



Contents lists available at ScienceDirect

## Addictive Behaviors



## Associations between alcohol outlet densities and adolescent alcohol consumption: A study in Australian students

B. Rowland<sup>a,\*</sup>, J.W. Toumbourou<sup>a</sup>, L. Satyen<sup>a</sup>, G. Tooley<sup>a</sup>, J. Hall<sup>a</sup>, M. Livingston<sup>b,c</sup>, J. Williams<sup>a,d,e</sup>

<sup>a</sup> Department of Prevention Sciences, Centre for Mental Health and Wellbeing Research and School of Psychology, Deakin University, Victoria, Australia

<sup>b</sup> Drug Policy Modelling Program, National Drug and Alcohol Research Centre, University of New South Wales, Sydney, NSW 2052, Australia

<sup>c</sup> Centre for Alcohol Policy Research, Turning Point Alcohol and Drug Centre, 54–62 Gertrude Street, Fitzroy, VIC 3065, Australia

<sup>d</sup> Murdoch Children's Research Institute, The Royal Children's Hospital, Melbourne, Victoria, Australia

<sup>e</sup> Department of Paediatrics, The University of Melbourne, Parkville, Australia

### HIGHLIGHTS

- Adolescent alcohol consumption is linked to an array of health and developmental problems.
- Understanding how alcohol is accessed will improve children's developmental trajectories.
- We examined whether density of outlets is associated with adolescent alcohol consumption.
- We identified that a greater density is associated with an increased risk of alcohol consumption.
- Managing the number of alcohol outlets per area may be a method of reducing access and consumption.

### ARTICLE INFO

Available online xxxx

#### Keywords:

Alcohol density  
Adolescents  
Alcohol availability  
Multilevel modelling  
Elasticity

### ABSTRACT

**Objective:** To assess whether the density of alcohol sales outlets in specific geographic communities is associated with adolescent alcohol consumption.

**Method:** A cross-sectional representative sample of secondary school students from Victoria, Australia (N = 10,143), aged between 12 and 17 years, self-reported on alcohol use in the last 30 days in 2009. The density of alcohol outlets per local community area was merged with this information.

**Results:** After controlling for risk factors, multilevel modelling (MLM) revealed a statistical interaction between age and density on alcohol consumption. While older adolescents had higher alcohol consumption, increases in the density of alcohol outlets were only significantly associated with increased risk of alcohol consumption for adolescents between the ages of 12 and 14.

**Conclusion:** Increased alcohol availability was associated with an increased risk of alcohol consumption specifically for early adolescents (12 and 14 years). Potential mechanisms such as on how density is associated with direct and indirect alcohol availability, such as through parents or older siblings, need to be explored in future research.

© 2013 Elsevier Ltd. All rights reserved.

### 1. Introduction

In Australia, the National Drinking Guidelines discourage children and adolescents from consuming alcohol under the age of 18, the legal age for purchasing alcohol (NHMRC, 2009). Despite this recommendation, 61% of Australian children aged between 12 and 17 have consumed alcohol (White & Smith, 2009). Further, Australian children have high rates of alcohol use relative to children in the United States (Toumbourou, Hemphill, McMorris, Catalano, & Patton, 2009) and consume alcohol at younger ages relative to children in Europe (Jonkman,

Steketee, Tombourou, Cini, & Williams, 2012). In many countries, adolescent consumption increases with age (AIHW, 2011; Johnston, O'Malley, Bachman, & Schulenberg, 2011).

The early uptake and consumption of alcohol by adolescents are associated with an array of poor physical, psychological, and psychosocial outcomes. These include greater risk of progressing to heavier adolescent alcohol use (Mason et al., 2011), poor academic outcomes (Koch & McGeary, 2005), greater risk of becoming dependent (Bonomo, Bowes, Coffey, Carlin, & Patton, 2004), problem drinking in adult life (McCambridge, McAlaney, & Rowe, 2011), and adverse mental and physical health in the adult years (Andreasson, Romelsjo, & Allebeck, 2006). Given these consequences, it behoves us to identify modifiable factors that may influence alcohol use by this population group.

\* Corresponding author at: Deakin University, School of Psychology, Faculty of Health, 221 Burwood Highway, Burwood, VIC 3125, Australia. Tel.: +61 3 9244 3002.

E-mail address: bosco.rowland@deakin.edu.au (B. Rowland).

A range of factors are known to increase the risk, or protect, an adolescent from using or taking up alcohol. Hawkins, Catalano, and Miller (1992) have organized these factors into domains at the community, school, family, peer and individual levels. While risk factors in each domain can be targeted as a means of changing alcohol-related behaviour, community influences may be particularly important factors affecting the supply of alcohol (Livingston, Chikritzhs, & Room, 2007), alcohol availability being a necessary precondition for its consumption.

Although research examining adolescents is lacking, cross-sectional and longitudinal studies in adults have shown strong evidence for an associations between the density of alcohol outlets and the levels of alcohol consumption and alcohol related harm (Gruenewald, 2007; Livingston et al., 2007; Stockwell & Gruenewald, 2004). Further evidence for this association comes from natural experiments, where alcohol related behaviour is measured in locations where alcohol outlets have increased or decreased in number due to changes in legislation (Babor et al., 2010).

In Australia, data gathered over 9 years (1996–2005) in the south-eastern state of Victoria, found that more relaxed alcohol policy regulations led to increased density of alcohol outlets within the community and that this was associated with both increased violence (Livingston, 2011) and an increase in the rate of physical assault (Livingston, 2008). Two Australian studies examining the relationship between outlet density and consumption, found significant associations between off-premise outlet densities and heavy episodic drinking in adults (Kavanagh et al., 2011; Livingston, Laslett, & Dietze, 2008).

