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Does geographic availability of alcohol influence drinking in adolescents? A systematic review of literature associations

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ABSTRACT

Background: The role of alcohol geographic availability in influencing adolescent drinking has been debated. However, clear literature consensus has not been reached.
Objective: To provide a systematic review of the associations between geographic availability of alcohol outlets measured through different methodologies and drinking outcomes in adolescents.
Methods: We conducted a systematic search (PubMed/SCOPUS/Web of Science) for articles exploring associations between alcohol availability and adolescent drinking before 2023. Original articles written in English that evaluated adolescent populations (10–19 years old), included at least one quantitative alcohol consumption outcome and its relationship with geographic availability of alcohol, and declared no conflicts of interest were selected for the review. A quality assessment of the selected articles was made using the Newcastle-Ottawa Scale and descriptive analyses were carried out to summarize results.
Results: Thirty-one articles were reviewed (19 cross-sectional and 12 longitudinal studies), which included a total of 507336 participants. Alcohol availability was positively related to drinking prevalence and risky patterns in 53.3% and 60.5% of associations, respectively. Individual-level covariates, the type of alcohol outlets measured and the different methodological approaches to measure outlet density were related to differences in the direction and magnitude of these associations.
Conclusion: Just over half of the studies in this review demonstrate a positive association between alcohol availability and adolescent alcohol consumption with no negative associations reported. The review highlights the mix of methodological approaches that are used, which made it difficult to conduct joint analyses. Additional research is needed to explore the appropriateness, effectiveness and reliability of these methods within various contexts.

1. Introduction

Alcohol use represents a significant and preventable global health concern (Warner and White, 2003). It causes 3 million deaths annually, constituting 7.1% and 2.2% of total deaths for males and females, respectively (World Health Organization, 2023; Rehm et al., 2012). Despite recent research indicating a decreasing prevalence of adolescent alcohol consumption (Caluzzi et al., 2022; Rossow et al., 2022), adolescence remains an important life stage with younger age of first alcohol drink linked to heavier consumption as one ages. Over a quarter of all adolescents worldwide are current drinkers with this figure being substantially higher in some countries (e.g. in Germany or Ireland this prevalence exceeds 70% (World Health Organization, 2024)). Alcohol consumption during adolescence adversely affects learning, memory,

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and executive functions, leading to potential issues in later adulthood (Bava et al., 2013; Edwards et al., 2014; Lees et al., 2020). Additionally, it is linked to impulsive and aggressive behaviors, unsafe sexual activity, and drunk driving, among other risky behaviors with health and social implications for people who drink and the broader populations within communities (Garcia et al., 2017; Trangenstein et al., 2018; de Goeij et al., 2015a; Amlung et al., 2014). Addressing excessive alcohol consumption in adolescents is a pressing public health and social priority, gaining attention from policymakers (World Health Organization, 2018; World Health Organization Regional Office for Europe, 2020).

The presence of alcohol in the environment has been described as ubiquitous in several regions, with alcohol outlets being highly available for adolescents (Pastor et al., 2020a; Azar et al., 2016; Young et al., 2013). The availability of alcohol outlets in the environment can be explored from different dimensions (temporal, social, economic, etc.) (Schofield and Denson, 2013; Holmes et al., 2014; Martín-Turrero et al., 2022), however, a spatial approach that explores the number, or density, of physical alcohol points of sale within a particular area (hereinafter, geographical availability) has been increasingly considered in the literature (Sacks et al., 2020). In this sense, previous work has argued that a greater number of alcohol outlets in a specific area (i.e., geographical availability) increases the options for the adolescents to buy alcohol, which may lead to higher consumption through various pathways including reduced cost, normalization and/or ease of access (Holmes et al., 2014; Petticrew et al., 2017; Bryden et al., 2012; Molina-de la Fuente et al., 2021; Pastor et al., 2020b).

The geographic availability of alcohol might be closely connected with other factors influencing consumption, such as price and marketing. A higher availability of alcohol outlets may lead to a higher market competition, which also may cause a lowering of the prices, getting alcohol products more affordable especially for adolescents, who are price sensitive customers. An increase in the market competition may also lead to a greater probability of breaching laws banning the sale of alcohol to minors. Further, advertising in retail outlets is an important form for alcohol promotion. In areas of higher availability of alcohol outlets, the marketing and promotion strategies within retailers might be more prominent, enhancing the normalization of alcohol consumption among adolescents.

However, mixed results are found in the literature and whilst several studies have reported a positive association between increased availability and adolescent consumption, several studies have reported no association (Tobler et al., 2009; Martin et al., 2019; Shamblen et al., 2011; Fairman et al., 2019). The reasons for this disagreement might be multiple. The studies published in this field were based on different regions around the World characterized by distinct social, economic, geographic, and policy contexts towards the geographic availability of alcohol and its consumption. This issue makes the comparison of results between different studies challenging.

The recent advances in Geographic Information Systems (GIS) technologies and its gradual implementation in alcohol research have led to a significant proliferation of different methods to quantify the geographical availability of alcohol outlets in the environment (Martín-Turrero et al., 2022; Richardson et al., 2013; Apparicio et al., 2017). Most of these measures rely on alcohol outlet density (AOD) calculations, which account for the provision and spatial concentration of alcohol points of sale in a given area. Some works utilized simple density calculations, presenting counts of alcohol outlets, offering a basic understanding of their numbers within an area (i.e., container-based measures) (Fairman et al., 2019; Martins et al., 2019; Cardoza et al., 2020). In contrast, others express densities as a rate of outlets per population (i.e., population-based measures) or outlets per roadway miles rate (i.e., length-based measures) (Jackson et al., 2016; Wang et al., 2013). Population- and length-based measures contextualize outlet supply concerning the population's demand measured by the number of residents who may access these outlets. Length-based measures account for the availability of alcohol outlets along the road pathways where population move within a given study area. Alternatively, other authors employed more complex distance-based density calculations such as Kernel Density Estimations (KDE) (Martin et al., 2019). In essence, KDE provides a smoothed estimate of outlet density across the entire study area reflecting how outlet density varies continuously in space, as opposed to, for example, container-based calculations (Shi et al., 2019). In a KDE surface, the density values are higher at the location of the outlet and it gradually reduces as we move away from these points up to a specific search distance, when density values equate zero (i.e., buffer). The Center for Disease Control and Prevention (CDC) offers a glossary including more details on how these different measures work (National Center for Chronic Disease Prevention and Health Promotion (U.S.)). However, the implications of the specific social, economic, geographic, and policy contexts of the study area and the type of AOD measure on the association results remain unexplored.

The objective of this study is to systematically review the existing evidence for the association between the geographic availability of alcohol outlets and drinking outcomes in adolescents. As a secondary objective, we describe the different types of AOD calculations used in different contexts and examine how these may modify the associations with alcohol consumption.

2. Methods

2.1. Search question and articles selection

We followed a PICOS (P=Population, I=Intervention/Exposure, C=Comparison, O=Outcome, and S=Study Design) strategy to form our systematic review search question: "In adolescents (P), does exposure to higher density of alcohol outlets in the environment (I) compared to lower density or absence of alcohol outlets (C) correlate with worse drinking outcomes, including prevalence and consumption patterns (O), in observational studies (S)?".

