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Maheswaran, R. orcid.org/0000-0002-3899-4421, Green, M.A., Strong, M. orcid.org/0000-0003-1486-8233 et al. (3 more authors) (2018) Alcohol outlet density and alcohol related hospital admissions in England: a national small-area level ecological study. Addiction, 113 (11). pp. 2051-2059. ISSN 0965-2140

https://doi.org/10.1111/add.14285

ADDICTION
SSA SOCIETY FOR THE STUDY OF ADDICTION
RESEARCH REPORT
doi:10.1111/add.14285

Alcohol outlet density and alcohol related hospital admissions in England: a national small-area level ecological study

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ABSTRACT

Background and aims Excessive alcohol consumption has a substantial impact on public health services. A key element determining alcohol availability is alcohol outlet density. This study investigated the relationship between on-trade and off-trade outlets and hospital admission rates in local neighbourhoods. **Design** National small-area level ecological study. **Setting and participants** All 32 482 lower layer super output census areas (LSOAs) in England (42 227 108 million people aged 15+ years). Densities for six outlet categories (outlets within a 1-km radius of residential postcode centroids, averaged for all postcodes within each LSOA) were calculated. **Measurements** Main outcome measures were admissions due to acute or chronic conditions wholly or partially attributable to alcohol consumption from 2002/03 to 2013/14. **Findings** There were 1 007 137 admissions wholly, and 2 153 874 admissions partially, attributable to alcohol over 12 years. After adjustment for confounding, higher densities of on-trade outlets (pubs, bars and nightclubs; restaurants licensed to sell alcohol; other on-trade outlets) and convenience stores were associated with higher admission rate ratios for acute and chronic wholly attributable conditions. For acute wholly attributable conditions, admission rate ratios were 13% (95% confidence interval = 11–15%), 9% (7–10%), 12% (10–14%) and 10% (9–12%) higher, respectively, in the highest relative to the lowest density categories by quartile. For chronic wholly attributable conditions, rate ratios were 22% (21–24%), 9% (7–11%), 19% (17–21%) and 7% (6–9%) higher, respectively. Supermarket density was associated with modestly higher acute and chronic admissions but other off-trade outlet density was associated only with higher admissions for chronic wholly attributable conditions. For partially attributable conditions, there were no strong patterns of association with outlet densities. **Conclusions** In England, higher densities of several categories of alcohol outlets appear to be associated with higher hospital admission rates for conditions wholly attributable to alcohol consumption.

Keywords Admissions, alcohol, density, England, hospital, outlets.

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Submitted 27 November 2017; initial review completed 6 March 2018; final version accepted 29 May 2018

INTRODUCTION

Excessive alcohol consumption is a major public health issue, and is the cause of a wide range of diseases wholly or partially attributable to alcohol consumption. The adverse impacts on health services are substantial; for example, costing the National Health Service (NHS) in England approximately £3.5 billion a year [1]. There is a range of policy options potentially available to policymakers to reduce alcohol consumption, including restricting the availability of alcohol. Availability is potentially amenable to control by local licensing boards and enforcement agencies which can target both specific areas and specific outlet types for more intensive regulatory scrutiny. A key element of availability is the density of outlets selling alcohol in local neighbourhoods. Previous studies of alcohol availability have focused particularly on the density of outlets selling alcohol in local neighbourhoods, as it links to several potential mechanisms by which availability may drive rates of alcohol-related harm [2]. These include reducing the real cost, including travel time, of purchasing alcohol, increasing competition between alcohol outlets so as to drive down prices and producing a more diverse market which matches supply to demand more effectively [3,4].

However, despite the substantial costs of alcohol-related hospital admissions and the striking increase in such admissions during the last two decades [5], few studies have examined the association between alcohol outlet density and hospital admissions [6–10]. These relatively small-scale studies all found some evidence of association between alcohol outlet density and hospital admissions. In contrast, several studies have examined the associations between alcohol outlet density, alcohol consumption and other alcohol-related harms, with studies generally finding positive associations [2,11–13].