The evidence linking density with adolescent consumption is gradually building. Studies in New Zealand and the USA have shown an association between density and the typical amount consumed, binge drinking, and the driving after drinking (Huckle, Huakau, Sweetsur, Huisman, & Casswell, 2008; Truong & Sturm, 2007). Further, recently, large national studies in Switzerland (Kuntsche, Kuendig, & Gmel, 2008) and the USA (Stanley, Henry, & Swaim, 2011) controlling statistically for “perceived availability”, a proxy measure for the degree to which families and the community may be more permissive of adolescents consuming alcohol have been undertaken. These studies have shown significant associations between the density of alcohol outlets and adolescent consumption.

However, to date, no study has examined such associations with an Australian population. As the likelihood of adolescent consumption increases with age, it is possible that the association of density with consumption also differs by age. Further, as the availability of alcohol physically differs by venue type (i.e. packaged outlets vs. on-premises), it is likely that the association of consumption with density also differs by venue type. Using a representative sample of Australian secondary school children across the State of Victoria, in Australia, the present study examined these possibilities while controlling for a variety of risk factors known to influence adolescent alcohol consumption.

Variables controlled included demographic, socioeconomic and family factors, adolescent adjustment (indicated by tobacco use and mental health) peer risk factors, and perceived availability of alcohol. We hypothesised that a greater community density of alcohol outlets would be associated with a higher risk of adolescent alcohol consumption. Given that adolescents report different sources of alcohol supply at different ages (AIHW, 2011; White & Smith, 2009), we further hypothesised that density would have different effects for different adolescent age-groups.

## 2. Methods

### 2.1. Design

Data were collected in 2009 through the HowRU secondary student survey that was designed to provide representative epidemiological estimates of adolescent health and wellbeing indicators for all metropolitan local government communities and non-metropolitan regions

across the state of Victoria (Department of Education & Early Childhood Development, 2009). The survey instrument was developed under the guidance of a steering committee convened by the State Government Department of Education and Early Childhood Development. The instrument was designed to provide data for key adolescent health and wellbeing indicators that could not be addressed through other sources of data.

Scales that had been validated in national and/or international studies for use in adolescents were chosen to address each indicator whenever possible. A two-stage cluster sample design was used to recruit students. In the first stage, schools were randomly selected based on a probability proportional to each community's grade-level size from a stratified sampling frame of all schools in Victoria (government, Catholic, and independent).

In the second stage of the data collection, whole classes in school years 7, 9 and 11 were chosen at random and tested. At the outset the study and survey procedures were approved through the Royal Children's Hospital Ethics Office. Following this, ethics approval was then sought from the all the education sectors (government schools, Catholic schools, and Independent schools). After this permission was sought from the principal from each school that was approached to participate in the study.

Prior to data collection, a letter was mailed directly to students and their parents describing the study, along with an information statement and a consent form. Passive consent was required from parents for student participation. On the day of the survey, students were informed of the survey purpose, content and implementation process. At that stage the students were given the option to “opt out” and “not participate”. A plain language statement was provided at the start of the survey indicating that all information collected would be anonymous, and no school or individual would be reported or be able to be identified through the data or in any of the published findings.

Of the 13,501 eligible students, 10,242 (77.2%) consented and participated. The analysis sample for this paper ( $N = 10,143$ ) included only those who were under the age of 18, the legal drinking age in Victoria. As there was only 19 individuals aged 11, these individuals were also excluded from the analysis. Community sampling was based on the school location within local government areas across metropolitan Melbourne. Outside Melbourne, sampling was based on Education Department Regions, reflecting the major community units responsible for youth services. The number of participants in each LGA/region ranged from 117 to 322 with a mean of 219 respondents.

### 2.2. Measures

#### 2.2.1. Dependent variable, alcohol consumption and supply

*Alcohol consumption in last 30 days* was measured by asking adolescents: “In the past 30 days on how many occasions (if any) have you had more than just a few sips of an alcoholic beverage (like beer, wine, spirits or pre-mixed drinks such as Bacardi Breezers or UDL's)? “This is based on similar questions used extensively in national drug and alcohol surveys of youth (e.g., Johnston et al., 2011; White & Smith, 2009). For adolescence, the measure of last 30 days, is a strong predictor of heavy alcohol use in the future for adolescents (McCambridge et al., 2011). It is also a measure that is commonly used in adolescent alcohol prevalence studies (Johnston, O'Malley, Bachman, & Schulenberg, 2011). Response options were “Never” (i.e. no current use), 1–2 times, 3–5 times, 6–9 times, 10–19 times, 20–29 times, 30–39 times and 40+ times. Responses were coded into a binary variable –“no”, for never used alcohol in the last 30 days; “yes”, for all other options.

Adolescents were also asked if they had ever consumed more than a few sips of alcohol in the last 12 months. Those who reported to have consumed more than a few sips of alcohol in the last 12 months were then asked how they got their last alcoholic drink. The options were “they bought the alcohol”, or “whether someone else bought or supplied

it for them". If they bought the alcohol they were asked to indicate at what type of outlet they had purchased the alcohol; if they did not buy it, they were asked to indicate how it was obtained.

Responses to ever consuming alcohol were: "never"; "1 or 2 times"; "3 to 5 times"; "6–9 times"; "10 or more times". These responses were recoded into a binary variable: "never" or "one or more times". Responses to how adolescents obtained alcohol were "I bought it" or "I did not buy it". Responses to where alcohol was bought were: "hotel, pub or tavern"; "licensed store/supermarket"; "walk-in bottle shop"; "club/disco/dance/sporting event"; "restaurant"; "other". Responses to I did not buy alcohol were: "brother/sister gave it to me"; "from home without permission"; "friends gave it to me"; "got someone to buy it"; "other".

### 2.2.2. Independent variable

**Alcohol density:** As we were trying to measure the impact of community-level alcohol availability on drinking, density was measured as outlets per 10,000 residents of a given local government area. The use of a youth-specific population denominator was not used as it would ignore the overall environmental influence of alcohol availability on all population groups in an LGA that can lead indirectly to increased supply of alcohol to adolescents. Using the total population denominator also adjusted for variations in LGA sizes. Other measures (e.g. area, roadway miles) (Scribner, Cohen, Kaplan, & Allen, 1999) provide an alternative way of capturing this information, but have their own biases (e.g. area-based density measures hugely underestimate density in rural areas) (Livingston, 2012).

