for 4.3 million deaths worldwide and represented 11.0% (10.2–11.6) of healthy life lost due to disability.[1] Among young people aged 10–24 years, unintentional injury is the second leading cause of death and disability, and alcohol has been pointed out as a critical risk factor.[2] Alcohol causes impaired motor skills, poor balance, loss of inhibitions and increased willingness to take risks,[3–5] putting young people at risk of unintentional injuries, violence, and self-harm. Furthermore, heavy drinking episodes cause high blood alcohol concentrations (BAC) and subsequent poisonings and hospital contacts.[6–9] Yet drinking alcohol at parties is an established social norm among many young people in Western countries, and binge drinking with the main purpose of intoxication is a widespread behaviour, not confined to a limited group of adolescents.[10,11] In retrospective studies, current alcohol use,[12–16] alcohol use frequency,[12,13,17] and binge drinking[14–16] have been estimated to increase the odds of self-reported injuries (OR = 1.10–6.0). However, self-reported data on poisonings and injuries may lead to recall bias, and it has been argued that differences in perception between genders, driven by social norms, and willingness to take risks may cause under-reporting.[16,18,19] Alcohol use in adolescence has been associated with injury severity in clinical studies involving young patients admitted to the hospital.[20,21] Further, dose-dependent associations between acute alcohol intake and injuries have been repeatedly established in adults using various statistical approaches.[22–25] Whereas adults are at risk of illness due to accumulating alcohol intake over time, adolescents are more prone to experiencing acute negative consequences, which is why studies on adolescents are needed. Additionally, surrounding factors characterising adolescence such as hormonal changes, maturing of the brain, risky behaviour, and parental involvement may influence the risk curve.[26,27] The extent to which adolescents' drinking behaviour affects the risk of acute harm has not previously been quantified in cohort studies using hospital registries. The alcohol culture among Danish youth is characterised by heavy episodic drinking,[11] thus weekly alcohol intake relates to intoxication, to an extent. Nevertheless, it is important for prevention strategies to investigate the influence of general drinking habits, as estimated by average weekly alcohol intake, on injury risk as a supplement to the current knowledge because it helps defining risk groups and provides an estimate of the burden resulting from alcohol at the population level.[25] Furthermore, it is unclear how associations between alcohol intake in adolescents and risk of hospital contacts due to alcohol and unintentional injuries are shaped, and whether there is a threshold under which the amount of alcohol is not associated with higher risk than abstention from alcohol.

We hypothesised that weekly alcohol intake (drinks per week) among 15–24-year-olds is associated with increased risk of acute harm in terms of hospital contacts due to alcohol and unintentional injuries. Furthermore, we investigated how associations are shaped, as it is still unknown to what extent each increase in alcohol intake affects the risk of acute harm.

Methods

We undertook a prospective cohort study by linking information on 71,025 adolescents from the Danish National Youth Study 2014[28] to information on hospital contacts from the Danish National Patient Register[29] for up to five years after baseline using personal identification numbers. The design is explained in detail below.

Data sources

The Danish National Youth Study 2014 (DNYS) is a web-based survey with data collected through self-completed questionnaires. Data collection took place from

September to December 2014 at Danish high schools and from January to December 2014 at Danish vocational schools. A total of 75,853 students participated. All high schools in Denmark were invited to participate (n = 137), of which 87% participated (n = 119). Of the invited high school classes (n = 137), 96% consented to participate, and 85% of the invited students participated. Ten out of 12 invited vocational schools agreed to participate (corresponding to 83%), and (n = 5179) 69% of the invited students participated. DNYS is considered representative of Danish high school students and is described in more detail elsewhere.[28] Generally, students were between 15 and 20 years old, but students aged 15–25 years were encouraged to participate. Since we wanted to study the youth population, we excluded participants younger than 15 years old and older than 24 years old (n = 959). Three thousand seven hundred and ninety-three students were excluded due to missing personal identification numbers, and 76 students were excluded due to lack of information on alcohol intake at baseline. The final study population consisted of 71,025 students (see Supplementary Figure S1 for flow diagram).

The Danish National Patient Register (NPR) contains information on all contacts with Danish public hospitals, including emergency departments and outpatient contacts.[29] The NPR is complete with regard to conditions requiring hospital encounter and the validity (positive predictive value) has been estimated to be 73–83% with variations between clinical specialties.[30] Denmark is a welfare society that offers free access to high-quality welfare benefits, encompassing medical services at all levels. When a patient is referred to the hospital, it is mandatory for the hospital to report the reason for contact in the event of injury resulting from accident, act of violence, or intentional self-harm. In addition, the primary clinical condition is registered as an action diagnosis (A-diagnosis), while any secondary diagnosis is registered as a B-diagnosis.

Variables

Key predictor

Students who reported never drinking alcohol on weekdays and weekends were categorised as "Never drinkers" (reference). The remaining participants were characterised based on the question of how many alcoholic drinks they normally drank each day during a typical week. A standard alcoholic drink was defined as containing 12 g of pure alcohol. A weekly alcohol intake score was calculated using the sum of alcoholic drinks consumed on each day of the week and categorised into the following groups: <7 drinks, 7–13 drinks, 14–20 drinks, 21–27 drinks, and >27 drinks.