There are two main categories of alcohol outlets: on-trade (on premise) outlets, where alcohol may be purchased and consumed on the premises, e.g. pubs and bars and off-trade (off premise) outlets where alcohol may be purchased but not consumed on the premises, e.g. supermarkets and convenience stores. Few studies, however, have distinguished between on-trade and off-trade outlets, and none have examined subcategories of on- and off-trade outlets [7–9]. Recent trends in outlet types in England include an increase in the number of restaurants licensed to sell alcohol and especially the marked increase in convenience stores selling alcohol, accompanied by a decrease in the number of pubs and bars [14]. In addition, alcohol consumption has both acute and chronic adverse effects on health and examination of hospital admissions offers the opportunity to examine such effects. However, few previous studies distinguished between admissions for acute and chronic alcohol-related conditions [7–9].

We carried out a national study to investigate associations between the densities of several subcategories of alcohol outlets and hospital admissions due to acute and chronic conditions wholly or partially attributable to alcohol. Our a-priori hypotheses included examining if there was any evidence of lagged effects [15].

METHODS

Study design, area and population

We employed a small area-level ecological study design, using all 32 482 lower layer super output areas (LSOAs) in England as the geographical units of analysis. LSOAs are census areas created in the 2001 national census, with approximately 1500 people per LSOA, and are the smallest spatial units at which anonymized hospital admissions data were available. Population data (mid-year estimates by LSOA, 5-year age band and sex for a 12-year study time-span) were obtained from the Office for National Statistics (ONS, London, UK). The analysis was based on people aged 15 years or more.

Data on alcohol outlets

Data on on-trade and off-trade alcohol outlets were obtained from CGA Strategy (Stockport, UK), a market research company, for the years 2003, 2007, 2010 and 2013. Details have been provided previously [14]. The company estimated that the databases included approximately 98% of all outlets in England. Each year approximately 85% of all outlets, including 95% of pubs, were actively confirmed to be trading. Data from this company have been used by Public Health England (London, UK) [16].

Outlet types were available in a 69-category classification for on-trade and an eight-category classification for off-trade outlets. We grouped on-trade outlets into: (i) pubs, bars and nightclubs; (ii) restaurants with a licence to sell alcohol; and (iii) all other on-trade outlets and off-trade outlets into: (i) supermarkets; (ii) convenience stores; and (iii) all other off-trade outlets, as described previously [14]. Pubs, bars and nightclubs decreased from 55 105 in 2003 to 49 940 in 2013 and other on-trade outlets decreased from 48 727 to 36 191, but licensed restaurants increased from 18 410 to 21 433 [14]. Off-trade outlets increased in all three categories (convenience stores from 8083 to 16 467; supermarkets from 4417 to 5859; and other off-trade outlets from 20 892 to 23 134) [14].

We defined outlet density as the number of outlets within a 1-km radius of a residential postcode centroid, averaged (postcode population weighted) for all postcodes within an LSOA (1.2 million residential postcodes; approximately 35 postcodes per LSOA). This approach did not constrain the density count to areas within an LSOA boundary, an approach we have used previously [17,18]. The National Travel Survey indicated that 1 km is the average walking journey length [19]. In a subset of the data, we also examined the effects of using other radii (250 m, 3 km and 5 km). A Competition Commission (London, UK) report indicated that 80–90% of consumers lived within 5 km of convenience stores [20]. We used linear interpolation to derive values between years with extrapolation to 2002.

Hospital admissions data

We used Hospital Episode Statistics (HES) data on admissions to NHS hospitals in England from 2002/03 to 2013/14 (financial years run from 1 April to 31 March the following year). We have described the extraction process for alcohol-related admissions in detail previously, including the list of the International Classification of Diseases, 10th revision (ICD-10) codes [5]. We were guided by the approach used by Public Heath England in their ‘narrow’ measure to identify admissions attributable wholly or partially to alcohol [21]. This measure used only the primary diagnosis of an admission, except for 'external' conditions from secondary diagnosis fields. Admissions were weighted by age- and sex-specific alcohol-attributable fractions (AAF) used by Public Health England [21,22].

We examined four main outcome categories. These were acute or chronic conditions attributable wholly (AAF = 1) or partially (AAF < 1) to alcohol. In addition, we examined two specific acute conditions wholly attributable to alcohol: (i) Acute Intoxication subcategory of Mental and Behavioural Disorders due to use of Alcohol (F10.0); and (ii) Intentional self-poisoning due to alcohol (X65); and two chronic conditions wholly attributable to alcohol, (i) All other Mental and Behavioural Disorders due to use of Alcohol (F10.1–F10.9); and (ii) Alcoholic Liver Disease (K70). For acute conditions, we considered only emergency admissions. For chronic conditions, we used data on emergency and non-emergency admissions. Admissions in HES comprise 'episodes' of care. We used information from the first episode in each admission [23,24].