Individual liquor licences were geocoded by a commercial organisation, Mapdata Sciences Australia. Overall 99.5% of licences were geocoded to at least the street level, comparable to the results of previous studies (Donnelly, Poynton, Weatherburn, Bamford, & Nottage, 2006; Hay, Whigham, Kypri, & Langley, 2009; Kypri, Bell, Hay, & Baxter, 2008). These licences were then assigned to the community in which they were located, using MapInfo to convert the point data to counts per community. Alcohol density outlet was organised into four categories: general density (GD); packaged outlet density (PO); on-premise density (OP); and club density (CD). General outlet density was defined as public bars (pubs), packaged liquor outlets was defined as shops that sold takeaway liquor such as bottle shops; on-premise alcohol outlets were defined as restaurants or venues that sold food (e.g. café) and alcohol; licensed clubs were categorised as venues where membership was required to drink at the venue.

### 2.2.3. Control variables/risk factors:

**Individual risk factors** General demographic information was collected and this included respondent's age, gender. Respondents were also asked "In your lifetime have you ever smoked cigarettes?" and responses were coded to indicate (yes/no). Mental health was assessed using the Kessler-10 (K10), a validated ten-item screening tool designed to identify probable mood and anxiety disorders (Kessler et al., 2003).

**Peer risk factors.** Respondents were asked to indicate the perceived proportion of friends who used four types of drugs (e.g., In the past year (12 months), how many of your four best friends have tried alcohol, marijuana, smoked cigarettes, used illicit drugs. (Cronbach's Alpha ( $\alpha = 0.77$ )). The average number of friends for these four questions was used as an index for the proportion of friends who use drugs.

**Parent birth in Australia:** As The cultural background of parents may also influence the extent that parents supply alcohol to their children (Rowland, Toumbourou, & Stevens, 2003), and as there is evidence that Australian adolescents are less likely to use alcohol when their parents were non-Australian born, respondents were asked to report their mother and father's country of birth. Parent's country of birth was recoded as 'Australian' or 'other'.

**Community risk factors:** Perceived alcohol availability was assessed with a question asking—how easy is it to get alcohol? Responses were

indicated by a 4-point likert scale: 1 = very hard; 2 = sort of hard; 3 = sort of easy; 4 = easy (Kuntsche et al., 2008). Socio-economic status of area where the respondent lived was identified using the respondents' post (zip) code. The index used was the advantage/disadvantage index, and is provided by the Australian Bureau of Statistics; it is a measure of relative socio-economic advantage and disadvantage; low values indicate areas of disadvantage, high numbers indicate areas of advantage (ABS, 2006). The index was used as a continuous variable. We also recorded whether respondents attended school in a metropolitan or non-metropolitan (rural/regional) area. Regional areas included the following: Barwon South Western; Grampians; Loddon Mallee; Hume; and Gippsland.

### 2.3. Statistical analysis

Missing data was imputed using regression procedures within STATA, version 12; a total of 20 imputations were made. Approximately 4% of the cases had missing data for the dependent variable. The independent variable mental health had 11% of data missing; all the other remaining independent variables had 5% or less missing data.

Multilevel modelling was used to assess whether the density of alcohol outlets predicted adolescent alcohol consumption. Multilevel Modelling (MLM) is usually employed when data are characterised by an hierarchical structure (e.g. individuals within a community/geographical area), or when observations are not independent of each other – that is, are clustered (Bickel, 2007; Bryk & Raudenbush, 1992). Given that we examined the influence of the density of outlets in a geographic community, the community variable was specified as a random variable.

For the analysis, the variables were organised into two levels. Level-one (individual) variables included the demographic variables age and gender; the individual and peer risk factors described above, and the outcome variable, alcohol consumption in the last 30 days. Level two (community) variables included the LGA, Density variables, and SES index, and whether students attended school in a non-metropolitan location, area.

### 2.4. Analytical strategy

Following West, Welch, and Galecki (2007), a three-stage analytical strategy was followed. First, a null model (only a random intercept, varying by LGA) was analysed to estimate community variance associated with adolescent alcohol use. The null model provided a baseline estimation of the community variance in predicting adolescent alcohol use enabling estimation of the contribution of variables hierarchically added in subsequent models to reducing the community variance.

Second, the level one variables were entered into the model and the consideration of level one random effects (slopes) were examined; that is, did any level one effect randomly vary by LGA. Interaction effects were examined and non-significant predictors were removed. Third, community level variables were entered. Potential interaction effects were examined; non-significant (fixed and random) predictors were removed. Separate models were developed for each type of outlet density (i.e. package, general, on-premise, club and overall). As one log likelihood, Aikake and Bayesian statistic is not produced with multiple imputed data, model improvement was assessed based on whether the variable added to the model was a significant predictor, at the .05 level, of the outcome variable. Level one random effects were assessed by whether, allowing a variable to vary randomly at the LGA level reduced the between LGA variance.

As recommended by Norton, Wang, and Ai (2004), significant interactions for binomial regression models were undertaken by examining elasticity effects. This is recommend, as interactions with binomial regression, can incrementally change direction and strength, and thus



methods used to interpret regression with a continuous outcome variable are not valid. For all models, elasticity estimates (eyex) examined the percentage increase in probability of adolescent drinking for every 10% increase in the density of alcohol outlets. This was undertaken for each one year age group, while holding all other variables in the model at the sample mean. All analysis was undertaken with Stata, version 12. Elasticities were calculated using a wrapper program for imputed data (UCLA, 2012).

