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Demographic and socioeconomic patterns in the risk of alcohol-related hospital admission in children and young adults with childhood onset type-1 diabetes from a record-linked longitudinal population cohort study in Wales

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Abstract

Background: Little is known about alcohol-related harm in children and young adults with type 1 diabetes (T1D). Education on managing alcohol intake is provided to teenagers with T1D in paediatric clinics in Wales, but its effectiveness is unknown. We compared the patterns in risk of alcohol-related hospital admissions (ARHA) between individuals with and without childhood-onset T1D.

Methods: We extracted data for 1 791 577 individuals born during 1979 to 2014 with a general practitioner registration in Wales, and record-linked the demographic data to ARHA between 1998 and June 2016 within the Secure Anonymised Information Linkage Databank (SAIL). Linkage to a national T1D register (Brecon Cohort) identified 3575 children diagnosed aged <15 years since 1995. We estimated hazard ratios (HRs) with 95% confidence intervals (95% CIs) for the risk of ARHA using recurrent-event models, including interaction terms.

Results: Individuals with T1D had a higher riskof ARHA (HR: 1.78; 95% CI: 1.60-1.98), adjusted for age group, sex, and deprivation. The risk in people with diabetes was highest aged 14 to 17 years, around three times higher than the peak in non-T1D aged 18 to 22. Females with diabetes had a lower risk generally. The association between deprivation and ARHA was weaker in the T1D group.

Conclusion: Young people with T1D had increased risks of ARHA, particularly at school age, and smaller socioeconomic inequalities in ARHA. A review of interventions to reduce alcohol-related harm in T1D is needed, perhaps including modification of current education and guidance for teenagers on managing alcohol consumption and reviewing criteria for hospital admission.

KEYWORDS

alcohol drinking, child, diabetes mellitus, socioeconomic factors, type 1, young adult

1 | INTRODUCTION

Frequent alcohol use is common in adolescents in the United Kingdom and many European countries.[1] Although regular drinking, getting drunk, and early initiation in younger people have reduced over the past two decades in the United Kingdom, the effects of alcohol misuse on young people, their families and wider society as well as the health service remains of concern.[1] Measures of alcohol-related harm such as hospital admissions and mortality at population-level show particularly wide health inequalities, and a reduction in avoidable alcohol-related harm is a focus of government and health services.[2,3] To that effect a minimum unit pricing policy has been introduced in Scotland, and more recently in Wales to tackle alcohol-related harm through affordability.[4]

Consumption of alcohol by young people with type 1 diabetes (T1D) is particularly problematic. Following a diagnosis of T1D, children and their families are required to absorb a wealth of information to effectively manage their condition with the overall aim to achieving effective glycaemic control.[5] Without attention to monitoring effects on blood glucose levels, there is an increased risk that excessive alcohol consumption will lead to increased risks of severe hypoglycaemia through adverse effects on hepatic gluconeogenesis.[6] This increases the risk of episodes of loss of consciousness and hospital admission.[7] As a result, current management policies for teenagers with T1D in the United Kingdom include delivering education about how to drink alcohol safely to avoid such risks.[8] Such education is provided to teenagers with T1D in paediatric clinics in Wales, but its effectiveness is unknown.[9]

There is limited evidence on alcohol-related harm in children and young adultswith T1D, and we identified two narrative reviews, each containing only a few relevant studies.[10,11] One broader review of both alcohol and drug use in young adults reported that young adultswith T1D often wanted to participate in substance use at similar levels to their peers, but did not specifically focus on alcohol-related harm and excluded children.[11] The other on alcohol-associated risks identified only six articles and two conference abstracts and concluded that research was needed on the social context of alcohol consumption to aid development of interventions.[10] We identified only three primary studies that investigated alcohol consumption as a risk factor for measured diabetes-related complications, two in a single hospital setting.[12-14] A study in Melbourne (14 participants) monitored glucose over a weekend, reporting an association between heavy alcohol consumption and increased glycaemic variation, but not low glucose levels.[14] The second, in Auckland (268 individuals), found that recurrent admission for ketoacidosis had alcohol abuse noted.[13] The only large study in Germany and Austria reported that higher self-reported alcohol consumption was associated with worse glycaemic control and diabetic ketoacidosis.[12] Self-reported alcohol consumption is, however, likely to underestimate the prevalence of exposure to this risk factor.[12] To our knowledge ours is the first study that investigated clinically coded alcohol-related hospital admissions (ARHA) in children and young adultswith T1D. ARHA are used as a proxy for adverse effects of alcohol consumption, often collectively referred to as alcohol-related harm, and in young people tend to measure acute effects rather than chronic conditions.[15]

Patterns by age and sex are important aspects to investigate considering that young males with T1D consumed more alcohol than females, and more with increasing age.[12] The risk of ARHA in all adolescents of Wales was, however, higher for females than males aged 10 to 16, albeit slightly lower than males aged 17.[16] It is unclear whether these patterns by sex are different for those with T1D.