Outcomes

The outcomes were: 1) alcohol-attributable hospital contacts; 2) unintentional injuries; and 3) unintentional head injuries specifically. Both A and B diagnostic codes were included. If a hospital contact was registered with both an A-diagnosis and a B-diagnosis representing one of the outcome variables, the A-diagnosis was prioritised. *Alcohol-attributable hospital contact* was defined by admissions wholly attributable to alcohol and included one of the following diagnostic codes registered as A or B diagnosis: DE24.4, DE51.2, DE52.9A, DF10, DG31.2, DG62.1, DG72.1, DI42.6, DI85.0, DI85.9, DK29.2, DK70, DK71.1B, DK85.2, DK86.0, DR78.0, DT50.0A, DT51, DZ72.1, KJCA20, or KJCA22. *Unintentional injury* was defined as a contact registered as an accident (EUN2) that had an additional diagnostic code of injury, poisoning, or other selected consequences of external causes registered (DS00–DT98). These codes have been used in similar studies.[18] In this way, we included unintentional injuries alone. Injuries due to medical treatment and complications were excluded (DT36–DT50, DT79, DT80–DT89, and DT90–DT98). *Head injury* was defined as any injury to the head in ICD 10 (DS00–DS09) due to an accident (EUN2). Supplementary Table S1 lists all ICD-10 codes included in the study. As noted later in the discussion, this study does not consider whether the injury was acquired under the influence of alcohol, as we did not have access to the medical journals.

Covariates

All models were adjusted for age (continuous), sex (male/female), perceived ethnicity (Danish/Danish and other/other ethnicities than Danish), school type (vocational school/upper secondary school leaving examination/higher preparatory examination course), school year (first/second/third), and parental level of education (elementary/short/medium/long). The full model was further adjusted by cohabitation (living with both parents/one parent/other) and smoking status (every day/sometimes/never). All covariate variables were obtained from the baseline survey except for parents' highest attained educational level, which was obtained through linkage with the Population Education Register.[31] Statistics Denmark reports 0–3% misclassification in the Population Education Register and 96% of the Danish population have non-missing education information.[31] Information on income for the sensitivity analysis was obtained from the Income Statistics Register which is generally of high quality as the information comes from administrative registers.[32]

Ethics statement

Participants gave informed consent before taking part. This study did not require research ethics approval but lives up to the highest standard for ethical research.

Statistical analysis

STATA version 16 was used to perform all analyses. Descriptive statistics were conducted to illustrate the characteristics of the participants. These analyses included frequencies, proportions, and medians.

Poisson regression was used to assess incidence rates and incidence rate ratios of first-time hospital contacts due to alcohol, unintentional injuries, and head injuries, respectively. Each person was followed from the date of participation in the baseline survey in 2014 to the occurrence of the outcome in question, emigration, death, or end of follow-up (approximately five years after baseline, being March 1, 2019). The individual risk time was incorporated in the Poisson analysis using an offset. Information on death and emigration was retrieved from the Danish Civil Registration System which holds information on all permanent residents in Denmark and Greenland. Registration in the Danish Civil Registration System is required by law and vital status is updated continuously. It contains complete information on emigration during the study period.[33] Since our data showed high statistical power, we performed additional analysis as post-hoc analysis, restricting follow-up to one year. Restricting follow-up is valuable when studying immediate consequences, as we do in this study. Additionally, drinking behaviour may change over time —especially in youth. By truncating the follow-up time, we enhance the likelihood that alcohol consumption reported at baseline aligns with the alcohol intake at the time of the accident. Multilevel models were used to account for dependency among students within the same school. We ran the regression specifically for head injuries as post-hoc analysis because head injuries constitute a substantial part of outcomes (12.4% of all unintentional injuries) and represent potentially severe injuries. Alcohol intake measured as drinks per week was operationalised into categories as described. In addition, alcohol intake was modelled continuously by restricted cubic splines to illustrate the shape of the risk curve in more detail, allowing for non-linearity.[34,35] Four knots were set at the 5th, 35th, 65th, and 95th centiles. We tested for potential non-linearity by using a likelihood ratio test comparing the model with only a linear term against the model with linear and cubic spline terms.[36,37] Effect modification between sex and weekly alcohol intake was tested in a model including main effects as well as interaction terms. We estimated the population-attributable risk for unintentional injuries related to drinking categories as $\Sigma Pe_i\ (IRR_i)\text{-}1/1+\Sigma Pe_i\ (IRR_i)$, where Pe_i is the prevalence of the i'th drinking category, and IRR_i is the incidence rate ratio one year following baseline associated with this category. To account for missing values, we used multiple imputations by chained equations.[38] For each outcome (alcohol-attributable hospital contact, unintentional injury, and head injury), imputation models were run separately. Each imputation model included variables we hypothesised to predict missing information. Thus, models included the outcome, weekly alcohol intake sex, perceived ethnicity, school type, school year, cohabitation, parental educational level, and smoking status. At the school level, we also included a categorical variable for school and a continuous variable for the median parental income. Information on age, sex, and school type was complete. The fraction of missing values for questionnaire variables (perceived ethnicity, cohabitation, smoking, and alcohol intake) was maximally 1.6%. Following imputation, estimation was performed on each imputation separately and then combined using Rubin's rules.[39] Sensitivity analysis including parental income to the fully model was performed to account for different effects from parental educations and income respectively on the associated risk.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. All authors confirm that they had full access to all the data in the study and accept responsibility for the decision to submit for publication.

