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Tobacco and alcohol use; suicide ideation, plan, and attempt among adolescents; and the role of legal purchase age restrictions: a pooled population-based analysis from 58 countries

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Abstract

Background We aimed to evaluate the potential independent and interactive associations of tobacco and alcohol use with suicide ideation, plan, and attempt among adolescents, and the role of legal purchase age restrictions among these associations.

Methods A pooled cross-sectional analysis was conducted with data from the Global School-based Student Health Survey (GSHS) (2013–2019), the US Youth Risk Behavior Surveillance System (YRBSS) (2021), and a Chinese school-based health survey (2017). Self-reported use of tobacco and alcohol during the past 30 days, and suicide ideation, plan, and attempt during the past year, were collected from questionnaires. Country-level purchase age restrictions on tobacco and alcohol products were obtained from official government websites.

Results Among the 211,022 adolescents from 58 countries, 46.7% were boys. Compared with adolescents who used neither tobacco nor alcohol, those who used both tobacco and alcohol had the highest odds of suicide ideation (boys: 2.42 [95% CI: 2.25–2.61]; girls: 3.19 [95% CI: 2.98–3.40]; $P_{\text{difference}} < 0.001$), suicide plan (boys: 2.39 [95% CI: 2.21–2.58]; girls: 3.33 [95% CI: 3.11–3.57]; $P_{\text{difference}} < 0.001$), and suicide attempt (boys: 3.24 [95% CI: 3.00–3.51]; girls: 4.03 [95% CI: 3.75–4.33]; $P_{\text{difference}} < 0.001$). In countries with higher suicide plan prevalence, boys who use tobacco and who live in countries with tobacco purchase age restrictions had lower odds of suicide plan (1.86 [95% CI: 1.64–2.12]) than those who lived in countries without restrictions (2.81 [95% CI: 2.32–3.42]). Similarly, girls who use tobacco and who live in countries with legal age purchase restrictions displayed lower odds of suicide plan (2.20 [95% CI: 1.98–2.45]) compared to those who live in countries without restrictions (4.61 [95% CI: 3.65–5.83]). However, our study revealed no subgroup differences in whether countries have legal tobacco or alcohol purchase age restrictions in association with suicide ideation, plan, and attempt risk in countries with a lower prevalence of suicide behaviors.

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Conclusions Tobacco and alcohol consumption are strongly associated with the risk of suicide behaviors among adolescents, particularly among girls. Country-level tobacco control strategies may have the potential to reduce risks of suicide behaviors associated with tobacco use among adolescents.

Keywords Adolescent health, Global health, Suicide behavior, Tobacco use, Alcohol use, Health policy

Background

Suicidal behaviors, including ideation, plan, and attempt, are the leading cause of death and disability among adolescents worldwide [1]. The Sustainable Development Goals (SDGs) emphasize the importance of ensuring healthy lives and promoting well-being for all ages, setting the target (Target 3.4) to reduce premature mortality from non-communicable diseases and promote mental health and well-being by one-third by 2030 [2]. Reducing suicidal behaviors is crucial for preventing premature deaths and achieving this target among adolescents and young people. However, as we approach the halfway mark to the 2030 goals, the global situation remains far from satisfactory and may be exacerbated by the ongoing impact of the pandemic [3, 4]. Suicide ideation, plan, and attempt share common risk factors, and recognizing these shared risk factors is crucial for implementing more effective suicide control strategies across diverse populations [5, 6].

Suicide behaviors are affected by a wide range of sociodemographic, psychiatric, physical, and other influences [7]. Among various risk factors, substance use, particularly tobacco and alcohol use, has been identified as a significant contributor to suicidal behaviors in adolescents from both high-income and low/middle-income countries [8, 9]. Recent studies have shown that tobacco and alcohol use are highly prevalent among adolescents and are often associated with an increased risk of suicidal behaviors [10]. For instance, a cross-sectional study from China and the USA in 2017 reported that adolescents aged 7 to 12 years who reported cigarette and alcohol use were more likely to be at risk for suicidal ideation and attempts [11]. Another large-scale study in the USA in 2019 reported that adolescents inpatients aged 12 to 18 years with alcohol use disorders were at 18% higher odds of suicide-related hospitalization [12]. Despite these findings, there is a substantial research gap regarding the global perspective on the associations between these substances and suicidal behaviors [13]. Most existing studies are region-specific and do not provide a comprehensive analysis of these associations across different countries.