Socioeconomic inequalities in alcohol-related harm in the population, including in young people, are persistent in Wales and elsewhere.[1,2,16] The reasons for these inequalities are complex and include behavioural factors and comorbidities but cannot simply be explained by drinking patterns.[2] Whether the role of socioeconomic disadvantage in those with T1D with respect to alcohol-related harm is different to those without has to our knowledge not been investigated before. Associations between lower socioeconomic status or higher area deprivation and diabetic ketoacidosis have been found, although the evidence is contradictory for an association with glycaemic control and hypoglycaemia.[17,18]

This study aimed to investigate whether and to what extent the age, sex, and socioeconomic patterns in the risk of ARHA differ between children and young adults with and without T1D in Wales.

2 | METHODS

2.1 | Data sources

This analysis was carried out using the Electronic Longitudinal Alcohol Study in Communities (ELAStiC) data platform and details on the data and linkage methods are outlined in the study protocol.[15] Very briefly, demographic data were record-linked to ARHA, deaths and other sources for the population of Wales. The summary and further specific details for this study are described below.

2.1.1 | Brecon Cohort

Details for children resident in Wales who have been diagnosed with T1D under the age of 15 in secondary care are entered into a national diabetes register, the Brecon Cohort.[19,20] The register was established in 1995 and includes children born from 1979 onwards. We have used data for children born in 1979 to 2014 for our study and their register data have been record-linked into the ELAStiC data platform for this study. The register dataset includes demographic and clinical information including the date of T1D diagnosis. Two major ascertainment analyses have been undertaken using a two-source capture recapture model with data from paediatricians and primary care. These demonstrated 98.5% ascertainment of all cases diagnosed from 1995 to 2005 and 98.1% of those diagnosed from 1995 to 2012.[20]

2.1.2 | Deprivation measure

We used area-based deprivation measures, the Welsh Index of Multiple Deprivation (WIMD) 2008[21] and the Townsend index 2001.[22] We also included three of the subdomains of the WIMD: education, income, and employment. The WIMD is the official measure of deprivation for small areas in Wales and every household within that area is assigned the area level of deprivation, calculated from both individual and household measures.[23] For education and employment these are based on adults in the household but other domains include data on benefits considering dependent children in the household[23] The Townsend index is a measure of material deprivation calculated from four indicators based on census data: unemployment (aged 16+), car ownership, non-home ownership, and overcrowding.[22] For all deprivation measures we grouped the two more deprived quintiles (40% more deprived) and three less deprived quintiles (60% less deprived) because of relatively small numbers in some groups, as used in a previous study.[2] This maps to widely used quintiles and specifically focuses on the more deprived groups.

2.1.3 | Outcome definition of alcohol-related hospital admission

The outcome was ARHA during the years 1998 to mid-2016 as ascertained from the Patient Episode Database for Wales (PEDW), with multiple admissions per individual included where present. We selected the earliest episode in each hospital spell with a wholly attributable diagnosis included in the definition outlined in the study protocol.[15] These are similar to the alcohol-specific definition used by Public Health England with a few additional codes, and include, for example, acute alcohol intoxication and alcohol poisoning.[15,24] These could be the primary diagnosis or a secondary diagnosis in any coding position. The details of the data sources, linkage, and extraction are outlined in the ELASTiC data platform study protocol.[15]

2.1.4 | Study design/processing

This was a longitudinal study of 1 791 577 residents in Wales (extracted from the Welsh Demographic Service, WDS), who were registered with a general practitioner (GP) and born in the years 1979 to 2014. These were individually record-linked to hospital admissions (PEDW), deaths (Public Health Mortality file from the Office for National Statistics), and to the Brecon Cohort within the Secure Anonymised Information Linkage (SAIL) Databank.[25] Linkage to the Brecon Cohort provided the childhood onset T1D diagnosis. Demographic data (WDS) included the Lower layer Super Output Area (LSOA) of residence at any time during the study period, including house moves. We censored for moving outside of Wales and death. Individuals were included in the study again if they moved back to Wales during the study period. We linked the WIMD and the Townsend scores to each LSOA of residence to provide the deprivation groups.