Results

We were unable to link 3753 individuals to the registers due to missing id numbers but found no substantial variations in background characteristics related to age, cohabitation, and weekly alcohol intake between individuals with successful register linkage and those without. Individuals with missing linkage were slightly more likely to be males from diverse ethnic backgrounds. The median age of participants with successful register linkage was 17.9 years, and 58.9% were females (Table 1). The majority were first-year students (41.0%), attending high school (93.5%), and perceived their ethnicity as Danish (90.0%). One in ten students were never drinkers (10.5%), and median weekly alcohol intake was 11 in males and 8 in females. Most of the students drank <7 drinks per week (36.0%) or 7–13 drinks per week (30.0%).

The first-time IR of having a hospital contact due to alcohol during the first year after baseline was 3.85 (3.20–4.63) per 1000 person-years in males and 3.41 (2.89–4.02) per 1000 person-years in females (Fig. 1). IRs of hospital contact due to alcohol were comparable in the youngest participants aged 15–17 years old and the oldest participants aged 18–24 years old. First-time IR of unintentional injuries were higher in males (IR = 110 (106–114) per 1000 person-years) compared to females (IR = 82 (80–85) per 1000 person-years), with no difference between age groups.

During the five years of follow-up, 901 (1.3%) participants had an alcohol-attributable hospital contact. The most registered contact was acute alcohol intoxication (n = 627, 70%), followed by toxic effect of alcohol (n = 122, 13.5%), and harmful use (n = 73, 8.1%). Within the first year following baseline, the number of alcohol-attributable hospital contacts was 254 (0.36%). Adjusted Poisson regression showed statistically significant associations between alcohol intake and increased risk of alcohol-

	Male (41.1%) n = 29.214	Female (58.9%) n = 41.811	All n = 71.025
Age[a]	18.0 (16.6, 19.6)	17.8 (16.4, 19.3)	17.9 (16.5, 19.4)
Ethnicity, n (%)			
Danish	25.967 (89.0)	38.087 (91.0)	64.054 (90.0)
Danish and other	1.043 (3.5)	986 (2.4)	2.029 (3.0)
Other than Danish	2.204 (7.5)	2.738 (6.6)	4.942 (7.0)
Type of education, n (%)			
Vocational school	3.148 (10.8)	953 (2.3)	4.101 (6.5)
High school	26.066 (89.2)	40.858 (97.7)	66.924 (93.5)
School year, n (%)			
1st	12.800 (43.8)	16.103 (38.5)	28.903 (41.0)
2nd	9.119 (31.2)	14.197 (34.0)	23.316 (33.0)
3rd	7.295 (25.0)	11.511 (27.5)	18.806 (26.0)
Cohabitation, n (%)			
Mother and father	19.787 (67.7)	27.815 (66.6)	47.602 (67.2)
Mother or father	7.007 (24.0)	10.968 (26.2)	17.974 (25.1)
Other	2.420 (8.3)	3.028 (7.2)	5.449 (7.7)
Parents' education, n (%)			
Elementary/short school	11.188 (38.2)	17.780 (42.5)	28.968 (40.6)
Medium education	11.073 (38.0)	15.978 (38.2)	27.051 (38.1)
Long education	6.53 (23.8)	8.053 (19.3)	15.006 (21.3)
Non-drinkers n (%)	3.108 (10.6)	4.367 (10.4)	7.475 (10.5)
Weekly alcohol intake among drinkers	11 (10.8–11.1)	8 (7.91–8.08)	10 (9.92–10.0)
Weekly alcohol consumption among alcohol drinkers, n, (%)			
<7 drinks	8.368 (32.0)	14.811 (39.6)	23.179 (36.0)
7–13 drinks	6.519 (25.0)	12.739 (34.0)	19.259 (30.0)
14–20 drinks	5.351 (20.5)	6.271 (16.7)	11.621 (18.0)
21–27 drinks	2.397 (9.2)	1.836 (4.9)	4.233 (7.0)
>27 drinks	3.471 (13.3)	1.787 (4.8)	5.258 (9.0)
Smoking status			
Every day	4.650 (16.0)	4.667 (11.2)	9.316 (13.5)
Sometimes	9.067 (31.0)	14.432 (34,5)	23.499 (33.0)
Never	15.497 (53.0)	22.712 (54.3)	38.210 (53.5)

[a]Median (10, 90 pct.).