Other variables

We used the Income Domain from the English Index of Multiple Deprivation (IMD) 2007 to adjust for socio-economic deprivation at the LSOA level [25], the ONS Rural Urban Classification to classify LSOAs as either (i) urban; (ii) rural (town and fringe); or (iii) rural (village; hamlets and isolated dwellings) [26], and included the nine English Regions to account for regional variation in admissions [27].

Admission to hospital may be influenced by a wide variety of service-level and local factors, including a hospital's admission policies, availability of hospital beds, the level and quality of primary and community care in a local area, geographical access to health facilities and local variation in cultural and social norms influencing illness behaviour. We used admissions for non-alcohol-related conditions as a proxy for these other factors.

In addition, a hypothesis that might potentially explain any association between outlet density and health outcomes is that outlets cluster in 'unhealthy' areas where illness levels are high and harmful health behaviours such as smoking are prevalent [15]. We used lung cancer admissions as a proxy for such areas. As annual LSOA counts of lung cancer admissions were very sparse, we summed admissions for all 12 years.

Statistical analysis

We used Poisson regression to examine associations between outlet densities on admissions, using the log of age and sex standardized expected counts as the offset. As the associations were non-linear, we categorized outlet densities by quartiles using distributions for the 12-year period combined.

Year, rural–urban classification, region and deprivation (categorized by quintile) were entered as categorical variables. The logs of the ratio of observed-to-expected counts for non-alcohol-related admissions and lung cancer admissions were entered as continuous variables.

We carried out subsidiary analyses based on a *priori* hypotheses [15]. We examined lagged effects, examined associations between changes in outlet density and changes in hospital admissions, examined the effects of changing the distance radius used for calculating outlet density and used Bayesian hierarchical modelling incorporating unstructured and spatially structured random effects to examine residual spatial autocorrelation [28]. Results are presented as rate ratios with 95% confidence intervals (95% CI). We inflated CIs to take account of any overdispersion.

Ethical approval

The study was approved by the University of Sheffield (School of Health and Related Research) Research Ethics Committee.

Data sharing

The data on alcohol outlets may be obtained from CGA Strategy (http://www.cgastrategy.co.uk/). Data on hospital admissions in England may be obtained from NHS Digital (https://digital.nhs.uk/).

RESULTS

Admission counts and outlet densities

There were 1 007 137 admissions wholly, and 2 153 874 admissions partially, attributable to alcohol over 12 years among a population of 42 227 108 (mid-2007) aged 15+ years (the partially attributable count is the sum of the fraction of each admission attributable to alcohol). Increases in admission counts by outcome category ranged from 37 to 189% during the study period (Table 1). This needs to be seen in the context of an increase of 37% in non-alcohol related admissions and 10% in the population aged 15+ years during the same period. Admissions for intentional self-poisoning using alcohol and acute alcohol intoxication accounted for 60 and 29%, respectively, of all acute wholly attributable conditions in 2013/14. Admissions for mental and behavioural disorders due to alcohol and alcoholic liver disease accounted for 54 and 32%, respectively, of all chronic wholly attributable conditions in 2013/14.

Outlet density by type (count within 1-km radius of a residential postcode centroid, averaged for all postcode centroids within an LSOA) ranged from a median

Table 1 Alcohol-attributable admissions to hospital for conditions related to alcohol in the population aged 15 years or more; England 2002/03 and 2013/14 (HES data years at the start and end of study period).

Conditions attributable to alcohol		*Year* 2002/03	*Year* 2013/14	*% increase (2013/14–2002/03)*
Wholly and partially attributable categories	Acute conditions wholly attributable to alcohol	20 602	51 363	149
	Chronic conditions wholly attributable to alcohol	34 086	50 117	47
	Acute conditions partially[a] attributable to alcohol	44 589	63 671	43
	Chronic conditions partially[a] attributable to alcohol	98 768	135 604	37
Specific conditions wholly attributable to alcohol	**Acute conditions**			
	Acute alcohol intoxication (F10.0)	5185	14 967	189
	Intentional self-poisoning using alcohol (X65)	11 798	31 046	163
	Chronic conditions			
	Mental and behavioural disorders due to alcohol (F10.1–F10.9)	19 318	26 905	39
	Alcoholic liver disease (K70)	11 135	16 142	45
Non-alcohol-related admissions		8 289 410	11 386 899	37
Population		40 443 423	44 287 500	10

[a]Partially attributable conditions totals are sum of the fraction of each admission attributable to alcohol. HES = Hospital Episode Statistics.