We conducted a search for articles that explored the geographic availability of alcohol outlets in the environment and its relationship with adolescent consumption, following the PRISMA guidelines (PRISMA). We stated the following inclusion criteria to identify potentially relevant articles to review: 1. full, original articles that use original data to respond novel research questions and obtain findings or insights that have not been previously published, 2. involving human adolescent populations (considering the WHO definition of adolescents as people between 10 and 19 years old), 3. related to at least one quantitative alcohol consumption outcome (i.e., prevalence and patterns of alcohol consumption, defined as quantity and frequency of consumption in a given period of time –day, week, month, etc.), 4. analyzed availability of alcohol outlets through quantitative spatial density calculations, 5. cross-sectional, case-control or longitudinal studies, 6. full text in English, 7. did not declare any conflicts of interest.

Similarly, we defined two specific exclusion criteria: 1. systematic reviews, non-peer review articles, or non-original articles (commentary, letters to editor, news, etc.), 2. articles that analyzed exposure to alcohol only through spatial proximity measures. Those articles were excluded since in this systematic review we aimed to focus solely on availability (i.e., density) and not accessibility (i.e., proximity) measures. However, proximity related terms were included in the search strategy as the concepts of "accessibility" and "availability" are often confused (and used interchangeably) in the literature.

A search for all articles published before January 2023 was performed in three databases: PubMed (National Library of Medicine, https://pubmed.ncbi.nlm.nih.gov/), SCOPUS (https://www.scopus.com/) and Web of Science (https://www.webofscience.com/). The full search strategy used was: ((alcohol* OR drink*) AND (retail* OR outlet OR outlets OR sale OR sales OR "point of sale" OR point-of-sale OR "point of purchase" OR point-of-purchase OR store OR stores OR shop OR supermarket OR "gas station" OR "petrol station" OR off-premise OR on-

premise OR bar OR bars OR restaurants OR restaurant OR cafeteria OR pubs OR discotheque OR distillery OR cafe OR "coffee shop" OR "snack bar" OR buffet OR club* OR casino*) AND (availab* OR access* OR density OR proximity OR obtain*)).

After applying the search criteria and removing duplicates, one author screened titles. Those which mentioned in their title exposure to alcohol outlets (e.g., availability, alcohol outlet, bar, pub) and at least one outcome related to alcohol drinking or consumption pattern in adolescents were selected. Secondly, abstracts of the selected articles were reviewed by pairs, to identify those that apparently met inclusion criteria. Finally, we obtained the full text of those articles that met inclusion criteria for the systematic review, and data extraction was reviewed also by pairs.

2.2. Data extraction

We pre-defined a coding sheet using Excel (Microsoft Corporation, 2020) to gather and store all the relevant information extracted from each article. We organized the coding sheet by a set of questions nested in thematic blocks to articulate the data extraction.

First, we assigned to each reviewed article an ID number, and retrieved generic information (i.e., authors, title, journal of publication, year and the country where the study was performed). Then, we gathered information on the population of study (e.g., age range or ethnicity), type of alcohol outlets (i.e., on-premises, off-premises or both) and place of exposure (i.e., residence, school, activity space). Lastly, specifications about the type of AOD measure and how it was calculated (e.g., count of outlets within user-defined containers, roadway length-based rate of outlets, etc.), outcome variables (prevalence and patterns of alcohol consumption and how they were accounted), the results of the associations and conclusions stated by each article were retrieved. Individual- and area-level covariates included in the analyses were also noted. Table A.1 in the Supplementary Material shows the questions included in the coding sheet.

Four researchers (n = 4) within the study team participated in a series of training sessions in which the final questions included in the coding sheet were defined and agreed upon to ensure consistency. As part of these training sessions, researchers responsible for data extraction reviewed a sample of articles randomly selected after the abstract review to compare their results, discussed possible discrepancies, and agreed systematic solutions. After that, all articles were peer-reviewed. When discrepancies aroused, a third researcher was involved to reach a decision.

2.2.1. Place of exposure and geographic unit of analysis

We classified each article by the type of place around which the AOD was calculated: residence or school or other (e.g., paths tracked through GPS – Global Positioning Systems, etc.). Information on the geographical unit of analysis, defined as the geographical area in which the data were aggregated, were also retrieved. Articles were related to different types of container units: administrative areas or buffers. Administrative areas are pre-defined geographic regions defined for governance and administration purposes, such as zip codes or census tracts. Buffers are user-defined areas that are drawn around a point, line, or polygon feature, which encompass all the area within a specified distance of that feature. The most common types of buffers are Euclidean and street network buffers. Euclidean buffers (also known as crow-flies' buffers) are delineated using a straight line around a point, line or polygon, while street network buffers are delineated using walkable distances through streets and are usually irregular (Martín-Turrero et al., 2023).

2.2.2. Alcohol availability measures

We collected information about the types of alcohol outlets targeted in each article. In line with the existing alcohol literature, we anticipated a checklist of alcohol outlet types including on-premises and off-premises outlets. On-premises alcohol outlets are places where alcohol can be purchased and consumed in the establishment, such as bars, restaurants, or night clubs (Shortt et al., 2015; de Goeij et al., 2015b). Off-premises outlets are stores that sell alcohol for consumption off the premises, including supermarkets, convenience stores or liquor and wine stores (Waller and Iritani, 2013; Rowland et al., 2014a).

In line with the CDC guidelines, we classified each article according to a pre-defined list of 6 types of calculations: 5 container-based and 1 distance-based density measures. Container-based measures of AOD are calculated based on the number of outlets within a specific area, and the containers can be pre-defined (e.g. city, ZIP code) or user-defined (e.g. buffer zone). Container based measures included in this systematic review: (1) count of alcohol outlets, (2) area-based rate of alcohol outlets, (3) population-based rate of alcohol outlets, (4) roadway length-based rate of alcohol outlets, and (5) presence or absence of alcohol outlets within a container (i.e., specified space). On the other hand, distance-based density measures are calculations that consider the distances between the location of two specific events of interest (i.e., alcohol outlets and participants' homes) to weight the value of density, which varies across different locations within the study area. In this systematic review we included (6) Kernel Density Estimations as a type of distance-based density measure in the pre-defined list of calculations. A similar classification was used in a previous study reviewing methods to measure the geographic availability of tobacco outlets in the environment (Valiente et al., 2020).

2.2.3. Drinking outcomes

We also extracted measures of alcohol consumption (i.e., drinking outcomes) and classified them into two groups: prevalence outcomes and patterns of alcohol consumption outcomes. The prevalence measures were those that categorized individuals into groups (i.e., number and percentage of people who drank vs. people who did not drink). Patterns of alcohol consumption referred to the frequency (e.g., number of days they have drunk in the past 30 days) and quantity (e.g., quantity of alcohol drunk on each occasion) of drinking or binge drinking episodes (e.g., drinking 5 or more drinks for men and 4 or more drinks for women, in a time lapse of 2 h). See Table A.2 in Supplementary Material for some examples of questions that were used in studies included in this systematic review to address prevalence and patterns of alcohol consumption.

2.2.4. Study results

We recorded study results regarding the direction (e.g., positive, negative) and magnitude (e.g., statistically significant or not) of the associations between the density measures and the prevalence and patterns of alcohol consumption. We classified these results in four triangulated categories: 1) "no association", 2) "negative association", 3) "positive association", and 4) "positive association under some circumstances". No association category indicated that there was no statistically significant association (i.e., the p-value was not less than 0.05, or the 95% confidence interval for an effect size included the null value). A negative association underlined that a higher density of alcohol was related to statistically significant lower alcohol consumption. Conversely, a positive association highlighted that higher density of alcohol was related to statistically significant higher alcohol consumption. Finally, positive association under some circumstances indicated that the association between both measures was significantly positive only in some specific contexts: 1. under adjustment by certain individual (e.g., participants' age, gender, etc.) or area-level (e.g., socioeconomic or urban/rural neighborhood status, etc.) characteristics; 2. when considering certain types of alcohol outlets (on-premise, off-premise or both); 3. when exploring a particular place of exposure (like residence, school or other); or 4. when using different geographic unit of analyses or parameters in the AOD calculations (e.g., different buffer types and sizes, etc.). Grouping articles that presented any of these four circumstances facilitated the synthesis of findings. This approach also helped us obtain an overall picture of the current evidence on the direction and

magnitude of the associations between AOD and drinking prevalence and consumption patterns. This categorization has been previously used in another systematic review (Valiente et al., 2020).