Table 1: **Characteristics of the Danish national youth cohort (n = 71.025), Denmark 2014.**

attributable hospital contacts. Associations were statistically significant for all levels of weekly alcohol intake compared to never drinkers, and higher alcohol intake was associated with higher risk in a dose–response relationship (Table 2). The dose–response relationship was further illustrated when modelling weekly alcohol intake continuously with cubic splines to account for non-linearity (Fig. 2), meaning that each increase in alcohol intake was associated with higher risk throughout the entire alcohol intake spectrum from low to high alcohol intake. The risk curve displayed a sharp incline at the lower end, corresponding to 0–7 drinks per week, reaching a plateau around 8–12 drinks per week. Beyond this range, for every 10 additional drinks per week, the incidence rate ratio within one year following baseline increased by approximately 1.0 per 10 additional drinks per week. For the analysis including five years of follow-up, the risk curves exhibited a less steep slope, and the incidence rate ratios seemed to rise by 0.3 per every 10 additional drinks per week (P for non-linearity <0.08). There were no substantial differences between the basic adjusted and the fully adjusted models (Supplementary Table S2). Restricting the analysis to one-year follow-up only showed stronger associations along with broader confidence intervals. For instance, the IRR of an event more than doubled among those who drank less than seven drinks per week measured one year from baseline (IRR = 3.83 (1.64–8.94)) compared to five years after baseline (IRR = 1.70 (1.23–2.34)). This trend applied to all categories of weekly alcohol intake levels. Similar results appeared in males and females (statistical test for interaction = p > 0.05) (Supplementary Table S3).

Nearly one in three participants had an unintentional injury during the five-year follow-up period (n = 19.173, corresponding to 27%). Unintentional injuries were more prevalent among males (31.0%) compared to

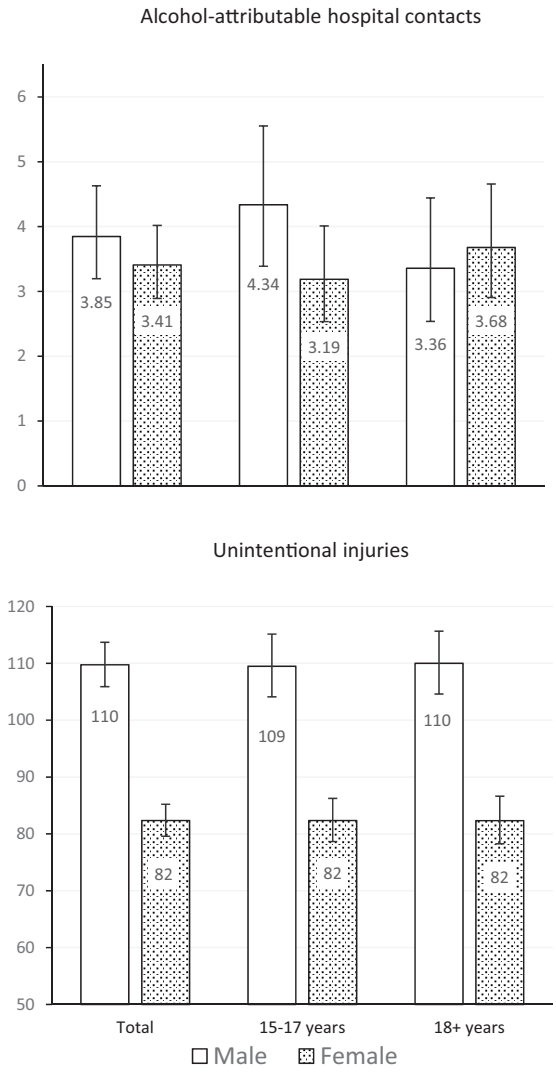


Fig. 1: First-time incidence rates (per 1000 person-years) of alcohol-attributable hospital contacts and unintentional injuries according to sex and age group one year following baseline. Adjusted for: perceived ethnicity, school type, school year, cohabitation, parental educational level, and smoking. The Danish National Youth Cohort (n = 71.025), Denmark 2014.

females (24.0%). The most frequent injuries were injury to the wrist and hand (n = 5.284, 27.6%), ankle and foot (n = 4.825, 25.2%), and the head (n = 2.383, 12.4%) (Table 3). Increasing levels of alcohol intake were positively associated with risk of sustaining an unintentional injury. As illustrated in Fig. 3, the association was characterised by a dose–response shaped relationship, meaning that each alcoholic drink was associated with an increase in IRR. For every 10 additional drinks per week, the incidence rate ratio raised by approximately 0.2. For instance, 10 and 20 drinks weekly corresponded to an incidence rate ratio of 1.1 and 1.3, respectively. Notably, the was a faint suggestion of a u-shaped risk curve one year following baseline corresponding to an incidence rate ratio less than 1.0 for 1–5 drinks per week (P for non-linearity <0.08). No significant differences were found between the basic adjusted and fully adjusted models (Supplementary Table S4). Reducing the follow-up from five years to one year did not change the associations (Table 4). Similar results appeared in males and females (statistical test for interaction = p > 0.05) (Table 5). Consequently, the IRR increased from 1.15 (1.05–1.25) to 1.55 (1.42–1.70) for males who drank 7–13 drinks per week and >27 drinks per week, respectively. Among females, IRR increased from 1.10 (1.01–1.20) to 1.56 (1.39–1.75) when alcohol levels increased from 7 to 13 drinks per week to >27 drinks per week. Regardless of sex, most injuries occurred among those who drank less than seven or 7–13 drinks per week, which also represented the largest alcohol intake groups.

Head injury was the third most common unintentional injury, representing one in eight of all injuries (n = 2.383, 12.4%). Looking at the different types of head lesions, intracranial injury was the third most frequent head injury, representing 15.9% (n = 522) (Table 6). Increasing alcohol intake and IRR of head injuries were independently associated in a dose–response relationship similar to the results on all unintentional injuries (Table 7). However, it appeared that IRR for head injury was statistically significant above a weekly alcohol intake of 14 or more drinks (IRR = 1.24 (1.06–1.44)).