(interquartile range) of 4.79 (2.39–10.47) for pubs, bars and nightclubs to 0.74 (0.00–1.70) for supermarkets (Table 2).

Main associations between outlet densities and admissions (Table 3)

For acute wholly attributable conditions, admission rate ratios (95% CI) were clearly highest in the highest, relative to the lowest, outlet density categories for all three on-trade outlet categories: 13% (11–15%) higher for pubs, bars and nightclubs; 12% (10–14%) for other on-trade outlets; and 9% (7–10%) for restaurants. For off-trade outlets, a clear association was seen for convenience stores (10% (9–12% higher)). For supermarkets, however, the rate ratio was only 3% (2–4%) higher, while for other off-trade outlets, it appeared to be lower at −12% (−13 to −11%).

Table 2 Distribution of outlet densities (number of outlets within a 1-km radius of a postcode centroid, averaged for all postcodes within an LSOA) in England, 2002–13.

Outlet category	*Median (IQR)*
On-trade outlets	
Pubs, bars, nightclubs	4.79 (2.39–10.47)
Restaurants	1.02 (0.03–4.06)
Other on-trade outlets	4.28 (1.98–8.13)
Off-trade outlets	
Supermarkets	0.74 (0.00–1.70)
Convenience stores	1.86 (0.81–3.23)
Other off-trade outlets	3.05 (1.03–6.87)
LSOAs in England (*n*)	32 482

LSOA = lower layer super output area; IQR = interquartile range.

For chronic wholly attributable conditions, associations with pubs, bars and nightclubs and other on-trade outlets were even stronger than those seen with acute wholly attributable conditions. The rate ratios were 22% (21–24%) higher for pubs, bars and nightclubs and 19% (17–21%) for other on-trade outlets. The 9% (7–11%) higher rate ratio for restaurants was similar to that for acute wholly attributable conditions. For off-trade outlets, the 7% (6–9%) higher rate ratio for convenience stores was marginally less than the equivalent for acute wholly attributable conditions but for supermarkets, the 4% (3–5%) higher rate ratio was similar. A positive association was seen for other off-trade outlets, with an 11% (9–12%) higher rate ratio in the highest density category, unlike the negative association for acute wholly attributable conditions.

For acute and chronic conditions partially attributable to alcohol, there was generally no strong evidence of association with any of the alcohol outlet categories. The only exception was for pubs, bars and nightclubs, where the admission rate ratio for chronic partially attributable conditions in the highest density category was 6% (6–7%) higher relative to the lowest density category.

For the two specific acute wholly attributable conditions, the pattern of associations with the on-trade categories was broadly in keeping with that for acute wholly attributable conditions as a whole, except for restaurants

Table 3 Associations between alcohol outlet density and hospital admissions attributable to alcohol for men and women combined at the LSOA level; England 2002/03 to 2013/14. Rate ratios (95% CI) for categories by quartile of outlet density for people aged 15+ years are shown (outlet density within a 1-km radius of a postcode centroid, averaged for all postcodes within an LSOA).