### 3. Results

#### 3.1. Sample

##### 3.1.1. Individual level

Table 1 below outlines the individual demographic characteristics of the sample. The most prevalent age was 14 years old (23%). The lowest age was 12 ( $n = 1907$ ) and the highest was 17 ( $n = 1148$ ). The majority of adolescents were born in Australia (87%), and had a mother that was born in Australia (63%). The average SES index was 1016.95 ( $SD = 48.03$ ).

Table 2 presents alcohol consumption by age group, for whether consumed alcohol in last 30 days and if “ever consumed alcohol”. Approximately 36.70% (95CI: 35.74, 37.65;  $n = 3594$ ) had reported using alcohol in the 30 days prior to the survey. Approximately 60% of the sample (5,912) reported to have drunk more than a few sips of alcohol in his/her lifetime. The proportion of individuals who reported to have consumed alcohol in their lifetime increased with age. For, individuals who reported to have drunk alcohol in their lifetime, 8.78% ( $n = 488$ ) indicated that they had bought the alcohol themselves; 85.06% ( $n = 4724$ ) reported they had it either bought for them, or given to them; 3% ( $n = 189$ ) indicated they got it from home without permission.

Table 2 also presents whether alcohol was brought from licensed retail outlet or provided by an adult, broken down by age. Adolescents purchasing their own alcohol increased with age. Greater proportion of adults provided alcohol to children between 12 and 14 (approx. 88%–90%), compared to children between the ages of 15 and 17 (approx. 83%–77.85%).

**Table 1**  
Details of sample and variables used in the analyses.

	N (%)
Female	5517 (48.1)
Age	
12	1907 (18.80)
13	1671 (16.47)
14	2075 (20.46)
15	1588 (15.66)
16	1754 (17.29)
17	1148 (11.32)
Alcohol last 30 days (yes)	3594 (36.70)
Perceived availability (easy & sort of easy)	5336 (56.19)
K10 (<20)	4800 (53.33)
Friends use drugs (yes)	5999 (62.00)
Ever smoked	2409 (24.43)
Mother born in Australia	6351 (63.32)
Father born in Australia	6047 (60.21)
Regions	
Metro	8515 (83.95)
Regional	1628 (16.05)
	M (SD)
Overall density	25.26 (29.83)
Packaged density	4.33 (1.64)
General density	4.51 (7.36)
On premise density	14.74 (20.88)
Club density	1.69 (1.04)
SEIFA*	1016.905 (48.0332)

SEIFA: Socio-economic index for area (ABS, 2006).

##### 3.1.2. Community level

Approximately 16% of the sample ( $n = 1628$ ) lived outside metropolitan Melbourne, spread across 5 regions. Across all the communities, the mean overall density of alcohol outlets (of all types) was approximately 25.26 outlets per 10,000 individuals ( $SD = 29.84$ ). The mean density as subdivided into the different categories is outlined in Table 1. Intraclass correlations (ICC), the measure of within-group (LGA) homogeneity, for the dependent measure (whether the respondent had consumed alcohol in the last 30 days) was 0.02 and was significant at the 5% level.

The Null model indicated that alcohol consumption in the last 30 days varied significantly between LGAs. Model building identified that all individual and peer variables, except gender, were significant predictors of adolescent alcohol consumption; none of these variables when allowed to vary randomly by LGA, reduced the variance between LGAs. All the community level variables except socio-economic status were found to be significant predictors of adolescent alcohol consumption. Across all types of densities there were no significant association with adolescent alcohol use. However, all types of density were found to be significantly associated with alcohol consumption when included as an interaction with age. For all models, the individual and peer variables reduced the variance between LGAs by approximately 70%; inclusion of both level one and level two variables in the models, reduced variance approximately 92–95% between the geographical areas (see  $\sigma^2$  (LGA), Table 3, below). The final regression models are outlined in Table 3 below.

The generic logistic MLM model depicted in Table 3 was as follows:

$$\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_0 + \beta_1(\text{age})_{ij} + \beta_2(m_{\text{cob}})_{ij} + \beta_3(f_{\text{cob}})_{ij} + \beta_4(\text{perceive})_{ij}$$

where  $\log\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right)$  = log odds of drinking alcohol in the last 30 days.

$m_{\text{cob}}$ : mother's country of birth;  $f_{\text{cob}}$ : fathers country of birth;  $\text{perceive}$ : perceived availability;  $\text{drugs}$ : proportion of friends who use drugs;  $\text{K10}$ : mental health;  $\text{Smoke}$ : ever smoked;  $\text{regional}$ : individual lived in regional area;  $\text{density}$ : density measure;  $\text{age}\#\text{density}$ : age and density interaction;  $i$  represents individuals;  $j$  represents local community area; the intercept  $\beta_0$  is shared by all communities. The random effect ( $u_{0j}$ ) is specific to each community ( $j$ );

Elasticity results are presented in Table 4, below. Overall, elasticity modelling indicated that for every 10% increase in alcohol density outlet, a significant increase in adolescent alcohol consumption occurred for children between the ages of 12 and 14 years of age (overall: range 2.0% to 1.1%; package: range 5.3% to 3.0%; general: range 1.3%–.74%; on premise: range 1.7%–.1.4%; club: range 2.8%–2.5%). While older individuals were at an increased risk of alcohol consumption in some models (see odds ratio: (OR) in Table 3 for age in general and on-premise models), elasticity results indicated that increases in density were generally not associated with significantly increased risk of consumption for individuals between the ages of 15 and 17.

The largest proportional change in risk of consumption was with package density. Increases between 3.03% (14 year olds) and 5.30% (12 year olds) were observed for every 10% increase in packaged outlet density. The smallest change occurred with on-premise density and general density; elasticity estimates ranged between 0.74% and 1.68%. For each type of outlet the significant elasticity effect was the greatest with younger individuals (12 year old) and the least with older individuals (13 and 14 year olds).