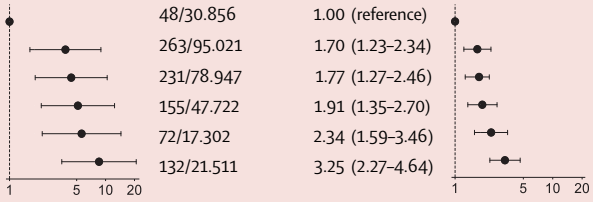
Sensitivity analysis including family income to the fully adjusted model did not change the results.

Finally, we estimated how much of the experienced harm in the cohort could be attributed to alcohol, conditional on causal relations to weekly alcohol intake. The population-attributable risk was 14% for unintentional injuries corresponding to 886 injuries in the cohort within the first year following baseline.

Discussion

In this prospective cohort study based on survey and register data on hospital contacts from 71,025 15–24-year-olds in Denmark, we identified several interesting findings. As hypothesised, we found that increasing levels of weekly alcohol intake were associated with higher risk of hospital contacts due to alcohol and unintentional injuries. We also found that the associations reflected a dose–response relationship, meaning that each increase of alcohol intake was associated with higher risk. Consequently, even low (<7 drinks/week) intake was associated with increasing risk of hospital contacts due to alcohol (IRR = 1.70 (1.23–2.34)) and unintentional injuries (IRR = 1.09 (1.03–1.15)). Thus, no lower limit at which alcohol intake did not associate with harm was observed. Furthermore, although the incidence of injuries was higher in males, IRR generally

Alcohol intake (drinks/week)	1 year follow up		5 years follow up	
	Events/person-year	IRR[a] (95% CI)	Events/person-year	IRR[a] (95% CI)
Never drink	6/7.460	1.00 (reference)	48/30.856	1.00 (reference)
<7	71/23.090	3.83 (1.64–8.94)	263/95.021	1.70 (1.23–2.34)
7–13	65/19.194	4.39 (1.86–10.4)	231/78.947	1.77 (1.27–2.46)
14–20	48/11.585	5.16 (2.15–12.4)	155/47.722	1.91 (1.35–2.70)
21–27	21/4.215	5.63 (2.19–14.5)	72/17.302	2.34 (1.59–3.46)
>27	43/5.228	8.55 (3.50–20.9)	132/21.511	3.25 (2.27–4.64)



The Danish National Youth Cohort (n = 71.025), Denmark 2014. [a]Adjusted for: age, sex, perceived ethnicity, school type, school year, cohabitation, parental educational level, and smoking.

Table 2: **Number of alcohol-attributable hospital contacts per person-year, and incidence rate ratios (95% confidence interval) by weekly alcohol intake within one year and five years following baseline.**

appeared similar in males and females. This visual impression was in alignment with the statistic test for interaction ($p > 0.05$ for alcohol-attributable hospital contacts and unintentional injuries as outcomes). Based on the population-attributable risk estimation, 14% of unintentional injuries were due to alcohol intake, assuming causality. Causality is discussed under limitations.

Previous emergency room studies have shown that BAC ≥0.01% and self-reported consumption within past 6 h associated with injury with odds ratios of 1.51 and 1.58, respectively.[40] To the best of our knowledge, this is the first prospective study to assess the impact of average weekly alcohol intake on the risk of unintentional injuries in adolescents specifically using data from hospital registries as opposed to self-reported data on injuries. Our data showed that 90% of the participants drank alcohol, and the median intake among drinkers was ten drinks per week, reflecting a widespread use and high intake of alcohol in Danish adolescents. Cross-national research among 40 European countries reveals that more Danish adolescents have consumed alcohol within the last 30 days (74%) and been intoxicated (40%) compared to the European average (47% and 13%, respectively), earning Danish youth with the European record for drinking.[11] Therefore, the high amount of alcohol intake found in the present study was not surprising. Furthermore, more than 80% of alcohol-attributable hospital contacts were due to intoxication and the toxic effect of alcohol. These results underscore that adolescents experience acute harm in relation to alcohol rather than illness due to a long-term alcohol intake and highlight the importance of studies conducted in adolescents specifically. A recent