2.3. Quality assessment

To assess the quality and risk of bias of the studies included in this systematic review we used the Newcastle-Ottawa Quality Assessment Scale (NOS) (Wells et al). The tool was modified for the purpose of this study, which includes cross-sectional and longitudinal studies, and it evaluates study quality according to three domains: selection, comparability and outcome (Wells et al.; Patra et al., 2015; Nayebirad et al., 2023). The tool can be found in Text A.1 of Supplementary Material.

2.4. Data analyses

We created summary tables to provide an overview of the data related to the place of exposure, the geographic unit of analysis, the type of alcohol outlets and the type of calculations used in each article to assess the AOD. These tables also included the results of their association with the two types of drinking outcomes. We generated different tables to look at articles exploring associations with drinking prevalence and consumption outcomes separately, with the articles sorted by AOD measure type.

We performed a descriptive analysis to summarize results on the direction and magnitude of the associations among the articles by considering the type of density measure and the geographic unit of analysis used. For this, we counted number of associations within articles, since some of the articles explored the influence of AOD on more than one drinking outcome. Consequently, the number of associations may vary from the number of articles.

3. Results

3.1. Study selection and overview

We retrieved a total of 16,964 articles from the different databases. After screening the titles and the abstracts, we obtained 68 articles for full text review. Ten articles were excluded as they used self-reported (not-quantitative) measures about the geographic availability of alcohol outlets. Fourteen articles due to a lack of drinking outcomes; and thirteen articles without AOD measures were also excluded. After full text revision, 31 articles met all the inclusion criteria and were considered for our systematic review. None of the selected articles declared any conflicts of interest. Fig. 1 shows a summary of the selection process of the articles included in this systematic review.

The included articles were published between 2008 and 2020. Of those, 16 were conducted with populations from North America [14 in USA], six from Oceania, three from South America [all in Brazil], three from Europe, and three from Asia.

Out of the 31 studies, 19 studied alcohol availability around residence (Azar et al., 2016; Young et al., 2013; Tobler et al., 2009; Martin et al., 2019; Fairman et al., 2019, 2020; Jackson et al., 2016; Treno et al., 2008; Shih et al., 2015; de Carvalho et al., 2020; Chen et al., 2010, 2016, 2019; Huckle et al., 2008; Morrison et al., 2019a, 2019b; Kuntsche et al., 2008; Stanley et al., 2011; Rowland et al., 2014b, 2016a; Paschall et al., 2012, 2014), seven around schools (Shamblen et al., 2011; Martins et al., 2019; Cardoza et al., 2020; Wang et al., 2013; Lo et al., 2013a, 2013b; Larsen et al., 2017), and two studied in both areas (residence and school) (Rowland et al., 2014b; Trapp et al., 2018). Moreover, two studies explored availability in both individuals' residence and activity spaces, tracking participants daily movement routes using GPS devices (Morrison et al., 2019a, 2019b). Finally, another study was focused only on alcohol availability around participants' activity spaces, delineated using GPS (Byrnes et al., 2016).

According to NOS for cohort studies, the assessment score ranged from 0 to 9 points, with higher scores indicating better quality. The total scores for all included cohort studies in this systematic review (n = 12) were equal or higher than 5, indicating good or satisfactory quality (see Table A.3. of Supplementary Material). The assessment score of modified NOS for cross-sectional studies ranged from 0 to 7 points, with higher scores indicating better quality. Of the cross-sectional studies included in this review (n = 19), seven presented good quality (with a score of 6), 11 presented satisfactory quality (score of 4–5), and one presented unsatisfactory quality (score less than 4) (see Table A.3. of Supplementary Material). This unsatisfactory score, however, reflects the fact that this study was a brief report on a small pilot study to demonstrate feasibility of GPS methods.

3.2. Description of alcohol outlet density (AOD) measures

Tables 1 and 2 summarize the information extracted from studies examining the relationship between alcohol density and drinking prevalence and consumption patterns, respectively. Twenty-one studies

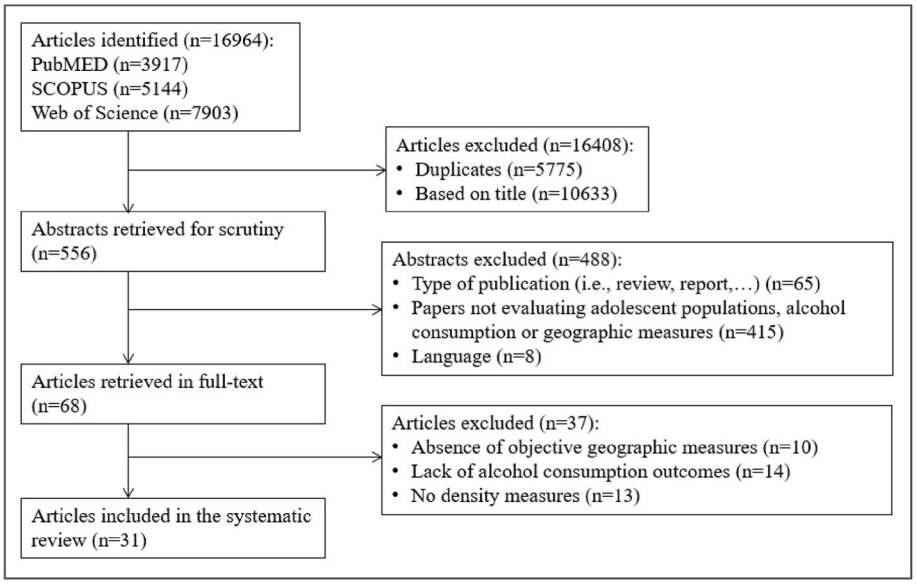

Fig. 1. PRISMA Flowchart of articles selected for the review.

Table 1
Summary of the articles included in the systematic review which evaluate relationship between alcohol outlet density and a prevalence of alcohol consumption in adolescents.