Fig. 1 portrays the significant proportional increases in drinking for every 10% increase in type of density outlets, for the age groups 12, 13 and 14 years. It also pictorially shows how the association between increases in density and adolescent consumption diminishes in magnitude as age increases.

**Table 2**  
Distribution of alcohol consumption in last 30 days by age.

	Age group						Total
	12	13	14	15	16	17	
Last 30 days							
%	14.37	20.78	34.20	40.09	59.02	61.5	36.70
(N)	(264)	(329)	(687)	(615)	(10111)	(688)	(3,594)
Consumed in last 12 months							
%	34.33	43.16	61.50	66.41	81.55	82.03	60.08
(N)	(632)	(6880)	(1,238)	(1,026)	(1,406)	(922)	(5912)
Bought from retail							
%	3.03	2.12	4.30	7.21	12.58	18.60	8.78
(n)	(17)	(13)	(50)	(69)	(171)	(168)	(488)
Adult provided alcohol							
%	88.59	89.40	89.61	86.31	83.96	77.85	85.06
(N)	(497)	(548)	(1009)	(826)	(1,141)	(703)	(4,724)

\*While 5,912 reported to have ever drunk alcohol, only 5,555 reported the source of their last alcoholic drink.

#### 4. Discussion

This is the first study to examine within a representative sample of Australian children (from the State of Victoria) the association between alcohol outlet density and adolescent alcohol consumption. The hypothesis that the greater density of alcohol outlets would be associated with overall increased alcohol consumption by adolescents over the entire age range studied was not supported. However, the association was found to be significant with adolescents between the ages of 12 and 14 years of age. Therefore, while older adolescents had higher rates of alcohol consumption, this did not appear to be directly associated with the density of alcohol outlets.

Elasticity estimates – a modelling of how changes in alcohol density are related to changes in adolescent consumption – revealed that the strongest increase in the probability of drinking for individuals between the ages of 12 and 14 was with increases in the density of packaged outlets. Increases in the density of club, on-premise and general liquor outlets were associated with smaller effects for this age group. The findings of this study are only partly comparable with previous studies undertaken in other countries. In New Zealand (Huckle et al., 2008) and the USA (Truong & Sturm, 2007) a greater density of alcohol outlets was associated with increased consumption in older adolescents. However, neither of these studies examined interaction effects between age and density.

Further, our findings suggest that while increases in density may be associated with consumption for children under the age of 14, for older Australian children other peer factors (e.g. friends who smoke) family

factors (parents' COB), and community factors (e.g. rural location), are stronger influences on consumption. Perhaps these are indicators of a more liberal approach to adolescent alcohol consumption in Australian, compared to the USA and New Zealand. Overall, these Australian findings suggest that addressing adolescent alcohol consumption requires a multilevel approach, if it is reduce consumption across the whole adolescent population.

Previous studies have argued for the need to control for “perceived availability” in analyses examining associations between density and adolescent alcohol consumption (Kuntsche et al., 2008; Stanley et al., 2011). Including this variable in the present study allowed testing of the possibility that the relationship between density and consumption could be an artefact of an overall tolerant approach to supplying alcohol to adolescents in specific communities. The present study found that perceived availability was in fact associated with increased consumption; similar increases in risk were found for all statistical models (OR = 1.65). However, after controlling for perceived availability, significant associations with density were still present. This finding lends support to the possibility that the density of alcohol outlets may be more directly associated with adolescent alcohol consumption than previously suggested.

By what mechanism does the density of alcohol sales outlets in the community influence early adolescent alcohol consumption? Chen, Gruenewald, and Remer (2009) observed that alcohol outlet density increased a range of forms of alcohol availability for adolescents including: direct underage purchasing; asking others to purchase and;

**Table 3**  
Multilevel models for adolescent alcohol consumption in last 30 days.

	Null	Overall		Package		General		On premise		Club	
	OR (95CI)	OR (95CI)	P	OR (95CI)	P	OR (95CI)	P	OR (95CI)	P	OR (95CI)	P
Age		1.046	.053	.950	0.264	1.064	0.003	1.056	0.011	1.035	0.287
Mothers' COB		0.715	.000	0.717	0.000	0.716	0.000	0.715	0.000	0.718	0.000
Fathers' COB		0.825	.005	0.826	0.005	0.826	0.005	0.825	0.004	0.826	0.005
Perceive		1.647	.000	1.646	0.000	1.647	0.000	1.647	0.000	1.645	0.000
% friend drugs		2.210	.000	2.210	0.000	2.208	0.000	2.207	0.000	2.210	0.000
K10		1.014	.000	1.014	0.000	1.014	0.000	1.014	0.000	1.012	0.000
Ever smoke		3.242	.000	3.248	0.000	3.249	0.000	3.238	0.000	3.256	0.000
Regional		1.295	.001	1.346	0.000	1.319	0.001	1.272	0.002	1.342	0.012
Density measure		0.989	.000	0.834	0.000	0.961	0.002	0.984	0.001	0.838	0.027
Age#density		1.002	.001	1.035	0.000	1.007	0.002	1.003	0.001	1.035	0.021
Constant		0.063	.000	0.136	0.000	0.057	0.000	0.062	0.000	0.063	0.000
N <sub>1</sub> (ind.)	10143	10143		10143		10143		10143		10143	
N <sub>2</sub> (groups)	36	36		36		36		36		36	
σ <sup>2</sup> (LGA)	0.078	.005		.005		.006		.005		.006	
(95CI)	(.035, .109)	(.0003, .0758)		(.0003, .0852)		(.0005, .0661)		(.0004, .0783)		(.0006, .0620)	

σ<sub>2</sub>: between: variance between LGAs (geographical areas); 20 imputations were done for each model; min observations per group was 149; maximum observations per group was 418; average observations per group was 282.

**Table 4**  
Proportional change in risk in drinking in last 30 days for proportional change in density outlet (ey/ex) for each age group.