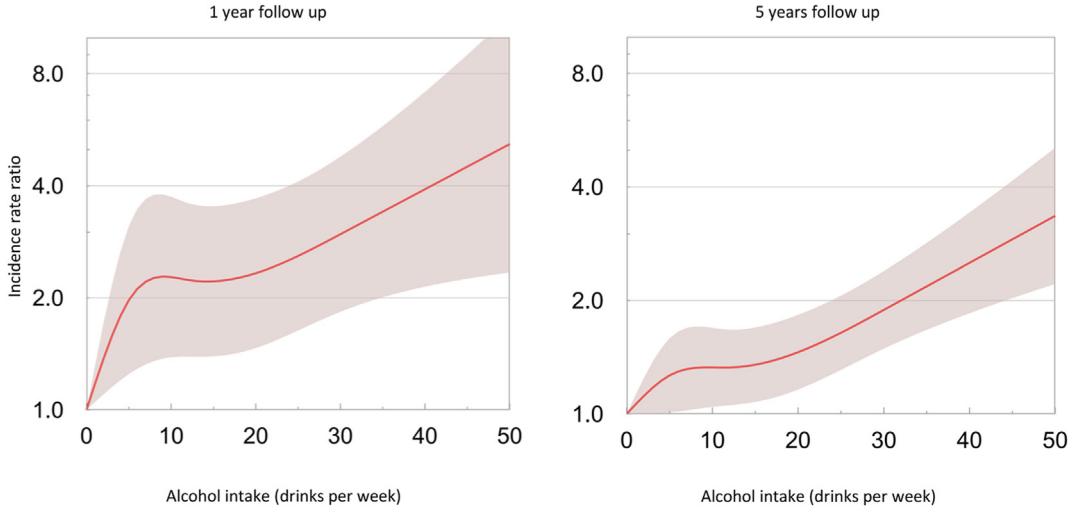


Fig. 2: Risk of alcohol-attributable hospital contacts by weekly alcohol intake one year and five years following baseline. The Danish National Youth Cohort (n = 71.025), Denmark 2014. Adjusted for: age, gender, perceived ethnicity, school type, school year, cohabitation, parental educational level, and smoking.

Injuries to the wrist and hand	5.284	(27.6)
Injuries to the ankle and foot	4.825	(25.2)
Injuries to the head	2.383	(12.4)
Injuries to the knee and lower leg	2.132	(11.1)
Injuries to the elbow and forearm	1.135	(5.9)

The Danish National Youth Cohort (n = 71.025), Denmark 2014. Distribution of registered injuries five years after baseline, n (%). Only the earliest occurring injury during five years follow up is included.

Table 3: **Type of the five most frequently occurring unintentional injuries.**

retrospective study by Beaulieu et al.[16] found that binge drinking once a month was associated with higher odds of self-reported unintentional injury (OR = 1.41 (0.56–4.50)). In retrospective studies, self-reported injuries (intentional and unintentional) have previously been shown to be associated with current alcohol use,[18,19,41–43] alcohol intake frequency,[12,13,17] and binge drinking.[14–16] Estimates ranged from OR = 1.10 to 6.0. Our study adds to the current knowledge base that the associations appear to reflect a dose–response relationship and that associations do not vary between sex. Previous, a dose-dependent-relationship of acute alcohol intake has been reported with an estimated OR of 10 at 10 drinks for all injuries in a polled analysis validating the fractional polynomial approach including 37 emergency rooms.[44] In line with our study a dose–response relationship was found but notably the risk curve flattened at a level of 30 drinks consumed. The risk curve in our study did not seem to hit a such plateau. Further, although drinks per week is not directly comparable to acute alcohol intake, risk estimates were much lower in our study as 10 drinks per week corresponding to an IRR of 1.2.

This study has several strengths. First, the statistical power is high, due to the large cohort size. Linkage to registers was unsuccessful for 3753 individuals, however we do not consider this to affect results substantially as this group was very similar to the group with successful linkage. Second, the prospective nature, due to the ability to obtain independent follow-up information from hospital registries, eliminates the risk of recall bias and reverse causality. Third, The Danish National Youth Cohort has a high response rate at class level as well as student level and is considered representative of Danish high school students. However, data may not be representative of all 15–24-year-old Danes. Fourth, we were able to adjust for a range of covariates, including parental socioeconomic status, that were obtained independently from the participants by linking to data on parents using data from national registers.

Limitations are as follows. First, the occurrence of injuries may be underestimated, as data from the National Patient Register does not include injuries that are handled in private hospitals, pre-hospital, general practice or at home. Thus, it is likely that our study only includes the more severe cases. Second, our data cannot tell if the student was under the acute influence of alcohol at the time of injury, as we did not have access to the medical journals. This is an important limitation when interpreting associations between weekly intake of alcohol and unintentional injuries, and one should be careful not to draw hasty conclusions on causality. We adjusted for a wide range of

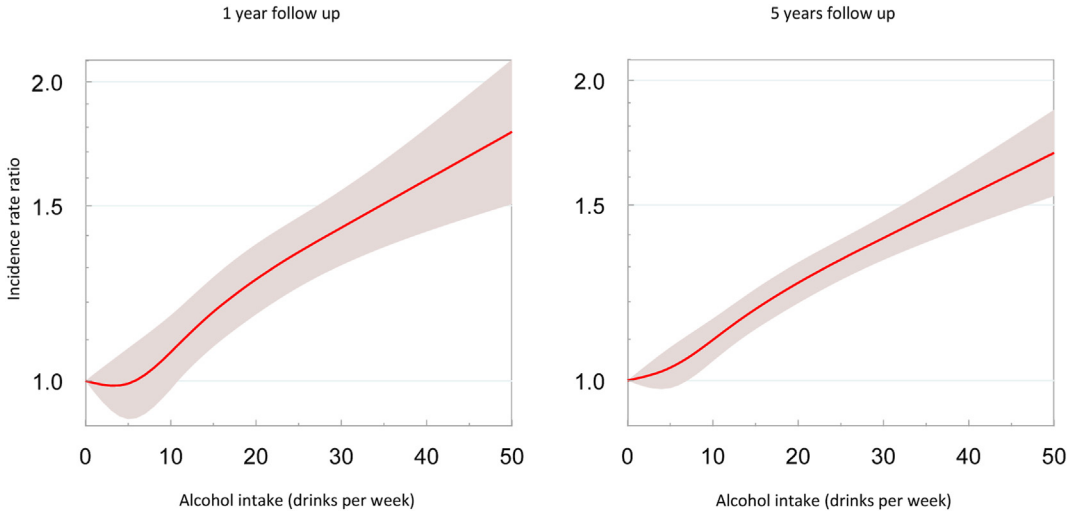
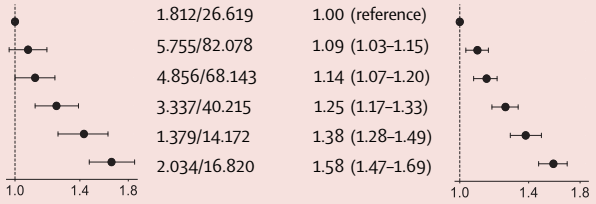