In many countries, policies have been developed to establish and increase legal purchase age restrictions (the minimum age at which individuals are allowed to buy such products) on alcohol and tobacco products, in order to decrease the health damage directly related to them, such as substance independence, injuries, and of course suicidal behaviors [14–16]. A meta-analysis suggested that interventions limiting alcohol use led to a reduction in self-harm suicide attempts in adolescents [17]. Studies in the USA have reported that increasing the minimum age for alcohol consumption is associated with a lower suicide rate among adolescents. These findings suggest that alcohol-related restrictions should be prioritized, especially when tobacco and alcohol use coexist, to reduce the risk of suicide [18, 19]. However, the findings of these studies do not sufficiently elucidate the associations between tobacco and alcohol use and various suicide ideation, plan, and attempt across different countries globally, nor do they explore the potential interactions between these factors. Additionally, few studies have investigated the applicability of policy interventions for reducing the risk of substance-related suicide behaviors, especially from a global perspective [20]. It remains unclear whether these policies are positively related to a decreased risk of suicidal behaviors associated with tobacco and alcohol use, and the consistency of these policies' effectiveness across different population groups also warrants discussion. More importantly, although it is well known that girls and non-Hispanic adolescents are more affected by these issues compared to boys and Hispanic adolescents [21, 22], it remains unclear whether they benefit equally from these policies.

To bridge these knowledge gaps, we examined the independent and interactive associations of tobacco and alcohol use with suicide ideation, plan, and attempt among adolescents using data from a pooled school-based survey of 211,022 adolescents from 58 countries, and further investigated whether the presence of legal purchase age restrictions on tobacco and alcohol use could reduce the risk of suicide ideation, plan, and attempt associated with tobacco and alcohol use among adolescents.

Methods

Study population and survey design

We performed a pooled analysis of data from three preexisting surveys that all employed a cross-sectional design and utilized a similar stratified multistage sampling method, along with consistent data curation procedures [23], including the US Youth Risk Behavior Surveillance System (YRBSS) in 2021, the Global School-based Student Health Survey (GSHS) from 2013 through

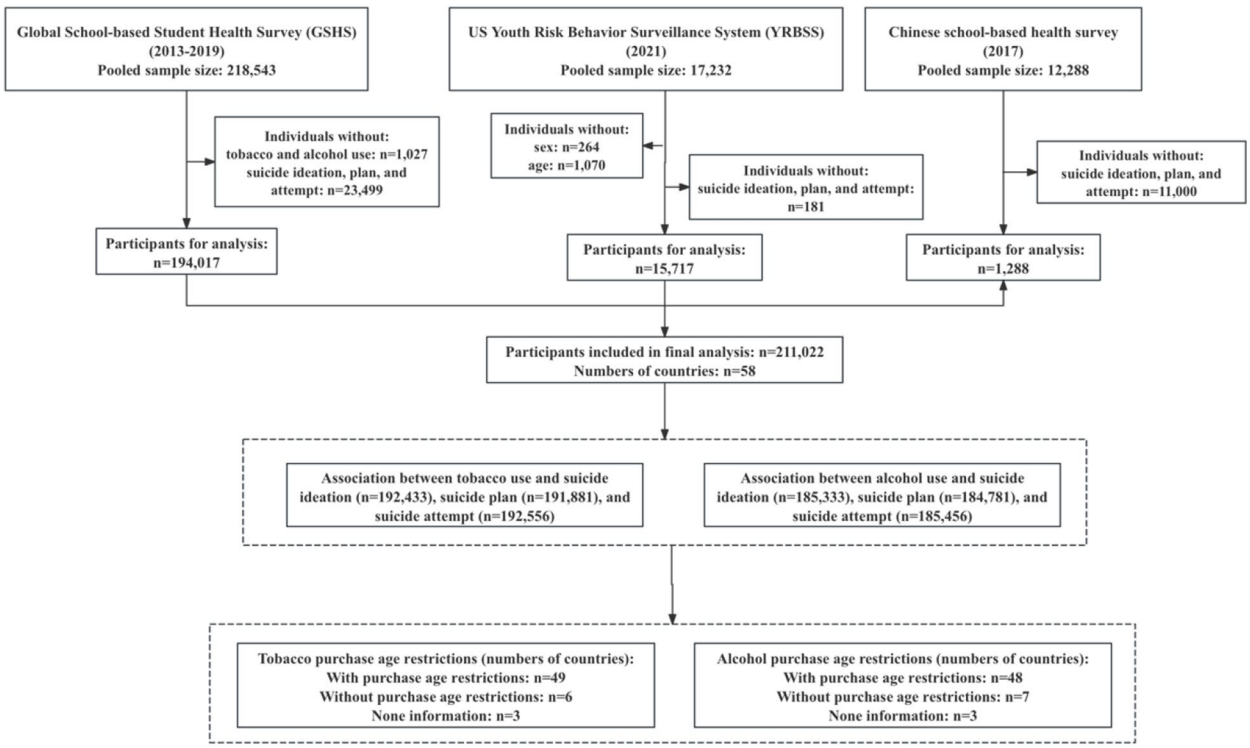

Fig. 1 Diagram of participant inclusion process for analysis

the most recent, and a school-based student health survey conducted in Jiangxi and Jiangsu Provinces of China in 2017. Analysis of deidentified secondary data did not involve an ethical review of human subjects.