We created age groups for children from birth to primary school age (<11 years), younger secondary school age (11-13 years), older secondary school age (14-17 years), those aged 18 to 22 years, and older (23-37) during the study period. Individuals changed age group on their relevant birthday and may therefore be included in more than one age group during the study period. Although the main focus of the study is teenagers, we have included the youngest children and the adults for both statistical efficiency and ability to contrast results with other age groups. All individuals were in the non-T1D group until their date of diagnosis, which marked their entry into the T1D group.

2.1.5 | Statistical analyses

We estimated hazard ratios (HRs) with 95% confidence intervals (95% CIs) for the relative risk of (multiple) ARHA in the T1D group compared to the group without T1D using Cox proportional hazard models. The time scale was calendar time. Specifically, we used a Prentice, Williams, and Peterson total time model[26] with ARHA as the outcome using the individual count of admission events during the study as strata. We followed the guidance of modelling these recurrent events by Amorim et al[27] and a recommendation for its application on multi-failure hospital admission data.[28] Both age group and deprivation group were used as time-varying covariates. All analyses were conducted using the statistical package R.[29]

The basic model A, as well as T1D status, included sex, age group, and the WIMD deprivation group as covariates.

Model B additionally included a two-way interaction term between T1D status and deprivation group.

Model C additionally included a two-way interaction term between T1D status and the deprivation group, as well as a three-way interaction term between age group, T1D status and deprivation group. We repeated this model for the different deprivation measures (Townsend score and WIMD).

Model D was like model A, but additionally included two-way interaction terms between T1D and age group and between T1D and sex, and a three-way interaction term between T1D status, age group, and sex.

For model C and model D including three-way interactions, we report HRs with 95% CIs and *P*-values.

To investigate socioeconomic inequalities by age group and diabetes status, we considered ratios of HRs and differences in HRs between the more deprived and less deprived.

Additionally, we investigated the length of stay in hospital as a proxy for the severity of alcohol-related harm and health care utilisation. We analysed differences in distribution of the length of stay (provided as full days only) of each admission between the T1D cohort and those without using chi-square tests, first with length of stay grouped by days (<24 hours, 1, 2, 3, 4, 5+ days), then comparing <24 hours vs ≥1 day, and finally comparing ≤4 days vs 5+ days.

3 | RESULTS

3.1 | Descriptive analysis

Our study population consisted of 1 791 577 individuals aged from birth to 37 years of age at the end of the study. Of these, 3575 children and young adults were in the T1D cohort (1883 males, 1692 females). An overview of the sample characteristics is shown in Table 1. The original register data file included 3656 people, but 81 individuals (2.2%) could not be successfully linked to the other sources of routine healthcare data in the SAIL Databank (see flowchart in Figure 1). Records for 28 people could not be linked to a unique person identifier (including 12 without a week of birth and four without sex). Another 53 people could not be linked to residence information, either because of missing GP residence information or a move out of Wales before study start and after diagnosis.

In the total study population, there were 19.1 million person-years of follow-up and 37 905 ARHA during the study period. In the T1D cohort, there were 248 admissions (up to four admissions per individual). There were no ARHA in the diabetes group aged under 11 years, unlike for those without. The oldest person at the end of the study was 37; however, the majority of person-years in the oldest age group (82%) were in younger adults aged 23 to 29.

Overall, there is evidence of a difference in the patterns of length of stay between those with and without T1D (chi-squared statistic = 19.25, P = .002).The number and proportions of ARHA by length of stay are shown in Table 2. The T1D group had a slightly higher proportion of ARHA lasting under 24 hours (although not statistically significant: P = .153), but a lower proportion lasting 5 days or longer (P < .001). The proportion of ARHA lasting under 24 hours broken down by age group did not provide additional insight (results not shown).

3.2 | Modelling analyses

Individuals with T1D were 78% more likely to have an ARHA than those without (HR, 1.78; 95% CI 1.60-1.98, P < .001) (Table 3), having conditioned on sex, age group and deprivation group.

3.3 | Patterns by age group

The results suggest that patterns differed by age group. The risk of ARHA was higher in the T1D group in all but the oldest age group compared to the non-T1D group (Table 4 and Figure 2). The highest risk in the T1D group was found in older secondary school children (aged 14-17 years) in more deprived areas (HR 15.95; 95% CI 10.95-23.23). In comparison, the highest HR in those without T1D was 5.78 (95% CI 5.14-6.51) in those aged (18-22 years) in the more deprived areas. The risk of ARHA was therefore higher and at younger ages in the T1D group than those without.