Type of density calculation	First author and year of publication	Country	Place of exposure to alcohol	Geographic unit of analysis	Buffer	Type of outlet	Individual and community covariates included in the analyses	Association with prevalence outcome and direction of association
Count of alcohol outlets	Treno A.J. et al. (2008)	USA	Residence	Buffer	Yes (Euclidean, 2 miles)	Off-premises	*Individual*: spending money available, gender, ethnicity, race, mobility variable, parent drinking, church, school and family information, measure of deviance, and perceived availability of alcohol. *Community*: race, ethnicity, home ownership, and median household income	*Past year use of alcohol* is positively associated with off-premises alcohol outlet density
	Shih R.A. et al. (2015)	USA	Residence	Buffer	Yes (Euclidean, 0.1, 0.25, 0.5 and 2 miles)	On-premises, club/bars and off-premises	*Individual*: gender, age, race and ethnicity. *Community*: SES	*Lifetime drinking* was positively associated with number of on-premises outlets (in 0.25 mile radius), number of clubs/bars (in 0.25 and 0.5 radius) and number of off-premise outlets (in 0.5 radius)
	Carvalho B. G.C. et al. (2020)	Brazil	Residence	Buffer	Yes (Euclidean, 200 m)	On-premises and off-premises	*Individual*: age, sex, bullying, participation in fights, difficulty interacting with colleagues, nice and helpful friends, cigarette use in life, current cigarette use, studying in 2008, failed school year, type of school, satisfaction with school life, participation in any organization, family fights/arguments, feeling loved, parents at home, talk time with parents, education of the head of the family, adult who drinks, and family income	The multivariate analysis showed a significant association between *current alcohol consumption* and density of snack bars, bars, and restaurants (on-premises). No association with other types of outlets, nor with *past alcohol consumption*
Population-based rate of alcohol outlets	Rowland B. et al. (2014)	Australia	Residence and school	Local government area	No	On-premises and off-premises	*Individual*: gender, age, perceived availability, mental health (k10), friends use drugs, ever smoked, and mother/father born in Australia. *Community*: region (metropolitan/rural)	Alcohol outlet density is positively related with *having consumed alcohol in the last 30 days* for younger adolescents (12–14 years old) but not for older adolescents (15–17 years old)
	Jackson N. et al. (2016)	New Zealand (NZ)	Residence	Synthetic neighborhood (area units in NZ) and buffer around it	Yes (500 m, Euclidean)	On-premises and off-premises	*Individual*: socioeconomic position, age, gender, and ethnicity. *Community*: area deprivation, belong to a neighborhood group, perceptions of safety, neighborhood disorder, collective efficacy, and neighborhood facilities	No association with *current drinking* under adjustments by neighborhood SES and age of participants
Area-based rate of alcohol outlets	Wang S.H. et al. (2013)	Taiwan	School	Buffer	Yes (Euclidean, 1000 m)	Off-premises	*Individual*: weekly monetary allowance, information on individual backgrounds (gender, age, single-parent family, truancy, weekly monetary allowance and employment experience), life events, substance-use experiences and behavioral/emotional problems	Positive relationship between alcohol outlet density and *recent alcohol use* (having consumed alcohol in the past 6 months)
	Chen Y.T. et al. (2016)	Taiwan	Residence	District	No	On-premises, off-premises,	*Individual*: monthly allowance, age, gender, living with parents, parental education, parental drinking, elder	Positive association between *alcohol drinking initiation* and higher densities of betel nut kiosks (unregulated off-

(*continued on next page*)

Table 1 (*continued*)

Type of density calculation	First author and year of publication	Country	Place of exposure to alcohol	Geographic unit of analysis	Buffer	Type of outlet	Individual and community covariates included in the analyses	Association with prevalence outcome and direction of association
						and betel nut kiosks	sibling drinking, peer drinking, and parental drinking approval. *Community*: economic disadvantage and violent crime rate	premises), but not with densities of on-premises nor off-premises outlets. Moreover, there was a positive association between *alcohol drinking continuation* and higher densities of off-premises outlets
Roadway length-based rate of alcohol outlets	Shamblen S. R. et al. (2011)	USA	School	Census tract	No	On-premises and off-premises	*Individual*: gender, race, ethnicity, alcohol resistance self-efficacy, attitudes toward alcohol, alcohol use by siblings, alcohol use by familiar adults, perceived low risk of alcohol dependence, and perceived low risk of harm from alcohol. *Community*: poverty, rural location, high school graduates, peer approval of use, and peer respect for refusal	Outlet density has no association with *lifetime alcohol consumption, nor with past-year or past-30 days consumption*. Students in high off-site density communities increased their alcohol use through time; however, students attending schools in low outlet density communities had higher initial levels of alcohol use that remained relatively stable
Kernel Density Estimation	Martin G. et al. (2019)	Scotland	Residence	Buffer	Yes (Euclidean, 800 m)	On-premises and off-premises	*Individual*: age, gender, ethnicity, family structure, perceived neighborhood disorder, perceived social cohesion, SES. *Community*: neighborhood SES, urban/rural status, neighborhood-level disorder, and neighborhood-level social cohesion	No association between alcohol outlet density and *lifetime drinking*
Presence or absence of alcohol outlets within a container	Trapp G.K. et al. (2018)	Australia	Residence and school	Buffer	Yes (Street network, 800 m)	Off-premises	*Individual*: gender and family income	Positive association between presence of liquor store around school (and home or school) at 14 years and *ever having had part of an alcoholic drink* at 14 years, but not at 17. No association with having had an alcoholic drink in the past 12 months

focused on the association with consumption patterns and five studies analyzed the association with drinking prevalence among adolescents. Additionally, five studies assessed both associations and were included in both tables.

There was heterogeneity on the type of outlet analyzed in each study (i.e., on-premises or off-premises). Most of articles (n = 23) analyzed on-premises and off-premises outlets together. Among those, only five articles conducted the analyses separately for on- and off-types. Seven articles focused on off-premises outlets, while one article exclusively examined densities of on-premises outlets.

Different geographic units of analysis were used throughout the studies. The most prevalent were buffers around the residence and/or school locations, which were used in 17 studies (54.9%). One of these 17 studies created the buffer around the administrative area boundaries where the place of exposure (e.g., residence and/or school location) was located in (Jackson et al., 2016), and another study used buffers created around GPS route lines to account for activity spaces of adolescents (Byrnes et al., 2016). Two studies used buffers created around GPS route lines, but also estimated the AOD within the administrative areas (i.e., neighborhoods) where participants resided for sensitivity (Morrison et al., 2019a, 2019b). Fourteen (45,1%) studies used administrative areas as the main geographic unit of analysis. The reviewed articles used official neighborhoods, census blocks, local government areas, districts, communities, zip codes, school catchment areas -residential areas from which students were assigned to school- and city boundaries as geographic unit of analysis.

We discovered a variety of calculation methods used to measure AOD. Thirty studies used container-based measures, among which: ten studies (32.3%) used count of outlets, seven (22.6%) used population-based rate of outlets, seven (22.6%) calculated the area-based rate of number of outlets, four (12.9%) used roadway length-based rate of alcohol outlets and two (6.4%) noted the presence or absence of alcohol outlets within a specified area. One study used distance-based measures, specifically KDE (3.2%).

3.3. Description of associations

The 31 studies included a total of 53 associations between availability of alcohol outlets and drinking among adolescents. Table 3 summarizes the distribution of the direction and magnitude of these associations stratified by drinking outcome (i.e., prevalence or consumption patterns) and geographic unit of analysis at which the AOD was calculated. We identified 15 associations (28.3%) centered on prevalence of alcohol consumption (e.g., people who drink/people who

Table 2
Summary of the articles included in the systematic review which evaluate relationship between alcohol outlet density and patterns of alcohol consumption in adolescents.