Age	ey/ex (95CI)				
	Overall	Package	General	On premise	Club
12	2.04 (.74, 3.35)*	5.30 (1.83, 8.75)*	1.31 (0.40, 2.24)*	1.68 (0.59, 27.96)*	2.80 (0.49, 5.12)*
13	1.66 (.53, 2.80)*	4.36 (1.31, 7.42)*	1.08 (0.28, 1.89)*	1.38 (0.42, 23.36)*	2.45 (0.24, 4.66)*
14	1.12 (.14, 2.11)*	3.03 (0.26, 5.80)*	.74 (0.03, 1.45)*	.92 (.01, 1.75)*	1.94 (−0.32, 4.21)
15	.29 (−7.32, 1.31)	0.96 (−2.14, 4.07)	.22 (−0.54, 0.97)	.22 (0.64, 1.07)	1.16 (−1.60, 3.92)
16	−1.19 (−2.91, 5.29)	−2.66 (−7.82, 2.49)	−.71 (−1.96, 0.55)	−1.03 (−2.48, 0.42)	−0.19 (−4.41, 4.02)
17	−4.452 (9.04, 0.01)	−1.07 (−22.88, 1.55)	−2.74 (−5.81, 0.32)	−3.85 (−7.71, 0.00)*	−0.31 (−1.14, 5.07)

ey/ex = For each age group and type of alcohol outlet, percentage change in drinking in last 30 days for each 10% change in density For each elasticity model, all risk factors, except age are held constant at the average level for the sample.

\* Significant changes in ey/ex.

a greater availability of alcohol in homes. Given that the statistical associations were identified even after controlling for perceived availability and other individual and peer risk factors associated with adolescent alcohol use (e.g. adolescent adjustment: smoking, mental health; peer risks: (friends who use drugs)), the findings support the notion that consumption of alcohol by adolescents may be linked to broader community availability, supply and access to alcohol.

As our study identified that the majority (approximately 85%) of adolescents had someone else purchase the alcohol for them, the association between the density of alcohol outlets and adolescent consumption, may be mediated by the means of how it is obtained. Perhaps density of alcohol outlets is more closely related to increased adult consumption, and this has an effect on the extent that parents or older siblings provide alcohol to children. Thus, the density of alcohol outlets needs to be considered as part of a community and family system. Further, how density affects various components of these systems should be examined in future research, and taken into consideration in future policy development.

The fact that elasticity estimates were more marked for packaged outlets suggests that perhaps business practices of specific venues maybe contributing to early adolescent alcohol consumption. It could be that packaged outlets in particular might be enabling adolescents to obtain alcohol. This may be through direct underage purchasing or by enabling adolescents to have alcohol purchased for them by others. Either of these mechanisms offer possible intervention points. For example, Interventions could be conducted through stronger liquor licence enforcement, such as covert and random checks of venue underage sales practices (Grube, 1997), or through community mobilisation to discourage secondary purchasing of alcohol for underage youth (Perry et al., 2002).

Why was increased local geographic density of alcohol outlets not associated with older adolescent alcohol use in the present study? One explanation may lie in the fact that older adolescents become

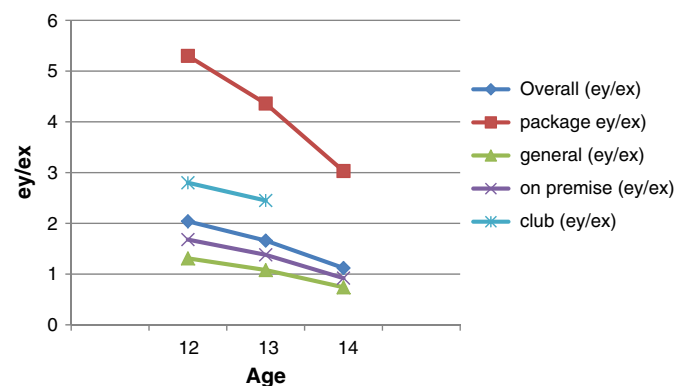
more mobile and therefore are able to travel outside their local community to parties and entertainment precincts to obtain alcohol. Australian studies indicate that early adolescents report obtaining alcohol from community sources such as at home (supplied by parents or siblings), at friends' homes or by having someone purchase it for them. At older ages adolescents are more likely to obtain alcohol independently at parties (White & Hayman, 2006) and through alcohol sales outlets outside their community they may be less dependent on local community supply sources.

The elasticity analyses revealed one significant protective effect whereby 17 year olds drank less frequently in communities with high densities of on-premise licenses. These findings might be explained by the behaviour of a proportion of 17 year olds living in close proximity to high densities of on-premise licenses in their communities. These individuals that have easy access to on-premise licensed outlets could be forced to make the decision to reduce the frequency of their visits to such outlets in order to successfully cope with the demands and intense pressures of final year secondary school studies that occur in Victoria in that age group.

Overall the findings of this study have substantial public health implications. The study suggests that the density of alcohol outlets may be associated with early age alcohol use, after controlling for other predictors. The need to intervene in the earlier years of adolescence to reduce factors that lead to early adolescent initiation of alcohol use is well recognised based on epidemiological (Hingson, Heeren, & Winter, 2006) and longitudinal studies (Toumbourou & Catalano, 2005). Such studies indicate that the earlier a child begins to consume alcohol, the greater the risk of progressing to heavier adolescent alcohol use (Mason et al., 2011) which, in turn, can lead to poor academic outcomes (Koch & McGeary, 2005), greater risk of becoming dependent on alcohol (Bonomo et al., 2004), problem drinking in adult life (McCambridge et al., 2011), and adverse mental and physical health in the adult years (Andreasson et al., 2006). There is also mounting evidence that alcohol consumption in the early adolescent years can adversely affect brain development (McQueeny et al., 2009). Given the breadth of these consequences, the findings of the present study should be considered important in indicating a potentially modifiable factor that may predict early alcohol use.