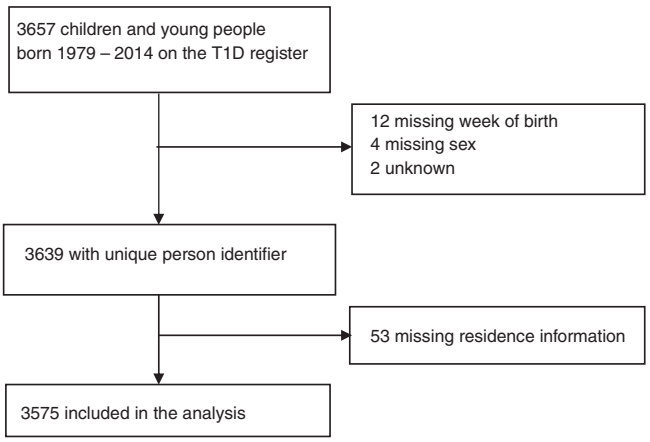

FIGURE 1 Participant selection from the diabetes register

TABLE 1 Characteristics of the study population

	Males	Females	Total
Number of people			
T1D diagnosed before study start	471	464	935
T1D diagnosed after study start	1412	1228	2640
Non-T1D	897 180	893 711	1 790 891
Person-years in study			
T1D cohort	20 614	18 611	39 225
Non-T1D	9 718 215	9 324 623	19 042 839
Number of alcohol-related admissions			
T1D cohort	138	110	248
Non-T1D	22 206	15 451	37 657
Area deprivation at study start/entry			
More deprived 40%	386 402	373 775	760 177
Less deprived 60%	511 286	520 114	1 031 400

Abbreviation: T1D, type 1 diabetes.

TABLE 2 Number of admissions by length of stay

	N (%) <24 h	N (%) 1 d	N (%) 2 d	N (%) 3 d	N (%) 4 d	N (%) 5+ d
T1D	118 (46.8)	71 (28.2)	30 (11.9)	13 (5.2)	11 (4.4)	9 (3.6)
Non-T1D	15 958 (42.4)	11 692 (31)	3351 (8.9)	1639 (4.4)	1011 (2.7)	4019 (10.7)

Abbreviation: T1D, type 1 diabetes, h, hours, d, days

TABLE 3 Basic model results (model A): relative riskof alcohol-related hospital admission by group

	cHR (95% CI)	*P*-value
Male	1	
Female	0.8 (0.78-0.82)	<.001
<11	0.05 (0.04-0.06)	<.001
11-13	1	
14-17	3.35 (3.16-3.54)	<.001
18-22	3.57 (3.37-3.77)	<.001
23-37	3.04 (2.87-3.22)	<.001
Non-T1D	1	
T1D	1.78 (1.6-1.98)	<.001
Less deprived	1	
More deprived	1.45 (1.41-1.49)	<.001

Note: 95% CI: 95% confidence intervals; WIMD index.
Abbreviations: cHR, conditional hazard ratio; T1D, type 1 diabetes; WIMD, Welsh Index of Multiple Deprivation.

3.4 | Patterns by sex

Females were overall 20% less likely to have an ARHA compared to males (Table 3). The results for each group suggested a pattern by sex that differed by age group and diabetes status. In the non-T1D group, females had slightly higher risks than males in the three younger age groups, including the 14- to 17-year olds, but a lower risk in those aged 18 to 22 and 23 to 37 than males (Table 5). Females with T1D had slightly higher risks than males only in the 11- to 13-year olds, but the opposite in the three older age groups including the 14- to 17-year olds. The risk in 14- to 17-year age group with T1D was very high and showed only relatively small differences between the sexes.

3.5 | Socioeconomic patterns

Individuals in more deprived areas overall had a 45% higher riskof ARHA than less deprived (Table 3). The association between deprivation and ARHA was, however, weaker in those with T1D compared to those without (*P*-value for two-way interaction: .014). This association between deprivation and ARHA also differed by age group for the diabetes group (Table 6). 14- to 17-year olds with T1D had the highest absolute difference in risk (relative to reference) of any group, but due to the very high HR in this age group a lower relative difference in risk than the non-T1D group aged 14 to 17 years.

More deprived 18- to 22-year olds with diabetes had a similar risk than the less deprived, thereby showing little discernible association with deprivation. In contrast, the non-T1D aged 18 to 22 years had a much higher relative and absolute difference than those with T1D, and the highest absolute (but not relative) difference amongst non-T1D.