Type of density calculation	First author and year of publication	Country	Place of exposure to alcohol	Geographic unit of analysis	Buffer	Type of outlet	Individual and community covariates included in the analyses	Patterns of consumption outcomes and direction of association
Count of alcohol outlets	Huckle T. et al. (2008)	New Zealand	Residence	Buffer	Yes (street network, 10 min by car)	On-premises and off-premises	*Individual*: frequency of social supply of alcohol (supply from parents, friends and others), own income, exposure to alcohol, own purchase, sex, age, ethnicity, number of adverts seen, and number of brands recalled. *Community*: NZDEP score (SES), and locality-based willingness to sell alcohol	Alcohol outlet density is associated with *typical occasional quantity of alcohol consumed*, but not with *frequency of drinking or with frequency of drunkenness*
	Young R. et al. (2012)	Scotland	Residence	Buffer	Yes (street network, 1200 m)	On-premises and off-premises	*Individual*: SES based on parents occupation, gender, and family structure	*Weekly alcohol use* was positively associated with density of off-premises outlets, except when the model was clustered by school of the student
	Shih R.A. et al. (2015)	USA	Residence	Buffer	Yes (Euclidean, 0.1, 0.25, 0.5 and 2 miles)	On-premises and off-premises	*Individual*: gender, age, race, and ethnicity. *Community*: SES	*Heavy alcohol use* in the past 30 days is positively related to on-premises (0.1-, 0.25- and 0.5-mile radius), and club/bar (0.1- and 0.25-mile radius) densities. No association with off-premises
	Fairman B.J. et al. (2019)	USA	Residence	Buffer	Yes (Euclidean, 1000 m)	Off-premises	*Individual*: family affluence, gender, age, and race/ethnicity. *Community*: SES and median age of census tract	The number of liquor stores within 1 km was not associated with any *binge-drinking trajectory*
	Morrison C. N. et al. (2019a)	USA	Residence and Activity Space (GPS route lines)	Buffer and census block for sensitivity	Yes (Euclidean, 50, 100 and 200 m)	On-premises and off-premises	*Individual*: percent of time at home, gender, age, and race/ethnicity. *Community*: neighborhood disorganization (which considers SES, among other variables)	No association between alcohol outlet density around or away from home using GPS data, and frequency and quantity of alcohol consumed, drunkenness or binge drinking in the past 30 days
	Martins J.G. et al. (2019)	Brazil	School	Buffer	Yes (Euclidean, 1000 m)	On-premises and off-premises	*Individual*: mother's educational level, sex, age, alcohol consumption by father, alcohol consumption by mother, and alcohol consumption by siblings. *Community*: type of school	The rates of binge drinking are lower in adolescents that go to school in areas with low alcohol outlet densities
	Cardoza L.S. et al. (2020)	Brazil	School	Buffer	Yes (Euclidean, 250 m)	On-premises and off-premises	*Individual*: gender, age, work, physical activity, and smoking. *Community*: per capita income, demographic density, cigarette outlet density, school size (number of students), and distance from city ground zero (km)	There was no association between *alcohol use* (frequency + quantity per week) and a higher density of alcohol outlets (on-premises or off-premises)
	Fairman B.J. et al. (2020)	USA	Residence	Buffer	Yes (5 km, buffer type calculation is not specified)	Off-premises	*Individual*: age, sex, race/ethnicity, family affluence, and family composition. *Community*: neighborhood disadvantage, neighborhood median age, the proportion of Black residents, and population density	The number of liquor, beer and wine stores within 5 km were associated with *binge drinking* when adjusting by race. Living near two or more beer stores or wine stores increased the odds of *binge drinking* among Whites, while living near higher density

(*continued on next page*)

Table 2 (*continued*)

Type of density calculation	First author and year of publication	Country	Place of exposure to alcohol	Geographic unit of analysis	Buffer	Type of outlet	Individual and community covariates included in the analyses	Patterns of consumption outcomes and direction of association
								of liquor stores increased this behavior among Blacks
Population-based rate of alcohol outlets	Kuntsche E. et al. (2008)	Switzerland	Residence	Community	No	On-premises and off-premises	Individual: Perceived availability (beer, wine, spirits), drinking peers, drinking siblings, public drinking, parental monitoring perceived availability, sex, and age	On-premises alcohol outlet density is positively related to *number of drinks consumed in the past* 12 months and to *risky single occasion drinking in the past 30 days*. No association with off-premises outlet density
	Tobler A.L. et al. (2009)	USA	Residence	Community area	No	Off-premises	Individual: home alcohol access, parental monitoring, and alcohol specific communication at home. *Community*: SES, commercial accessibility of alcohol, exposure to alcohol advertisements, perceived neighborhood problems, neighborhood and police preventive action and neighborhood strength	No association between *alcohol use*, and alcohol outlet density. Alcohol use was defined by 5 items assessing alcohol use in the past year, past month, past week, heavy episodic use and having ever been drunk
	Stanley L.R. et al. (2011)	USA	Residence	Zip code	No	On-premises and off-premises	*Individual*: perceived alcohol availability, gender, grade, alcohol in the family environment, alcohol in peer's environment, trouble if caught drinking at school, and chances of getting caught drinking by the police. *Community*: rurality, community perceived availability, and ethnic composition of the community	Density of liquor outlets is significantly related to *past month alcohol use* among younger students (7th-9th graders), but not among older students (10th-12th graders). Beer/wine in grocery or other stores is not associated with past month alcohol use
	Azar D. et al. (2016)	Australia	Residence	Zip code	No	On-premises and off-premises	*Individual*: age group, sex, indigenous heritage, and smoking in the past. *Community*: SES, urban/rural status	General and on-premises outlet density was associated *with past month alcohol use* and *risky drinking* among all adolescents. Positive association between off-premises outlet density and club density, with *risky drinking* in urban, but not regional areas
	Rowland B. et al. (2016)	Australia	Residence	Local government area	No	On-premises and off-premises	Individual: SES, age, sex, Australian born, and alcohol use at Wave 1. Wave 1 risk factors: interaction antisocial peers, parental attitude favorable to drugs, parental attitude favorable to antisocial behavior, laws and norms favorable to drug use. Wave 2 mediators: proportion of friends that use drugs, and perceived availability of alcohol	A 10% increase in overall density of alcohol outlets at Wave I (2002) of the study was associated with an approximately 17% increase in the *odds of an adolescent drinking alcohol* at Wave II (2003)
	Jackson N. et al. (2016)	New Zealand	Residence	Synthetic neighborhood (area units in NZ) and buffer around it	Yes (500 m)	On-premises and off-premises	*Individual*: socioeconomic position, age, gender, and ethnicity. *Community*: area deprivation, belong to a neighborhood group,	Young adolescents (<16 years) residing in high outlet density and economic deprived neighborhoods are more likely to *binge drink* and

(*continued on next page*)

Table 2 (*continued*)

Type of density calculation	First author and year of publication	Country	Place of exposure to alcohol	Geographic unit of analysis	Buffer	Type of outlet	Individual and community covariates included in the analyses	Patterns of consumption outcomes and direction of association
							perceptions of safety, neighborhood disorder, collective efficacy, and neighborhood facilities	*consume high typical quantities of alcohol*. This relationship was not found for adolescents that were 16 or older
Area-based rate of number of alcohol outlets	Lo C.C. et al. (2013a)	USA	School	School catchment area (SCA)	No	On-premises and off-premises	*Community*: population disadvantage, community instability, protective role of school, protective role of community, percentage of African American residents, percentage of White residents, percentage of female-headed single-parent families, percentage of population living below poverty level, percentage of population 15–18 years old, percentage of families residing in one and the same domicile from 1995 to 2000, percentage of population 25 years and older having a college degree in 2000, and percentage of population 25 years and older having a high school diploma	No association between alcohol outlet density and *past 30 days alcohol use*
	Lo C.C. et al. (2013b)	USA	School	School catchment area (SCA)	No	On-premises and off-premises	*Individual*: grade, gender, religion, protective role of family, peer drug use, and protective role of self. *Community*: population disadvantage, community instability, protective role of school, and protective role of community	No association between alcohol outlet density and *binge drinking in the past 2 weeks*
	Larsen K. et al. (2017)	Canada	School	Buffer	Yes (Street network, 1600 m)	On-premises and off-premises	*Individual*: age and sex. *Community*: SES and population density	No association between alcohol outlet density and binge drinking in the past 4 weeks
	Chen C.Y. et al. (2018)	Taiwan	Residence	District region	No	On-premises and off-premises	*Individual*: monthly spending, gender, pubertal development, living with parents, parental education, parental drinking, perceived peer drinking, childhood alcohol initiation, childhood alcohol purchasing, and leisure-activity participation. *Community*: recreational resource density	Occasional drinking in the past 12 months was associated with density of Betel nut kiosks (unregulated off-premises), but not with on- or off-premises
	Morrison C. N. et al. (2019b)	USA	Residence and Activity Space (GPS route lines)	Buffer and census block for sensitivity	Yes (Euclidean, 800 m–around residence and activity locations- and 100 m -path line-)	On-premises and off-premises	*Individual*: household income, alcohol, tobacco and other drug use, age, sex, race/ethnicity, and whether they reported ever consuming alcohol	Some of the residence-based measures (e.g., census tract), none of the activity location–based approaches, and most of the activity path–based approaches (e.g., outlets per hour, 100 m buffer) were associated with *alcohol consumption*
Roadway length-based rate of alcohol outlets	Chen M.J. et al. (2010)	USA	Residence	Zip code	No	Off-premises	*Individual*: age, sex, race, perceived parent drinking, mean perceived peer drinking, mean personal income, had a car, and friends had a car. *Community*: median household income	Positive association with frequency of drinking and excessive drinking in the past 12 months