Fig. 3: Risk of unintentional injuries by weekly alcohol intake one year and five years following baseline. The Danish National Youth Cohort (n = 71.025), Denmark 2014. Adjusted for: age, gender, perceived ethnicity, school type, school year, cohabitation, parental educational level, and smoking.

Alcohol intake (drinks/week)	1 year follow up		5 years follow up	
	Events/person-year	IRR[a] (95% CI)	Events/person-year	IRR[a] (95% CI)
Never drink	595/7.158	1.00 (reference)	1.812/26.619	1.00 (reference)
<7	1.868/22.170	1.07 (0.97–1.18)	5.755/82.078	1.09 (1.03–1.15)
7–13	1.550/18.448	1.11 (1.00–1.23)	4.856/68.143	1.14 (1.07–1.20)
14–20	1.094/11.050	1.24 (1.11–1.39)	3.337/40.215	1.25 (1.17–1.33)
21–27	479/3.976	1.43 (1.25–1.62)	1.379/14.172	1.38 (1.28–1.49)
>27	744/4.866	1.65 (1.47–1.86)	2.034/16.820	1.58 (1.47–1.69)

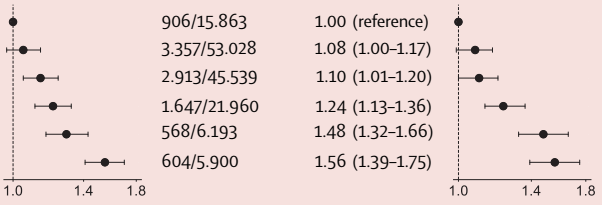


The Danish National Youth Cohort (n = 71.025), Denmark 2014. [a]Adjusted for: age, sex, perceived ethnicity, school type, school year, cohabitation, parental educational level, and smoking.

Table 4: **Number of unintentional injuries per person-year and incidence rate ratios (95% confidence interval) by weekly alcohol intake within one year and five years following baseline.**

confounders, but we cannot know for certain that injuries resulted directly from alcohol intake, and differences in IRR may also be due to a proclivity for risky behaviour. However, it is meaningful to use average weekly alcohol intake as a measure of alcohol's impact, rather than relying solely on acute alcohol intake such as blood alcohol concentration. Quantifying the harm associated with alcohol is important for public health prevention strategies and major studies, such as the Global Burden of Disease Study, which assess the burden caused by different diseases and risk factors, also utilise average alcohol intake rather than acute measures.[25,45] Third, alcohol intake was assessed at one point only and by self-report without validation. This leaves a risk of non-differential bias, since health-risk behaviour, including alcohol intake, may change over time. This is particularly relevant for young individuals, as evidenced by studies investigating fluctuations in alcohol use during the transition from adolescence to early adulthood (ages 15–30 years) and from pre-to post-graduation.[46,47] Outcomes were not related to the exposure due to the prospective study design, thus bias would lead to underestimation of associations between drinking and hospital contacts due to alcohol and unintentional injuries. Nonetheless, we found significant dose dependent differences in IRR even at low weekly alcohol intake levels, and the baseline self-reports of alcohol intake were associated with IR of alcohol-attributable hospital contacts speak in favour of the validity of our baseline measurement. This was further substantiated by the strengthening of associations in the one-year follow-up analysis (compared to five years) of hospital contacts that were completely attributable to alcohol. However, underestimation of associations between each increase in alcohol intake and hospital contacts due to alcohol and unintentional injuries is plausible and should be considered when results are interpreted. The one-year follow-up analysis for unintentional injury did not lead to the same steep risk function as for alcohol-attributable hospital contacts. This may reflect that alcohol intake is intertwined with other factors, such as

Alcohol intake (drinks/week)	Males		Females	
	Events/person-year	IRR[a] (95% CI)	Events/person-year	IRR[a] (95% CI)
Never drink	906/10.756	1.00 (reference)	906/15.863	1.00 (reference)
<7	2.397/29.050	1.06 (0.98–1.15)	3.357/53.028	1.08 (1.00–1.17)
7–13	1.943/22.603	1.15 (1.05–1.25)	2.913/45.539	1.10 (1.01–1.20)
14–20	1.690/18.255	1.22 (1.12–1.33)	1.647/21.960	1.24 (1.13–1.36)
21–27	812/7.979	1.30 (1.17–1.43)	568/6.193	1.48 (1.32–1.66)
>27	1.430/10.920	1.55 (1.42–1.70)	604/5.900	1.56 (1.39–1.75)



The Danish National Youth Cohort (n = 71.025), Denmark 2014. [a]Adjusted for: age, perceived ethnicity, school type, school year, cohabitation, parental educational level, and smoking.