The results using the other four deprivation measures (excluding WIMD overall reported above) were generally similar, also showing narrower inequalities in the T1D group. In the non-T1D group, the results are very similar between measures, but for those with T1D, although not statistically significant, indicated some notable differences. Using the Townsend index, relative and absolute differences in the 14- to 17-year olds with diabetes were higher compared to using WIMD in the model (Table 6). In contrast, in the 23- to 37-year olds with diabetes there was little association between the Townsend deprivation group and ARHA as differences were slightly negative. Only deprivation measured by the WIMD education domain indicated a stronger association with ARHA for the oldest age group with T1D than for all other measures.

4 | DISCUSSION

Our study found that children and young adults with T1D overall had a higher riskof ARHA, and patterns suggesting a peak at a younger age and narrower socioeconomic inequalities than those without T1D. Of particular concern are teenagers with diabetes aged 14 to 17 years who appeared to have the highest risk, around three times higher than their peers without. Females with diabetes had a lower riskof ARHA generally, including those aged 14 to 17 years, who conversely had a higher risk in non-T1D.

In the non-T1D group, females had slightly higher risks than males in the younger age groups but the opposite in the two older age groups. A similar pattern was found in a previous study of alcohol-related emergency admissions in all adolescents in Wales in which females aged 11 to 16 years had higher rates of ARHA, but males aged 17 years had higher rates than females.[16] In the T1D group in our study, however, females had a lower risk in all except the 11- to 13-year olds, suggesting that higher rates in males than females begin at an earlier age, aged 14 to 17, than in those without T1D aged 18 and above. This is perhaps surprising, as females with T1D have been shown to have worse glycaemic control and diabetes complications.[30] "Psychological barriers to optimal insulin therapy" are of particular concern in adolescent females, as are challenges relating to puberty.[31,32] This could indicate riskier behaviour and potentially

TABLE 4 Interaction model results (model C): relative risk of alcohol-related hospital admission by age group and WIMD deprivation, conditional on sex

	Non-T1D			T1D		
	Events	Person-years	cHR (95% CI)	Events	Person-years	cHR (95% CI)
Less deprived						
<11	138	3 710 843.0	0.06 (0.05-0.08)	0	3910.2	0 (0-0)
11-13	682	1 142 287.5	1 (0-0)	7	3482.6	3.37 (1.62-7)
14-17	3619	1 580 211.0	3.58 (3.29-3.9)	55	5730.6	13.08 (8.97-19.08)
18-22	5052	1 957 453.8	3.73 (3.43-4.05)	40	5259.4	7.19 (4.56-11.34)
23-37	6156	2 253 696.0	3.43 (3.15-3.74)	21	4548.7	3.35 (1.68-6.67)
More deprived						
<11	139	3 043 107.9	0.08 (0.06-0.1)	0	2915.8	0 (0-0)
11-13	875	865 090.2	1.67 (1.51-1.85)	7	2436.8	4.64 (1.49-14.43)
14-17	4221	1 182 801.6	5.26 (4.66-5.93)	57	3894.6	15.95 (10.95-23.23)
18-22	6783	1 416 355.3	5.78 (5.14-6.51)	36	3556.0	6.93 (4.22-11.35)
23-37	9992	1 890 992.3	4.67 (4.15-5.27)	25	3489.9	4.07 (2.28-7.27)

Note: 95% CI: 95% confidence intervals; three-way interaction between age group, T1D status and WIMD deprivation group. All HRs are conditional on sex (but assumed not to vary by sex) and are relative to the reference group, namely 11- to 13-year-old, less-deprived, non-T1D.
Abbreviations: cHR, conditional hazard ratio; T1D, type 1 diabetes; WIMD, Welsh Index of Multiple Deprivation.