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Table 2 (*continued*)

Type of density calculation	First author and year of publication	Country	Place of exposure to alcohol	Geographic unit of analysis	Buffer	Type of outlet	Individual and community covariates included in the analyses	Patterns of consumption outcomes and direction of association
	Paschall M. J. et al. (2012)	USA	Residence	City	No	On-premises and off-premises	*Individual*: age, gender, ethnicity, race, perceived alcohol availability, perceived enforcement, and perceived acceptability of alcohol use. *Community*: median household income, total population, population density, % receiving public assistance, % unemployed, and % ethnic minority	*Past-year alcohol use* (frequency x quantity) and *heavy drinking* were positively associated with outlet density when perceived alcohol availability, perceived enforcement of underage drinking laws and perceived parental approval of alcohol use were excluded from the analysis. These three variables are positively correlated to consumption
	Paschall M. J. et al. (2014)	USA	Residence	City	No	On-premises	*Individual*: gender, age, race, and ethnicity. *Community*: SES, population density, percent of people minor than 18 years old, and percent of people by race/ethnicity	*Past-year alcohol use* over time (frequency x quantity) was positively associated with bar density when perceived alcohol availability, perceived enforcement of underage drinking laws and perceived parental approval of alcohol use were excluded from the analysis. No association between *heavy drinking* over time and bar density
Kernel Density Estimation	Martin G. et al. (2019)	Scotland	Residence	Buffer	Yes (Euclidean, 800 m)	On-premises and off-premises	*Individual*: age, gender, ethnicity, family structure, perceived neighborhood disorder, perceived social cohesion, SES. *Community*: neighborhood SES, urban/rural status, neighborhood-level disorder, and neighborhood-level social cohesion	No association between alcohol outlet density and weekly *drinking* or *drunkenness* (felt drunk two or more times ever)
Presence or absence of alcohol outlets within a container	Byrnes H.F. et al. (2016)	USA	Activity Spaces (GPS route lines)	Buffer	Yes (100 m, buffer type calculation is not specified)	On-premises and off-premises	NA	No association between alcohol outlet density exposure and *alcohol consumption*
	Trapp G.K. et al. (2018)	Australia	Residence and school	Buffer	Yes (Street network, 800 m)	Off-premises	*Individual*: gender and family income	Positive association between liquor store proximity around home or school at 14 years and engaging in heavy drinking at 14 years, but not at 17. No association with having been drunk in the past 6 months

do not drink). Of these, we found two positive associations; six6 positive associations under some circumstances and seven showed no association (Table 3). We observed 38 (71.7%) association measurements focused on the relationship between AOD and alcohol consumption patterns (i.e., drinking frequency, quantity, or binge drinking), where positive associations, positive associations under some circumstances and no associations were found in 5, 18 and 15 measurements, respectively. No negative associations between AOD and drinking prevalence or consumption patterns were found in any article (See Table 3).

Additionally, out of the eight associations that found a positive relationship with prevalence of alcohol consumption (either 'positive' or 'positive under some circumstances'), six evaluated off-premises in separate analysis. Of the seven associations that did not find any relationship with prevalence of consumption, five analyzed on- and off-premises alcohol outlets together (making no distinction between one and the other). When evaluating the associations with patterns of consumption, no matter the result of the association, most of the studies evaluated on- and off-premises outlets together (24/38). No patterns were found between the result of the associations and the type of outlet evaluated.

The distribution of the associations by the geographic unit of analysis used for the density calculations was very heterogenic (Table 3). We observed that 26.4% (n = 14) of the associations used AOD calculations referred to count of outlets within an area. Nine of these studies counted number of outlets within Euclidean buffers and four studies used street network buffers. One paper counted number of outlets within the participant's activity spaces estimated by buffers around route lines tracked with GPS, and also within their residential census block for sensitivity.

Table 3
Number of associations between availability measures and alcohol consumption outcomes in adolescents in the studies included in the systematic review.

Type of density calculation (n = 53)	Alcohol prevalence outcome (n = 15)				Alcohol consumption pattern outcome (n = 38)			
	Positive association	Positive association under some circumstances	No association	Negative association	Positive association	Positive association under some circumstances	No association	Negative association
0. Count (n=14)	**1**	**2**	**1**	**0**	**2**	**6**	**2**	**0**
Within Euclidean buffer	1	2	1	–	1	2[b]	2[c]	–
Within Street Network buffer	–	–	–	–	1	3	–	–
Within activity space (buffer around GPS route lines)	–	–	–	–	–	1	–	–
1. Population-based rate (n=11)	**0**	**1**	**1**	**0**	**1**	**7**	**1**	**0**
Within Euclidean buffer	–	–	–	-	–	–	–	-
Within administrative area	–	1	-	-	1	5	1	-
Within buffer around administrative area	–	–	1[a]	–	–	2[a]	–	–
2. Area-based rate (n=11)	**1**	**2**	**0**	**0**	**0**	**1**	**7**	**0**
Within Euclidean buffer	1	–	–	–	–	–	–	–
Within Street Network buffer	–	–	–	–	–	–	1	–
Within administrative area	–	2	–	–	–	1	2	–
Within activity space (buffer around GPS route lines)	–	–	–	–	–	–	4	
4. Roadway length-based rate (n=9)	**0**	**0**	**3**	**0**	**2**	**3**	**1**	**0**
Within administrative area	–	–	3	–	2	3	1	–
5. Kernel Density Estimation (n=3)	**0**	**0**	**1**	**0**	**0**	**0**	**2**	**0**
6. Presence/Absence (n=5)	**0**	**1**	**1**	**0**	**0**	**1**	**2**	**0**
Within activity space (Euclidean buffer around GPS route lines)	–	–	–	–	–	–	1[d]	–
Within Street Network buffer	–	1	1	–	–	1	1	–
TOTAL	**2**	**6**	**7**	**0**	**5**	**18**	**15**	**0**

[a] In the article of Jackson N. et al. (2016) we assume that the calculation used was Euclidean, since it is not specified in the text of the corresponding article.
[b] In the article of Fairman B.J. et al. (2020) we assume that the calculation used was Euclidean, since it is not specified in the text of the corresponding article.
[c] In the article of Fairman B.J. et al. (2019) we assume that the calculation used was Euclidean, since it is not specified in the text of the corresponding article.
[d] In the article of Byrnes H.F. et al. (2016) we assume that the calculation used was Euclidean, since it is not specified in the text of the corresponding article.