	Rate ratios (95% CI) for alcohol outlet categories by quartile of outlet density (1 = lowest; 4 = highest)			
Condition and alcohol outlet category	*1*	*2*	*3*	*4*
Acute conditions wholly attributable to alcohol				
Pubs, bars, nightclubs	1	1.03 (1.02–1.04)	1.05 (1.04–1.06)	1.13 (1.11–1.15)
Restaurants	1	1.00 (0.99–1.01)	0.98 (0.97–0.99)	1.09 (1.07–1.10)
Other on-trade outlets	1	1.04 (1.02–1.05)	1.04 (1.02–1.05)	1.12 (1.10–1.14)
Supermarkets	1	0.99 (0.98–1.00)	0.98 (0.97–0.99)	1.03 (1.02–1.04)
Convenience stores	1	1.04 (1.03–1.05)	1.06 (1.05–1.07)	1.10 (1.09–1.12)
Other off-trade outlets	1	1.01 (0.99–1.02)	0.96 (0.95–0.98)	0.88 (0.87–0.89)
Chronic conditions wholly attributable to alcohol				
Pubs, bars, nightclubs	1	1.04 (1.02–1.05)	1.06 (1.05–1.08)	1.22 (1.21–1.24)
Restaurants	1	1.00 (0.99–1.01)	0.96 (0.95–0.97)	1.09 (1.07–1.11)
Other on-trade outlets	1	1.06 (1.04–1.07)	1.06 (1.05–1.08)	1.19 (1.17–1.21)
Supermarkets	1	0.98 (0.97–0.99)	0.97 (0.96–0.98)	1.04 (1.03–1.05)
Convenience stores	1	1.02 (1.01–1.03)	1.03 (1.02–1.04)	1.07 (1.06–1.09)
Other off-trade outlets	1	1.06 (1.04–1.07)	1.08 (1.07–1.10)	1.11 (1.09–1.12)
Acute conditions partially attributable to alcohol				
Pubs, bars, nightclubs	1	1.00 (1.00–1.01)	1.00 (0.99–1.01)	1.02 (1.01–1.03)
Restaurants	1	1.00 (0.99–1.00)	0.98 (0.98–0.99)	0.99 (0.98–1.00)
Other on-trade outlets	1	1.00 (0.99–1.01)	1.00 (1.00–1.01)	1.02 (1.01–1.03)
Supermarkets	1	1.00 (0.99–1.01)	1.00 (1.00–1.01)	1.02 (1.01–1.03)
Convenience stores	1	1.01 (1.00–1.02)	1.01 (1.00–1.02)	1.02 (1.01–1.03)
Other off-trade outlets	1	1.00 (0.99–1.01)	0.99 (0.98–1.00)	0.97 (0.96–0.98)
Chronic conditions partially attributable to alcohol				
Pubs, bars, nightclubs	1	1.01 (1.00–1.02)	1.03 (1.02–1.04)	1.06 (1.06–1.07)
Restaurants	1	0.99 (0.99–1.00)	0.99 (0.99–1.00)	1.01 (1.00–1.01)
Other on-trade outlets	1	1.00 (0.99–1.00)	0.98 (0.98–0.99)	1.00 (0.99–1.01)
Supermarkets	1	1.01 (1.00–1.01)	1.01 (1.00–1.02)	1.00 (1.00–1.01)
Convenience stores	1	0.99 (0.99–1.00)	1.00 (0.99–1.00)	0.98 (0.98–0.99)
Other off-trade outlets	1	0.98 (0.98–0.99)	0.99 (0.98–0.99)	1.01 (1.00–1.02)
Acute alcohol intoxication (F10.0)				
Pubs, bars, nightclubs	1	1.02 (1.00–1.04)	1.04 (1.02–1.06)	1.16 (1.13–1.19)
Restaurants	1	1.00 (0.98–1.02)	1.02 (1.00–1.04)	1.22 (1.19–1.25)
Other on-trade outlets	1	1.03 (1.01–1.05)	1.01 (0.99–1.03)	1.11 (1.08–1.13)
Supermarkets	1	0.98 (0.97–1.00)	0.97 (0.95–0.99)	1.01 (0.99–1.03)
Convenience stores	1	1.03 (1.01–1.05)	1.06 (1.04–1.08)	1.12 (1.10–1.14)
Other off-trade outlets	1	1.04 (1.02–1.06)	1.03 (1.01–1.05)	0.99 (0.96–1.01)
Intentional self-poisoning using alcohol (X65)				
Pubs, bars, nightclubs	1	1.04 (1.03–1.05)	1.07 (1.05–1.08)	1.13 (1.11–1.15)
Restaurants	1	1.00 (0.99–1.01)	0.96 (0.95–0.97)	1.03 (1.01–1.04)
Other on-trade outlets	1	1.04 (1.03–1.05)	1.04 (1.03–1.06)	1.11 (1.09–1.13)
Supermarkets	1	1.00 (0.99–1.01)	0.99 (0.98–1.00)	1.06 (1.05–1.07)
Convenience stores	1	1.05 (1.04–1.07)	1.07 (1.06–1.09)	1.11 (1.10–1.13)
Other off-trade outlets	1	0.98 (0.97–0.99)	0.92 (0.91–0.93)	0.81 (0.80–0.82)
Mental and behavioural disorders due to alcohol (F10.1–F10.9)				
Pubs, bars, nightclubs	1	1.01 (1.00–1.03)	1.04 (1.02–1.05)	1.18 (1.16–1.21)
Restaurants	1	0.99 (0.97–1.00)	0.96 (0.94–0.97)	1.12 (1.10–1.14)
Other on-trade outlets	1	1.06 (1.04–1.07)	1.08 (1.06–1.09)	1.25 (1.22–1.27)
Supermarkets	1	0.97 (0.96–0.98)	0.98 (0.97–1.00)	1.05 (1.04–1.07)
Convenience stores	1	1.03 (1.02–1.05)	1.04 (1.02–1.05)	1.09 (1.07–1.10)
Other off-trade outlets	1	1.07 (1.05–1.08)	1.09 (1.07–1.11)	1.07 (1.06–1.09)
Alcoholic liver disease (K70)				
Pubs, bars, nightclubs	1	1.05 (1.04–1.07)	1.10 (1.08–1.12)	1.30 (1.27–1.33)
Restaurants	1	1.02 (1.01–1.04)	0.96 (0.95–0.98)	1.03 (1.01–1.05)