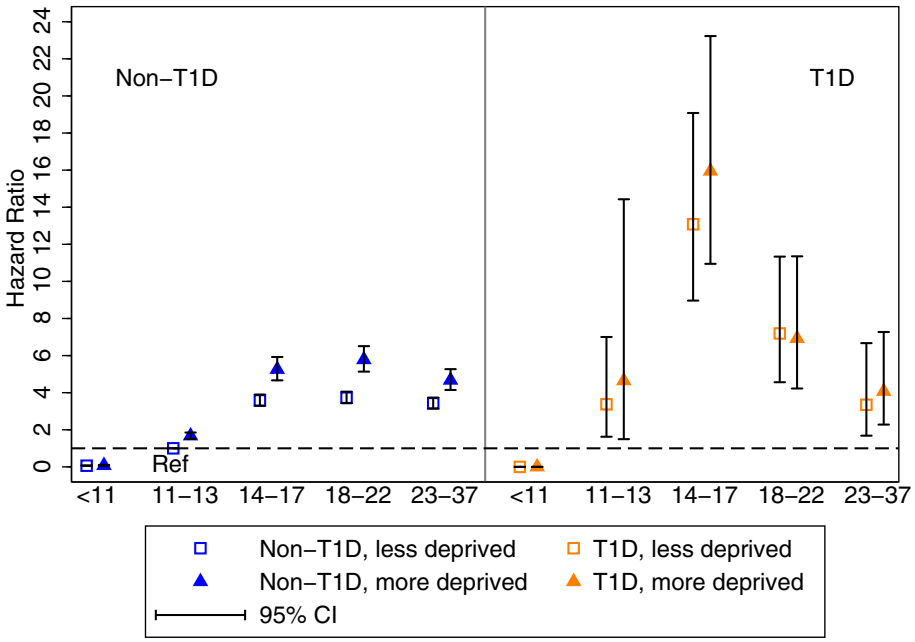

FIGURE 2 Relative risk (conditional hazard ratios and 95% confidence intervals) of alcohol-related hospital admission by type 1 diabetes (T1D) status, age group and deprivation, all relative to the reference group (11- to 13-years-old, less deprived, non-T1D). Note that all hazard ratios are also conditional on sex

include higher alcohol consumption. Reported consumption in young males with T1D in Germany and Austria was, however, higher than for girls.[12] Alcohol consumption in Europe was overall higher in young males than females, although recently in the United Kingdom and Ireland there has been gender convergence.[1] This trend would have coincided with our study of 18.5 years only in the last few years. The risk of ARHA is much higher in the T1D group generally, but with smaller differences between the sexes. The results suggest that T1D has modified the association between sex and ARHA in the age-groups, and illustrate the complex interactions.

Deprivation showed a weaker association with ARHA for the T1D group than those without and that the less deprived group is nearly as likely to be admitted. Deprived populations tend to report similar or lower alcohol consumption compared to less deprived groups, but experience differentially higher alcohol-related harm, suggesting lifestyle factors and comorbidities as possible reasons.[2] This pattern appears to be weak or absent in the T1D group unless the less deprived group disproportionally seeks help by presenting for possible admission or the less deprived drink a lot more in one sitting. Deprivation in those with T1D had previously been shown to be

TABLE 5 Interaction model results (model D): relative risk of alcohol-related hospital admission by age group and sex, conditional on deprivation

	Non-T1D			T1D		
	Events	Person-years	cHR (95% CI)	Events	Person-years	cHR (95% CI)
Males						
<11	180	3 463 296.7	0.08 (0.06-0.1)	0	3558.0	0 (0-0)
11-13	671	1 029 081.1	1 (1-1)	6	2984.5	3.1 (1.28-7.52)
14-17	3577	1 414 109.3	3.6 (3.3-3.91)	61	5119.3	14.16 (9.95-20.15)
18-22	7277	1 703 822.0	5.16 (4.75-5.6)	45	4730.3	6.89 (4.51-10.51)
23-37	11 501	2 107 906.2	4.23 (3.9-4.6)	26	4222.2	3.47 (1.84-6.56)
Females						
<11	97	3 290 654.2	0.05 (0.03-0.06)	0	3268.1	0 (0-0)
11-13	886	978 296.6	1.39 (1.25-1.54)	8	2934.9	4.12 (1.58-10.74)
14-17	4263	1 348 903.3	4.35 (3.85-4.9)	51	4505.9	12.19 (8.01-18.56)
18-22	4558	1 669 987.0	3.36 (2.98-3.8)	31	4085.0	6.02 (3.36-10.8)
23-37	5647	2 036 782.1	3.01 (2.66-3.42)	20	3816.5	3.31 (1.76-6.24)

Note: 95% CI: 95% confidence intervals; three-way interaction between age group, sex and T1D status (model D). All hazard ratios are conditional on deprivation (but assumed not to vary by deprivation) and are relative to the reference group, namely 11- to 13-year-old, male, non-T1D.
Abbreviations: cHR, conditional hazard ratio; T1D, type 1 diabetes.

positively associated with all-cause admission and ketoacidosis.[17,18,33] A study in Germany, however, found that area-level deprivation, as opposed to individual disadvantage, was only of minor importance in relation to quality of life and glycaemic control. Further research using individual-level deprivation and the social context of alcohol consumption could provide further insight. Area deprivation based on the education and employment domains showed an association with poor glycaemic control in children in England.[18] In our analysis, the choice of deprivation measure made little difference overall. We found an indication of stronger associations using the Townsend index for some age groups, and education specifically in the oldest age group with T1D. Whereas the risk of ARHA in the 23- to 37-year olds was similar in those with T1D and without, and lower than other age groups, our findings might suggest that adults living in an area with low average educational attainment could benefit from attention.