Beyond the type of geographic unit of analysis implemented, these articles averaged a higher number of positive or positive under some circumstance associations regardless the type of buffer used (3 vs 1 no association with alcohol prevalence; and 8 vs 2 no associations with consumption).

Population-based rate and area-based rate of outlets were used in 11 (20.1%) associations, each. For those that explored population-based rates of outlets, two articles analyzed the relationship with prevalence outcomes, and one found a positive association but the other did not. Nine studies explored associations with consumption patterns, from which eight found a positive association (88.89%). On the other hand, for those that measured density as area-based rates of number of outlets, three manuscripts analyzed the relationship with prevalence outcomes and found a positive association. Eight associations were focused on consumption patterns, and only one found association with alcohol consumption under some circumstances.

Nine analyses of associations used roadway length-based rate of alcohol outlets within administrative areas as the measure of availability. Among these, three associations evaluated with prevalence outcomes found no association. The others studied relationships to consumption patterns, and five of them found positive associations.

KDE were found in three analyses within the same article, one with prevalence outcomes and two with consumption pattern outcomes. None of them found associations between availability and drinking.

Finally, two analyses explored the availability as presence or absence of alcohol outlets within a specified area with prevalence outcomes, where one found positive association and the other one no association. Presence or absence of alcohol outlets within a specified area was also explored in three analyses with patterns of consumption outcomes: one found a positive association and the other two found no association.

4. Discussion

The present study aimed to review the existing evidence on how the geographic availability of alcohol is associated with drinking among adolescents. Overall, just over half of associations reviewed showed positive relations between geographic AOD and alcohol prevalence (n = 8/15, 53.3%) or consumption patterns (n = 23/38, 60.5%), respectively. No articles found any negative association between these measures. However, some of these positive associations were identified under some circumstances, when specific decisions were made towards the individual-level covariates, the types of alcohol outlet involved, the method to calculate the AOD and the geographic unit of analysis.

4.1. Differences in findings according to individual-level covariates

AOD measures report the physical concentration of alcohol outlets in a pre-defined space. However, the spatial density of outlets might influence differently on the drinking behaviors of adolescents according to their individual characteristics. In the studies included in our systematic review, there was a great variability in the individual-level characteristics included as covariates in the analyses. However, there were some similarities. Most of the studies included sex/gender (n = 28) and age (n = 25) as covariates. There are only three studies that do not adjust either by sex/gender nor age, and neither of them find associations in their analyses (Tobler et al., 2009; Lo et al., 2013b; Byrnes et al., 2016). Additionally, 17 studies included adjustments by race/ethnicity/origin and 16 by some variable that served as proxy for individual SES (e.g. monthly allowance or family income). Demographic variables have been seen to influence health outcomes in populations (Collins, 2016a; Chartier and Caetano, 2010), thus, their inclusion may be important to understand the effect of geographic availability on adolescent drinking.

Moreover, we found that some associations between AOD and consumption patterns were only positive after adjusting by individual-covariates (Morrison et al., 2019a, 2019b; Paschall et al., 2012, 2014). Examples are the studies of Morrison et al. (2019) (Morrison et al., 2019a, 2019b), which found no direct association between AOD and patterns of consumption in adolescents. However, AOD around home was positively associated with accessing alcohol from peers aged <21, and in turn, accessing alcohol from peers aged <21 was positively associated with alcohol consumption. Also, we observed differences in the interpretation of variables included in each study. For instance, the laws regarding the purchase of alcohol, such as minimum age, are an important matter to consider when defining or testing individual covariates. In the case of the studies of Morrison et al. (2019) (Morrison et al., 2019a, 2019b), legal age to buy and drink alcohol is 21, thus, this covariate in this concrete policy context makes sense, while in other countries with different regulations it may not.

Furthermore, two studies found positive associations between AOD and consumption patterns, where physical perceived availability (i.e., perception of easiness to access to alcohol) was a mediator for such relationships (Paschall et al., 2012, 2014). This means that perception of the easiness to access alcohol could also influence alcohol consumption among adolescents, as it also has been stated in previous articles on this specific area (Molina-de la Fuente et al., 2021; Dimova et al., 2023). Thus, the inclusion of this variable as a covariate in future studies in this area could be relevant to understand potential pathways through which the geographical availability of alcohol outlets affects adolescent drinking.

4.2. Differences in findings by alcohol outlet type

Our results identified disparate findings on the associations according to the alcohol outlet types. Positive associations with prevalence of alcohol consumption were more numerous among those studies that considered off-premises outlets separately, compared to those that included only on-premises or analyzed both on- and off-premises outlets together. This could be because underage alcohol purchasing may be easier in off-premises outlets (than in on-premises outlets), where may exist a lower enforcement of minor purchasing bans and alcohol might be cheaper (Pastor et al., 2020b; Rowland et al., 2016b). However, the types of outlets (on- or off-premises) seemed not to have a distinct effect when exploring associations with patterns of consumption.

4.3. Differences in findings by AOD calculation method

We found a great heterogeneity in the methodologies used to measure density of alcohol outlets, including count of outlets, population, area or roadway length-based rates of outlets, and presence/absence of outlet within an area measures.

The result of the associations between the alcohol prevalence outcomes and availability of alcohol did not exhibit a clear link with the type of AOD method in each study. However, concerning the alcohol consumption patterns, we noticed a trend: studies using count of alcohol outlets, population-based rate of outlets or roadway length-based rate of outlets to measure availability showed more positive associations than those using area-based rate of number of outlets, presence/absence or KDE measures. We should interpret these results cautiously and acknowledge that each study included different confounding factors and each type of density method describes unique insights into the spatial concentration of alcohol outlets.

To illustrate, consider a hypothetical study case where the population and alcohol outlets are concentrated in an urbanized section covering a small portion of the whole study area. Density calculations expressed as area-based rates of number of outlets will encompass the entire study area extent, including the non-urbanized areas, potentially misrepresenting the true retailer density in the specific urbanized section, where most of the population resides. In contrast, density calculations based on population-based, or roadway length-based rates of outlets provide a different perspective of the alcohol availability, accounting for a ratio of outlets per resident or per each kilometer along walking routes.

These findings underscore the importance of future studies on alcohol outlet availability carefully selecting appropriate density methods to use according to their objectives and data limitations. Different measurement methods may be appropriate for different population groups. An area rate of availability may be less important to adolescents than the number of outlets immediately available around them (count). Researchers must be mindful of the nuances offered by each method to accurately interpret their findings.

4.4. Differences in association findings by geographic unit of analysis and the UGCoP

Around a half of articles used user-defined areas (i.e., buffers) or administrative areas as the geographic unit of analysis (n = 54.9% and n = 45.1%, each) in this review. Among those using buffers, the Euclidean buffer types were the most common. The prevalent use of Euclidean buffers is notable given that some studies have pointed out that street network buffers measures offer a more precise calculation of the areas that are accessible to participants (Martín-Turrero et al., 2023; Frank et al., 2005). However, Euclidean buffers are less complicated to calculate and interpret (Martín-Turrero et al., 2023; Frank et al., 2005).