(***Continues***)

Table 3. (Continued)

	Rate ratios (95% CI) for alcohol outlet categories by quartile of outlet density (1 = lowest; 4 = highest)			
Condition and alcohol outlet category	*1*	*2*	*3*	*4*
Other on-trade outlets	1	1.06 (1.04–1.08)	1.03 (1.02–1.06)	1.13 (1.10–1.15)
Supermarkets	1	0.99 (0.98–1.01)	0.96 (0.95–0.98)	1.03 (1.01–1.04)
Convenience stores	1	1.01 (1.00–1.03)	1.02 (1.00–1.03)	1.06 (1.04–1.08)
Other off-trade outlets	1	1.04 (1.02–1.05)	1.06 (1.04–1.08)	1.15 (1.12–1.17)

LSOA = lower layer super output area; CI =confidence interval.

(stronger association with acute alcohol intoxication and weaker association with intentional self-poisoning using alcohol). The patterns for off-trade outlets for the two specific acute wholly attributable conditions were broadly similar to those for acute wholly attributable conditions as a whole.

For the two specific chronic wholly attributable conditions, overall patterns of association were similar to those for chronic wholly attributable conditions as a whole for on-trade and off-trade outlet categories. However, there were some differences in the magnitude of associations observed (30% (27–33%) higher admission rate ratio for pubs, bars and nightclubs in relation to alcoholic liver disease; 25% (22–27%) higher admission rate ratio for other on-trade outlets in relation to mental and behavioural disorders due to alcohol).

Lagged effects, changes in density and admissions, distance radii and spatial random effects

Effect sizes were very similar for concurrent and previous (lagged) exposure measures (Supporting information, Table S1). In particular, there was no evidence to suggest that concurrent outlet density was associated more strongly with acute conditions, and outlet density in previous years was associated more strongly with chronic conditions. Most admissions were in LSOAs that remained unchanged in terms of outlet density category, and there were no consistent patterns overall in associations between changes in outlet density and changes in hospital admissions (Supporting information, Table S2). The use of radii greater than 1-km diminished effect sizes (Supporting information, Table S3). Results obtained from Bayesian spatial models were generally consistent with results from non-spatial models (Supporting information, Table S4).

DISCUSSION

Summary of results

Higher densities of all three subcategories of on-trade outlets (pubs, bars and nightclubs; licensed restaurants; other on-trade outlets) were associated with higher admission rate ratios for acute and chronic wholly attributable conditions. With regard to off-trade outlets, convenience store density was associated with higher admissions of acute and chronic wholly attributable conditions. Supermarket density was associated only with modestly higher admissions of acute and chronic conditions, while other off-trade outlets were associated only with higher admissions for chronic wholly attributable conditions. For conditions partially attributable to alcohol, there were no strong associations with outlets. There was no evidence of lagged effects of outlet density on admissions. Examination of associations between changes in outlet density and changes in admissions was inconclusive.