The finding that teenagers and young adults with T1D have a greatly increased risk of hospital admission is surprising given the focus on education of teenagers about how to drink alcohol safely.[8] We speculate that this finding raises questions about the effectiveness of such education and whether this needs to be delivered in a different manner to impact risk-taking behaviour at an age when such behaviour is common. Prohibitionist approaches seem ineffective in this age group who report being more likely to respond to motivating healthcare professionals who promote accepting, responsive and person-centred relationships.[34] A recent systematic review on preventing alcohol-induced hypoglycaemia in T1D suggested a limited evidence base to inform clinical practitioners and that the advice provided by most national diabetes associations is therefore based on best clinical practice alone.[6,35] However, an observational study in adolescents has suggested a reduced risk of hypoglycaemia when drinking alcohol with eating meals or snacks.[14]

An alternative possible interpretation of our findings is that paediatricians have a lower threshold for admitting teenagers aged 14 to 17 years with T1D who have been drinking alcohol because of excessive clinical concerns about these young people being at increased risk of the acute metabolic complications of alcohol ingestion such as hypoglycaemia.[7] Possible support for this interpretation arises from the observation of reduced admission rates in those with diabetes aged 18 to 22 years who are under the care of adult services, whereas the reverse pattern is seen in those without diabetes, and also that lengths of hospital stay may be slightly shorter in those with diabetes. A shorter length of hospital stay may suggest a lower threshold for admission. Alternatively, parents may ensure that teenagers are taken to hospital after alcohol consumption, whilst independent adults with T1D may not present.

The main strengths of this study are the longitudinal study design covering 1.8 million people in Wales with the birth years 1979 to 2014, and linkage to the national diabetes register with almost complete coverage.[20] The study benefitted from record-linkage and follow-up of over 18.5 years, as well as considering multiple admission events during the study period.

We have included sex as the main confounder in all main analyses, in light of sex differences in diabetes-related outcomes, as well as alcohol intake generally.[1,16,30] Deprivation is not considered to have a strong association with prevalence of T1D,[36] and genetic factors relating to country of origin with high rates of incidence are likely to be extremely rare in our population. Generalizability of our findings to other countries depends on the similarity in care system, delivery

TABLE 6 Socioeconomic inequalities in ARHA: differences between conditional HRs (relative to reference group) and ratios of conditional hazards, stratified by age group and T1D status, comparing more with less deprived

	Non-T1D		T1D	
	Difference	Ratio (95% CI)	Difference	Ratio (95% CI)
WIMD overall				
<11	0.01	1.23 (0.78-1.94)	0.00	1.02 (0.87-1.19)
11-13	0.67	1.67 (1.44-1.93)	1.27	1.38 (0.3-6.3)
14-17	1.67	1.47 (1.38-1.57)	2.87	1.22 (0.73-2.03)
18-22	2.05	1.55 (1.46-1.64)	−0.27	0.96 (0.5-1.85)
23+	1.25	1.36 (1.27-1.47)	0.72	1.22 (0.5-2.95)
Townsend				
<11	0.01	1.2 (0.77-1.89)	0.11	1.01 (0.86-1.17)
11-13	0.80	1.8 (1.55-2.08)	1.56	1.46 (0.32-6.64)
14-17	1.82	1.49 (1.4-1.59)	7.33	1.63 (0.98-2.71)
18-22	1.56	1.39 (1.31-1.47)	0.24	1.03 (0.54-1.99)
23+	1.15	1.32 (1.23-1.42)	−0.51	0.87 (0.36-2.12)
WIMD education				
<11	0.02	1.26 (0.79-1.99)	0.00	1.02 (0.87-1.19)
11-13	0.68	1.68 (1.45-1.95)	−2.16	0.55 (0.11-2.81)
14-17	1.56	1.43 (1.34-1.52)	2.34	1.17 (0.72-1.93)
18-22	1.82	1.48 (1.39-1.57)	−0.43	0.94 (0.49-1.81)
23+	1.10	1.31 (1.22-1.41)	2.20	1.85 (0.76-4.51)
WIMD income				
<11	0.02	1.25 (0.79-1.97)	1.01	1.01 (0.86-1.18)
11-13	0.70	1.7 (1.47-1.97)	1.33	1.33 (0.29-6.1)
14-17	1.70	1.47 (1.38-1.57)	1.26	1.26 (0.76-2.09)
18-22	2.21	1.59 (1.5-1.69)	0.91	0.91 (0.47-1.74)
23+	1.34	1.39 (1.29-1.5)	1.18	1.18 (0.47-2.94)
WIMD employment				
<11	0.02	1.26 (0.8-1.99)	0.00	1.01 (0.87-1.18)
11-13	0.70	1.7 (1.47-1.97)	2.17	1.72 (0.38-7.88)
14-17	1.52	1.41 (1.32-1.51)	2.70	1.2 (0.73-1.98)
18-22	2.00	1.52 (1.43-1.61)	0.32	1.05 (0.55-1.99)
23+	1.39	1.4 (1.3-1.51)	0.56	1.16 (0.48-2.82)