Positive associations between AOD and drinking were described regardless of the type and size (e.g., 200m vs 5000m buffer or small vs medium/large administrative areas) of the geographic unit of analysis used. However, previous evidence suggests that the choice of the type and size of the geographic unit of analysis for calculating exposure to alcohol outlets should not be considered a trivial decision, as it may influence the magnitude and implications of the obtained results (Apparicio et al., 2017; Martín-Turrero et al., 2023). This evidence pertains to the Uncertain Geographic Context Problem (UGCoP), which acknowledges the daily mobility of individuals across space and argues that populations are exposed to environmental harms beyond their home or school/work locations, suggesting that the use of buffers or administrative areas might not capture the total individuals' activity space and therefore their exposure to environmental harms (Chen and Kwan, 2015). The UGCoP also emphasizes the importance of incorporating a temporal perspective into environmental exposure assessments, as availability might change over the time (e.g., alcohol availability change during the day as the outlets schedules).

Additionally, as discussed before, although different populations were exposed to similar contexts of alcohol outlet availability exposure (at the same space and time), the influence of such exposure on their drinking behaviors might differ by individual level characteristics (sex/gender, age, income level, etc.). Thus, it is important to acknowledge

that not all positive associations have the same implications across areas and populations. Understanding how the geographic availability affects alcohol consumption across different populations and contexts is crucial for future policy interventions to mitigate adolescent drinking.

In recent years, numerous studies had integrated GPS-based methods to mitigate the contextual uncertainty (UGCoP) and created more precise exposure measurements by considering all frequented areas by the individual rather than just their resident or school location. Our systematic review identified three articles employing GPS to measure activity spaces, (Morrison et al., 2019a, 2019b) but only one found a positive association between the density of outlets and alcohol consumption.

The ubiquity of alcohol outlets throughout the environment, described across different regions and contexts (Molina-de la Fuente et al., 2021; Pastor et al., 2020b; Dimova et al., 2023), may explain why many articles in our review demonstrated positive associations between the AOD and drinking independently of the type and size of the geographic units of analysis they chose.

4.5. Potential implications for policy and further research

Out of 53 associations between alcohol consumption in adolescents and availability of alcohol outlets included in this review, 31 yielded a positive association (including those positive under some circumstances). This research summarizes the associations found for adolescents and whilst the findings are mixed, they do add to the current body of evidence that explores the geographic availability of alcohol and population health.

Previous studies have empirically demonstrated the effectiveness of interventions restricting the geographic availability of alcohol outlets on reducing consumption and health-related harms (Sherk et al., 2018). However, the implementation of these policies has been challenged by a lack of government regulatory and legislative structure and a lack of longitudinal evidence. There remains a gap in the evidence base related to the longitudinal impact of availability change and related outcomes, or how growing up in areas of varying density may impact consumption in later life. Much of the work in this area is cross-sectional and as a result it remains difficult to infer causal direction (Gmel et al., 2016). Future work should explore geographic availability changes over time, consumption across the life course, the relative importance of outlet type for different population groups, the impact of different methodologies to measure outlet density and the impact of confounders in any model.

Moreover, specific cultural, social, urban, and economic factors rooted in each particular region must be considered when addressing the geographic availability of alcohol outlets. For instance, almost half of the studies in this review were conducted in USA, where the legal drinking age is 21, and where some states have an alcohol monopoly. However, in other countries, like in Europe, there is a different policy landscape, with minimum drinking age established in 18 years old. These differences in the policy context of alcohol availability and accessibility within countries might lead to differential perceptions and social norms around drinking and, therefore, consumption patterns across adolescents with different demographic and socioeconomic backgrounds. Subsequentially, the legal landscape of each country also conditions the geographic pattern of distribution of alcohol outlets and the advertising and marking strategies within retailers. Acknowledging the specificities of the geographic alcohol outlet availability regulations and related legal provisions restricting alcohol purchasing within each country is crucial to understand associations between the AOD and drinking outcomes across geographies and individuals and population sub-groups (Sudhinaraset et al., 2016; Aresi et al., 2023). However, in this systematic review there is no consistency in the results found about the direction and magnitude of associations between AOD and drinking outcomes across studies conducted within the same regions or countries (Martins et al., 2019; Cardoza et al., 2020). This lack of consistency might be explained by the methodological differences between studies, including how the AOD calculations are conceptualized, the types of alcohol outlets evaluated, or the covariates used to adjust the analyses.

4.6. Strengths and limitations

This study has notable strengths. It is the first study to evaluate literature consensus on the association between drinking in adolescents and AOD, offering an overview of the geographic methods used to measure alcohol outlet availability. Moreover, this review contains a large number of articles (n = 31), which allows drawing supported conclusions to apply public health policies.

However, some limitations should be acknowledged. The absence of homogeneity between the geographic availability measures among the studies included in this systematic review, made it difficult to conduct meta-analysis or other joint analyses. Future studies could explore how associations with drinking may change when using different methodologies to estimate the AOD across similar regions. This kind of studies may help to clarify potential advantages and disadvantages of each type of availability measures when considering a specific geographic context.

The search strategy of this study yielded over 16,000 results, reflecting the broad search terms included, which were considered necessary to capture all the relevant articles in the literature. For instance, we included terminology for both on- and off-premises outlets separately, in case any studies focused on the availability of just one type of outlet. While this strategy has the disadvantage of a high cost in terms of screening articles, it ensures that our work provides a comprehensive review of the current evidence on the association between AOD and adolescents drinking.

This systematic review excluded the articles which only evaluated proximity measures to alcohol outlets (i.e., distances from home/school to alcohol outlets). The proximity measures may offer an alternative perspective of the geographic accessibility of alcohol outlets that we may overlook in this review. In essence, while density measures capture a degree of spatial concentration of outlets within a given area, the proximity measures provide distance or time accessibility to alcohol outlets from a given place of exposure (home, school, etc.). Nevertheless, we noted that, as compared to density, proximity measures are far less studied.

Finally, the scope of this review was focused on geographic availability measures and influence over alcohol consumption in adolescents. However, we could have missed some other possible factors that mediate this interaction (e.g., temporal availability of outlets -opening times- or alcohol price, etc.) (Martín-Turrero et al., 2022; Kilian et al., 2023), which have been found to relate with alcohol consumption and its consequences (Collins, 2016b; Peña et al., 2017; Wiles et al., 2007).

5. Conclusion

In this review, just over half of the associations studied find evidence of a positive relationship between the availability of alcohol outlets and drinking in adolescents. The remaining, found no association. Several positive associations were outlined only under some circumstances. These circumstances were related to decisions towards the studies analytical plans, such as the adjustment for individual-level covariates, the types of alcohol outlet involved, the method to calculate the AOD and the geographic unit of analysis.

Positive associations between AOD and drinking prevalence outcomes were found mostly in those articles that evaluated off-premises outlets separately. Positive associations between AOD and drinking consumption patterns outcomes were found primarily in studies that defined AOD as counts of alcohol outlets, roadway length-based ratios of outlets, and population-based rates of outlets. However, it was not possible to make a systematic comparison of the implications of different types of alcohol outlet availability measures on the results of their associations with drinking. Most of the studies were carried out in different

regions, with specific socio-economic, geographic and policy contexts towards alcohol consumption and outlet availability. Moreover, distinct AOD calculations captured different aspects of availability. Thus, the methods and analytic plans to explore associations between alcohol outlet availability and drinking should be well-justified and tailored to the idiosyncrasies of the alcohol environment in the study area, and potential data limitations, to address meaningful objectives within each case.

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None.

CRediT authorship contribution statement

Irene Martín-Turrero: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Roberto Valiente:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Andrea Pastor:** Writing – review & editing, Investigation. **Usama Bilal:** Writing – review & editing, Investigation. **Xisca Sureda:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2024.103362.

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