Interpretation of results

Few studies have examined links between outlet density and hospital admissions [6–10]. A study in San Diego County found higher admissions associated with higher outlet density, but did not differentiate between on and off-trade outlets or acute and chronic conditions [6]. In Melbourne, on-trade outlets were found to be associated with admissions for assault (used as an indicator of acute effects) and, to a lesser extent, chronic conditions attributable to alcohol while off-trade outlets were linked to both acute and chronic conditions [7]. In contrast, a study in British Columbia found no significant links between on-trade outlets and acute and chronic alcohol-related admissions, but observed associations with off-trade outlets [8]. A four-city study in Scotland, which examined alcoholic liver disease in addition to all wholly attributable conditions combined, reported higher admissions in relation to both on- and off-trade density [9]. An all-Wales study found that increasing outlet density was linked to higher admissions, but did not distinguish between the effects of on- and off-trade outlets [10].

A key novel aspect of our study is that we examined subcategories of on-trade and off-trade outlets. For on-trade outlets, we found associations between pubs, bars and nightclubs and both acute and chronic wholly attributable conditions, as we had expected [15]. The strongest link was between pubs, bars and nightclubs and admissions for alcoholic liver disease. We also observed associations between restaurants and other on-trade outlets and acute and chronic wholly attributable conditions, which we had not expected [15]. The other on-trade outlets category is a heterogeneous group of outlets, but restaurants are a clearly defined category and merit further investigation to establish if there is a causal link.

With regard to off-trade outlets, we found that convenience stores were associated with both acute and chronic wholly attributable conditions, while supermarkets had only minimal associations with both, broadly in line with our prior expectations [15]. Although supermarkets are likely to account for a significant proportion of alcohol sales, they tend to serve large catchment areas and are unlikely to exert strong local density effects. Other off-trade outlets are a heterogeneous group, and while they were associated positively with chronic wholly attributable conditions there was an apparent negative association with acute wholly attributable conditions. Possible explanations for the latter include negative confounding and a chance finding. In this context, however, it is interesting to note that a study in Perth, Australia also found unexpectedly that a higher density of off-trade outlets was associated with lower emergency department attendances for alcohol-related injuries [29].

While Stockwell *et al.* observed that alcohol price changes exerted effects observable at zero lag for acute alcohol-related conditions but which became apparent only from a 2-year lag onwards for chronic conditions, we found no evidence of differential lagged effects for outlet density [8]. In addition, we found no consistent patterns of association between changes in outlet density and changes in hospital admissions. Current and previous outlet densities were, however, correlated quite highly, which would have reduced our chances of detecting differential lagged effects or covariation in outlet density and hospital admissions.

It has been postulated that increases in availability of alcohol may have diminishing effects as baseline availability increases [30]. Overall outlet density is generally relatively high in England [31]. However, we did not observe any diminishing effects, and in fact observed that effects were much more noticeable in the highest density categories. This raises the possibility that if outlet density and hospital admissions are causally linked, the mechanisms mediating the link (e.g. reduction in real cost, diversification of the market to better match supply to demand) [3,4] only exert their effects when density is quite high. With regard to the distance radii used to calculate density of outlets around postcode centroids, the 1-km radius was sufficient for detecting associations. While more complex measures of density have been used in other studies, we felt that the method we used was intuitive and relatively easy to interpret.

Limitations

Our study has a number of key strengths, including the novel use of detailed outlet types, the analysis of a substantial volume of hospital admissions data at a fine spatial scale with a temporal element and examination of acute and chronic conditions wholly and partially attributable to alcohol. Nevertheless, there are a number of potential limitations to be considered.

We used an ecological study design which has recognized limitations, including ecological bias, which describes the situation where associations observed at the ecological (area) level are different from those which exist at the individual level. However, we used small geographical areas as the units of analysis and exposures and population characteristics are likely to be more homogeneous in smaller geographical areas, reducing the risk of ecological bias.

Hospital admissions data have a number of potential limitations. There are likely to be geographical variations in admission practices and in other factors influencing admission. We adjusted for this using several covariates, but residual confounding cannot be ruled out. Spatial analysis adjusting for residual spatial autocorrelation on a subset of the data did not, however, alter patterns of association observed substantially. Inaccuracies in diagnosis and coding and variation in diagnostic and coding practices over time and by place are further potential sources of error. Imprecision in attributable fractions could have contributed to the general lack of association observed in relation to partially attributable conditions.