Note: 95% CI: 95% confidence intervals; difference and ratio of HR for more deprived and less deprived group based on WIMD overall, WIMD individual domains, and separately Townsend index (model C).
Abbreviations: ARHA, alcohol-related hospital admissions; HR, hazard ratio; T1D, type 1 diabetes; WIMD, Welsh Index of Multiple Deprivation.

of education and culture of drinking, and are likely applicable to several Western European countries.

There are inevitably some limitations relating to the data. Those who were diagnosed aged 15 years or older in Wales, or diagnosed in England or elsewhere having moved to Wales since, are incorrectly included in the non-T1D group. We estimate, however, that the number of these miscoded individuals is relatively small and unlikely to change the result and interpretation. The original register data file included 3656 people, but 81 individuals (2.2%) could not be successfully linked. Some may have left Wales or address records could not be matched, and we estimate the number of young people mistakenly included in the non-T1D group due to linkage problems to be very small. A study from 2009 compared a sample of the WDS register used within SAIL to GP records and these matched 99.99%.[25] We therefore expect any effect of linkage error on our analyses to be small. Linkage to other datasets including measurement of HbA1c could provide further insight into glycaemic control of the sub-groups.

There are limitations relating to the deprivation measure. We used two area deprivation groups, the 40% more deprived and 60% less deprived instead of deprivation fifths, because of relatively small numbers of events in some age-groups with T1D.We therefore underestimated inequalities in ARHA compared to using the full extent of

the deprivation gradient using fifths, but this underestimation is likely to be similar in the T1D group and the non-T1D group. We used area-based deprivation as a proxy for individual-level socioeconomic disadvantage, which was unfortunately not available in our dataset. We have, however, used five measures of area deprivation to investigate potential sensitivity to the type of measure used. We also incorporated deprivation as a time varying covariate, therefore reducing potential misclassification due to deprivation change through house moves.

To our knowledge this longitudinal study is the first to investigate ARHA in children and young adults with childhood onset T1D using a national diabetes register and comparison to the relevant non-T1D population. Higher alcohol consumption poses an increased risk of harm to children and young adults with T1D, particularly teenagers. A review of interventions to reduce alcohol-related harm in T1D is needed, including modification of current education and guidance for teenagers on managing alcohol consumption and possibly review of criteria for hospital admission. Further research into the individual social context in those with T1D could provide additional insight.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

John W. Gregory had the idea for the study. Rhian Daniel, Daniel Farewell, Andrea Gartner, and Shantini Paranjothy designed the study. Andrea Gartner processed and analysed the data, and drafted the manuscript. Andrea Gartner, Daniel Farewell, and Rhian Daniel decided on the statistical method. All authors interpreted the results. Andrea Gartner and John W. Gregory performed the literature search. All authors commented on the manuscript and approved the final version. None of the funders had a role in the design of the study, data collection, analysis, or interpretation, or in writing the manuscript.

DATA ACCESSIBILITY

The datasets used in this study are available in the SAIL Databank at Swansea University, Swansea, UK, but as restrictions apply, they are not publicly available. All proposals to use SAIL data are subject to review by an independent Information Governance Review Panel (IGRP). Before any data can be accessed, approval must be given by the IGRP. The IGRP gives careful consideration to each project to ensure proper and appropriate use of SAIL data. When access has been granted, it is gained through a privacy-protecting safe haven and remote access system referred to as the SAIL Gateway. SAIL has established an application process to be followed by anyone who would like to access data via SAIL at https://www.saildatabank.com/application-process.

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