## 5. Limitations

While this study has identified associations with the density of alcohol outlets and adolescent consumption, the cross-sectional nature of the study design cannot be ignored. Although modifications to the design of the study and its analysis cannot rule-out counterfactual causal effects, it is intuitively reasonable to suspect that increases in density precede increases in adolescent alcohol consumption, as the reverse causal direction is not logical. It is possible that links between alcohol outlet density and higher rates of adolescent alcohol consumption arise from common associations with underlying factors such as disadvantaged localities having higher rates of adolescent



**Fig. 1.** Elasticities (ey/ex): Proportional change in consumption for 12, 13, and 14 year olds, for every 10% change in type of density outlet.



maladjustment or favourable community attitudes to alcohol. The present analysis however, has provided better control for factors of this type, relative to previous studies.

The cross-sectional design of the present study precludes analysis of causal mechanisms linking alcohol outlet density to adolescent consumption. Longitudinal analyses would help tease out the potential mechanisms more clearly and should be the subject of future research. Future research should also examine whether there are cultural differences in the association between the density of alcohol outlets and adolescent consumption. For example, are the temporal links with density and adolescent consumption different in countries with: different legal ages for alcohol purchase and or use (e.g. USA = 21; AUS = 18); different social norms toward adolescent alcohol use; or differences in race and culture (e.g., children of European versus Asian extraction).

Notwithstanding the limitations of the present study, this is the first Australian study of this scale to assess the association of the relationship between the density of alcohol outlets and adolescent alcohol consumption at different ages. Using a representative sample of Victorian secondary school children, and controlling for a range of confounding factors, the findings demonstrate that increases in the number of outlets in the local community is linked to the proportion of early adolescents who consume alcohol. Mechanisms as to how this happens should be given priority in future research.

#### Role of funding sources

This study was partly funded by the Australian Research Council grant, Deakin Faculty Research Grant. Bosco Rowland was also supported by the Alfred Deakin Post-doctoral Fellowship. Michael Livingstone was supported by an NHMRC Early Career Fellowship and by the Foundation for Alcohol Research and Education (FARE), an independent, charitable organisation working to prevent the harmful use of alcohol in Australia. The HowRU secondary student survey was funded by the Victorian State Government Department of Education and Early Childhood Development.

#### Statement of contributors

BR lead the paper and the analysis. JT assisted with the development of the analysis. JT and JW helped secure funding from the Australian Research Council. JHI helped with data collation, preparation and analysis. LA, GT & ML helped to develop the literature review and discussion.

#### Declaration of interest

None.