Table 5: **Number of unintentional injuries per person-year and incidence rate ratios (95% confidence interval) by weekly alcohol intake in males and females within five years following baseline.**

Open wound of head	1.310	(39.9)
Superficial injury of head	803	(24.5)
Intracranial injury	522	(15.9)
Injury of eye and orbit	354	(10.8)
Fracture of skull and facial bones	196	(6.0)

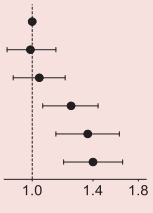
The Danish National Youth Cohort (n = 71.025), Denmark 2014. Distribution of registered head injuries during five years follow up, n (%).

Table 6: **Type of the five most frequently occurring head injuries.**

an individual's propensity to take risks including substance use, vehicle-related risk, and self-harm.[48] Individuals who are more inclined towards risk-taking behaviour may be more likely to engage in excessive drinking episodes. This alignment between risk taking behaviour and alcohol intake could potentially explain the higher risk of injuries observed in individuals with higher weekly alcohol intake.

Alcohol intake in adolescence has been associated with changes in brain tissue,[4,49] poorer performance in school,[50] and alcohol problems later in life, as drinking patterns formed in adolescence and early adulthood reach into adult life.[51] This study adds to the body of evidence on harmful consequences that each alcoholic drink may be associated with a heightened risk of experiencing harm due to poisonings and unintentional injuries in adolescence in a dose–response relationship. We found alcohol-attributable hospital contacts to be equally frequent among the youngest adolescents (less than 18 years old) and the older adolescents, reflecting the existence of a liberal alcohol culture, present even among minors (in Denmark, 16 years old is the age limit for buying alcoholic beverages, however, alcoholic beverages with an alcohol volume above 16.5% are restricted to an age limit of 18 years). These are novel insights that may inform health authorities when defining drinking guidelines or limits. In this study, a substantial proportion of injuries were head injuries, pointing to the degree of injury severity. Up to 80% of patients with even a mild traumatic brain injury will develop post-concussion syndrome (PCS), defined by the presence of symptoms such as headache, dizziness, fatigue, irritability, and concentration and memory problems following the injury.[52] PCS may persist for up to six months, but for some the symptoms become chronic. Most injuries in terms of absolute numbers occurred among those who drank less than seven or 7–13 drinks per week, which represented by far the largest proportion of the participants. Thus, the increased risk for the numerous students with a low weekly alcohol intake results in more cases of acute harm than the small number of students whose drinking implies a high risk of acute harm. This is a paradox, referred to as the prevention paradox,[53] which policymakers and stakeholders should be aware of when defining target groups for preventive measures. It is well known in the literature that restrictions on alcohol availability, such as increasing minimal drinking age limit, higher prices, and restrictions on alcohol trading hours, can decrease harm due to alcohol-related unintentional injury in adolescents.[54,55] Our study emphasises the need for such initiatives. In accordance with previous studies, this study uncovers positive associations between alcohol intake and risk of hospital contacts due to alcohol and unintentional injuries among adolescents aged 15–24 years old. Our findings add to the body of evidence that associations may reflect a dose–response relationship. These novel insights may support politicians and stakeholders in making evidence-based preventive strategies to improve adolescent health. Future research should focus on factors that influence associations between alcohol-related harm in adolescents, such as injury mechanism (violence, self-harm, accidents), mental health, drinking patterns, and socioeconomic position.

Alcohol intake (drinks/week)	Head injury	
	Events/person-year	IRR[a] (95% CI)
Never drink	319/30.291	1.00 (reference)
<7	908/93.678	0.99 (0.87–1.14)
7–13	786/77.829	1.04 (0.90–1.20)
14–20	618/46.805	1.24 (1.06–1.44)
21–27	270/16.905	1.36 (1.14–1.62)
>27	382/21.006	1.40 (1.19–1.65)



The Danish National Youth Cohort (n = 71.025), Denmark 2014. [a]Adjusted for: age, sex, perceived ethnicity, school type, school year, cohabitation, parental educational level, and smoking.

Table 7: **Number of head injuries per person-year and incidence rate ratios (95% confidence interval) by weekly alcohol intake within five years following baseline.**

Contributors

JST planned and designed the study. ZIS and JST was responsible for data management and analysis. SK drafted the manuscript. LH, UB, OA, SK, JST and ZIS contributed to the interpretation of study results, critical revision of the paper and approval of the final version and agree to be accountable for all aspects of this article.

Data sharing statement

Data from the Danish National Youth Study can be shared after reasonable request to the corresponding author.

Declaration of interests

All authors have completed the ICMJE uniform disclosure form at https://www.icmje.org/disclosure-of-interest/and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.eclinm.2023.102187.

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