There may also have been limitations of the alcohol outlets data used, including varying levels of completeness of data capture over time and by place, and misclassification of outlet type.

Chance findings remain a possibility although the substantial volume of data analysed reduces this likelihood. Although our analyses were pre-specified, associations arising by chance remain a possibility, given the multiple analyses undertaken. Reverse causality is another possible explanation, as higher demand for alcohol could have led to an increase in outlet density. However, while reverse causality may apply to pubs and bars, it seems unlikely that local demand for alcohol would be a key driver for opening more restaurants and convenience stores in the neighbourhood. Nevertheless, although we have observed clear associations between alcohol outlet densities and hospital admissions, our study cannot confirm if these associations are causally linked.

Potential implications

There is emerging evidence suggesting that local authorities more active in implementing licensing policy, including using cumulative impact zones and increased licensing enforcement, may see bigger falls in harm outcomes [32,33]. The evidence from our national study contributes to the evidence base informing licensing policy decisions, including in relation to decisions targeting specific areas and outlet types for more intensive regulatory scrutiny. Local licensing decisions may have an impact on the health of the local population and the burden on local hospitals.

Declaration of interests

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare that all authors report a grant from Alcohol Research UK, during the conduct of the study. C.A. has received funding for unrelated commissioned research from Systembolaget, the Swedish government-owned alcohol retail monopoly. All other authors declare no other financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years; and no other relationships or activities exist that could appear to have influenced the submitted work.

Acknowledgements

This study was funded by Alcohol Research UK (Grant no.: R 2014/03). Alcohol Research UK is an independent charity working to reduce alcohol-related harm through ensuring policy and practice can be developed on the basis of reliable, research-based evidence. The views expressed in this paper are those of the authors and do not necessarily reflect those of the funding body. We would like to thank Alcohol Research UK for supporting this research. The authors are solely responsible for the content of this paper. Hospital Episodes Statistics data are copyright 2015©, re-used with permission of NHS Digital. All rights reserved. This work uses Crown copyright data supplied by Ordnance Survey.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1 Lagged effect (3–4-year lag)* of outlet density measures limiting the outcome data examined to years where there was a concurrent as well as a previous set of outlets data provided by CGA Strategy (i.e. 2007, 2010 and 2013). Acute and chronic conditions wholly attributable to alcohol were examined in relation to pubs, bars and nightclubs and convenience stores, England. Rate ratios (95% confidence interval) for category by quartile of outlet density for men and women combined are shown (outlet density within a 1-km radius of a postcode centroid, averaged for all postcodes within a lower layer super output area.

Table S2 Associations between changes in alcohol outlet density and changes in hospital admissions, examined by cross-classifying lower layer super output areas (LSOAs) by concurrent and previous exposure.* Outcome data were limited to years in which outlets data were provided by CGA Strategy (i.e. 2003, 2007, 2010 and 2013). Acute and chronic conditions wholly attributable to alcohol were examined in relation to pubs, bars and nightclubs and convenience stores, England. Ratios (95% confidence interval) of concurrent observed/expected admissions to previous observed/expected admissions, relative to the appropriate unchanged category along each row, are shown. Results are for men and women combined (outlet density within a 1-km radius of a postcode centroid, averaged for all postcodes within an LSOA).

Table S3 Effect of varying the distance radii used to calculate outlet density on the associations between alcohol outlet density and acute admissions wholly attributable to alcohol; examined in relation to pubs, bars and nightclubs and convenience stores, England 2002/03 to 2013/14. Rate ratios (95% confidence interval) for category by quartile of outlet density for men and women combined are shown (outlet density within the specified radius of a postcode centroid, averaged for all postcodes within a lower layer super output area SOA) .

Table S4 Effect of Bayesian hierarchical modelling incorporating unstructured and spatially structured random effects on rate ratios compared with the standard modelling approach. Rate ratios (95% confidence interval) are for acute conditions wholly attributable to alcohol and are shown only for the highest outlet density category by quartile for men and women combined (outlet density within a 1-km radius of a postcode centroid, averaged for all postcodes within a lower layer super output area; England 2002/03 to 2013/14.