#### References

- ABS (2006). An introduction to socio-economic indexes for areas (SEIFA) 2006. *Report No.: 2039.0*. Canberra: Australian Bureau of Statistics.
- AIHW (2011). *2010 National Drug Strategy Household Survey*. Canberra: Australian Institute of Health and Welfare.
- Andreasson, S., Romelso, A., & Allebeck, P. (2006). Alcohol, social factors and mortality among young men. *British Journal of Addiction*, *86*(7), 877–887.
- Babor, T. F., Caetano, R., Casswell, S., Edwards, G., Giesbrecht, N., Graham, K., et al. (2010). *Alcohol: No ordinary commodity: Research and public policy* (2nd ed.). Oxford: University Press.
- Bickel, R. (2007). *Multilevel analysis for applied research: It's just regression!* New York, NY: The Guilford Press.
- Bonomo, Y. A., Bowes, G., Coffey, C., Carlin, J. B., & Patton, G. C. (2004). Teenage drinking and the onset of alcohol dependence: A cohort study over seven years. *Addiction*, *99*(12), 1520–1528.
- Bryk, A. S., & Raudenbush, S. W. (1992). *Hierarchical Linear Models, Applications and data analysis methods*. Newbury Park, CA: Sage Publications.
- Chen, M. -J., Gruenewald, P. J., & Remer, L. G. (2009). Does alcohol outlet density affect youth access to alcohol? *The Journal of adolescent health: Official publication of the Society for Adolescent Medicine*, *44*(6), 582–589.
- Department of Education and Early Childhood Development (2009). *The state of Victoria's children 2008: A report on how children and young people in Victoria are faring*. Victoria.
- Donnelly, N., Poynton, S., Weatherburn, D., Bamford, E., & Nottage, J. (2006). Liquor outlet concentrations and alcohol-related neighbourhood problems. *Alcohol Studies Bulletin*, *8*, 15.
- Grube, J. W. (1997). Preventing sales of alcohol to minors: Results from a community trial. *Addiction*, *92*, S251–S260.
- Gruenewald, P. J. (2007). The spatial ecology of alcohol problems: Niche theory and assortative drinking. *Addiction*, *102*(6), 870–878.
- Hawkins, J.D., Catalano, R. F., & Miller, J. Y. (1992). Risk and protective factors for alcohol and other drug problems in adolescence and early adulthood: Implications for substance abuse prevention. *Psychological Bulletin*, *112*(1), 64.
- Hay, G. C., Whigham, P. A., Kypri, K., & Langley, J.D. (2009). Neighbourhood deprivation and access to alcohol outlets: A national study. *Health & Place*, *15*(4), 1086–1093.
- Hingson, R. W., Heeren, T., & Winter, M. R. (2006). Age at drinking onset and alcohol dependence: Age at onset, duration, and severity. *Archives of Pediatrics & Adolescent Medicine*, *160*(7), 739.
- Huckle, T., Huakau, J., Sweetsur, P., Huisman, O., & Casswell, S. (2008). Density of alcohol outlets and teenage drinking: Living in an alcogenic environment is associated with higher consumption in a metropolitan setting. *Addiction*, *103*(10), 1614–1621.
- Johnston, L. D., O'Malley, P.M., Bachman, J. G., & Schulenberg, J. E. (2011). *Monitoring the Future national results on adolescent drug use: Overview of key findings, 2011*. Ann Arbor: Institute for Social Research, The University of Michigan.
- Jonkman, H., Steketee, M., Tombourou, J. W., Cini, K., & Williams, J. (2012). *Community variation in adolescent alcohol use in Australia and the Netherlands*. : Health Promotion International.
- Kavanagh, A., Kelly, M., Krnjacki, L., Thornton, L., Jolley, D., Subramanian, S. V., et al. (2011). Access to alcohol outlets and harmful alcohol consumption: A multi-level study in Melbourne, Australia. *Addiction*, *106*(10), 1772–1779.
- Kessler, R. C., Barker, P. R., Colpe, L. J., Epstein, J. F., Gfroerer, J. C., Hiripi, E., et al. (2003). Screening for serious mental illness in the general population. *Archives of General Psychiatry*, *60*(2), 184.
- Koch, S. F., & McGeary, K. A. (2005). The effect of youth alcohol initiation on high school completion. *Economic Inquiry*, *43*(4), 750–765.
- Kuntsche, E., Kuendig, H., & Gmel, G. (2008). Alcohol outlet density, perceived availability and adolescent alcohol use: A multilevel structural equation model. *Journal of Epidemiology and Community Health*, *62*(9), 811–816.
- Kypri, K., Bell, M. L., Hay, G. C., & Baxter, J. (2008). Alcohol outlet density and university student drinking: A national study. *Addiction*, *103*(7), 1131–1138.
- Livingston, M. (2008). Alcohol outlet density and assault: A spatial analysis. *Addiction*, *103*(619–628).
- Livingston, M. (2011). A longitudinal analysis of alcohol outlet density and domestic violence. *Addiction*, *106*(5), 919–925.
- Livingston, M. (2012). The social gradient of alcohol availability in Victoria, Australia. *Australian and New Zealand Journal of Public Health*, *36*, 41–47.
- Livingston, M., Chikritzhs, T., & Room, R. (2007). Changing the density of alcohol outlets to reduce alcohol-related problems. *Drug and Alcohol Review*, *26*(5), 557–566.
- Livingston, M., Laslett, A., & Dietze, P. (2008). Individual and community correlates of young people's high-risk drinking in Victoria, Australia. *Drug and Alcohol Dependence*, *98*(3), 241–248.
- Mason, W. A., Tombourou, J. W., Herrenkohl, T. I., Hemphill, S. A., Catalano, R. F., & Patton, G. C. (2011). Early age alcohol use and later alcohol problems in adolescents: Individual and peer mediators in a bi-national study. *Psychology of Addictive Behaviors*, *25*(4), 625.
- McCambridge, J., McAlaney, J., & Rowe, R. (2011). Adult consequences of late adolescent alcohol consumption: A systematic review of cohort studies. *PLoS Medicine*, *8*(2), e1000413.
- McQueeny, T., Schweinsburg, B. C., Schweinsburg, A.D., Jacobus, J., Bava, S., Frank, L. R., et al. (2009). Altered white matter integrity in adolescent binge drinkers. *Alcoholism, Clinical and Experimental Research*, *33*(7), 1278–1285.
- NHMRC (2009). *Australian guidelines to reduce health risks from drinking alcohol*. Canberra, ACT: National Health and Medical Research Council.
- Norton, E. C., Wang, H., & Ai, C. (2004). Computing interaction effects and standard errors in logit and probit models. *Stata Journal*, *4*, 154–167.
- Perry, C. L., Williams, C. L., Komro, K. A., Veblen-Mortenson, S., Stigler, M. H., Munson, K. A., et al. (2002). Project Northland: Long-term outcomes of community action to reduce adolescent alcohol use. *Health Education Research*, *17*(1), 117.
- Rowland, B., Tombourou, J. W., & Stevens, C. (2003). *Preventing Drug Related Harm in Communities Characterised by Cultural and Linguistic Diversity*. Melbourne: Drug Info Clearinghouse, Australian Drug Foundation.
- Scribner, R. A., Cohen, D., Kaplan, S., & Allen, S. (1999). Alcohol availability and homicide in New Orleans: Conceptual considerations for small area analysis of the effect of alcohol outlet density. *Journal of Studies on Alcohol*, *60*, 310–316.
- Stanley, L., Henry, K., & Swaim, R. (2011). Physical, social, and perceived availabilities of alcohol and last month alcohol use in rural and small urban communities. *Journal of Youth and Adolescence*, *40*(9), 1203–1214.
- Stockwell, T., & Gruenewald, P. (2004). Controls on the physical availability of alcohol. In H. N., & T. Stockwell (Eds.), *The essential handbook of treatment and prevention of alcohol problems* (pp. 213–233). New York: John Wiley.
- Tombourou, J. W., & Catalano, R. F. (2005). Predicting developmentally harmful substance use. *Preventing Harmful Substance Use*, 53–65.
- Tombourou, J. W., Hemphill, S. A., McMorris, B. J., Catalano, R. F., & Patton, G. C. (2009). Alcohol use and related-harms in school students in the United States and Australia. *Health Promotion International*, *24*(4), 373–382.
- Truong, K. D., & Sturm, R. (2007). Alcohol outlets and problem drinking among adults in California. *Journal of Studies on Alcohol and Drugs*, *68*(6), 923–933.
- UCLA (2012). How can I get margins and marginsplot with multiply imputed data? Retrieved 16th October, 2012, from [http://www.ats.ucla.edu/stat/stata/faq/ologit\\_mi\\_marginsplot.htm](http://www.ats.ucla.edu/stat/stata/faq/ologit_mi_marginsplot.htm)
- West, B., Welch, K. B., & Galecki, A. T. (2007). *Linear mixed models: A practical guide using statistical software*. Chapman & Hall/CRC.
- White, V., & Hayman, J. (2006). Australian Secondary School Students' Use of Over-the-counter and Illicit Substances in 2005. *Report: Australian Government Department of Health and Ageing*.
- White, V., & Smith, G. (2009). *Australian secondary school students' use of tobacco, alcohol, and over-the-counter and illicit substances in 2008*.