The US adolescent data were derived from the YRBSS, which was established in 1991, and aims to monitor six categories of priority health-risk behaviors among young people and adolescents [23], and the latest YRBSS data can be accessed freely from the Centers for Disease Control and Prevention of the USA at https://www.cdc.gov/healthyyouth/data/yrbs/data.htm [24].

The GSHS is a collaborative surveillance project designed to help countries measure and assess behavioral risk factors and protective factors in 10 key areas among adolescents aged 12 to 17. The system has generated comparable data across countries. More than 100 countries worldwide have conducted at least one round of GSHS [25, 26]. The GSHS followed a two-stage sampling design in each of the surveyed countries. In the first stage, schools were randomly selected from a list of all schools in a country with a probability proportional to the number of students enrolled. In the second stage, classes were randomly selected within schools using a random-start systematic equal probability sampling method [27]. GSHS data were collected through self-administered questionnaires with a standardized methodology. The raw data from the GSHS can be downloaded freely from the World Health Organization website (http://www.who.int/ncds/surveillance/microdata) [26, 28]. Specifically, we selected data from countries where the survey was conducted between 2013 and the most recent available year. All countries with available data on tobacco and alcohol use, and suicide ideation, plan, and attempt, were included. If a country conducted more than one survey during the period, the latest survey data were included in the cross-sectional analysis.

The Chinese school-based student health survey was carried out by the Centers for Disease Control and Prevention in Jiangxi and Jiangsu Provinces, aligned with the methodology of the GSHS, and was gathered in 2017. The two provinces were selected based on their geography, gross domestic product (GDP), average standing within China, and Han Chinese population, with one representing coastal areas and inland areas to ensure they are broadly representative.

In this study, 211,102 adolescents aged 12 to 17 years from 58 countries were recruited. The participant inclusion process from each data source is displayed in Fig. 1.

Exposure variables

The main exposure variables were self-reported use of tobacco products during the past 30 days (yes/no), and

self-reported alcohol intake during the past 30 days (yes/no). Tobacco use was assessed using two questions: "During the past 30 days, on how many days did you smoke cigarettes?" and "During the past 30 days, on how many days did you use any tobacco products other than cigarettes?". Alcohol use was assessed via the following question: "During the past 30 days, on how many days did you have at least one drink containing alcohol?". The questionnaire details and definitions of exposure are displayed in Additional file 1: Table 1.

Country-level legal purchase age restrictions on tobacco products and alcohol were collected from official national websites or from the World Health Organization (see details from the Additional file 1: supplementary methodology). We recorded whether the countries (or territories) had legal purchase age restrictions at the time when the data were collected, as well as the specific age. The details of countries with or without such restrictions are displayed in Additional file 1: Tables 2 and 3. Regarding legal purchase age restrictions for tobacco use, 49 countries have purchase age restrictions, 6 countries have no purchase age restrictions, and 3 countries have no relevant information. As for legal purchase age restrictions for alcohol use, data from the Global Information System on Alcohol and Health (age limits for on-premise service of beer, wine, and spirits) available at https://www.who.int/data/gho/data/indicators/indicator-details/GHO/age-limits-on-premise-service- indicates that 48 countries have purchase age restrictions, 7 countries have no purchase age restrictions, and 3 countries have no relevant information.

Outcome assessments

Three suicide-related variables, namely suicide ideation, suicide plan, and suicide attempt during the past 12 months, were applied as binary variables (yes or no). Additionally, suicide ideation, plan, and attempt represent stages of suicide behavior, ranging from thinking about suicide without action, to forming a specific method for it, and finally engaging in behaviors with the intent to end one's life. Questionnaire details and definitions of the outcomes were displayed in Additional file 1: Table 1. A sample size of each country and the prevalence of suicide ideation, suicide plan, and suicide attempt are shown in Additional file 1: Table 4. Since prior research evidence suggests that policies are not uniformly effective across regions with different suicide behavior prevalence rates [29], in stratified analysis, countries were categorized as having low prevalence or high prevalence rates, on the basis of the country-level median prevalence of suicide ideation, plan, and attempt, respectively, to explore the potential effect of age restrictions on alcohol and tobacco purchases on the risk of suicide ideation, plan, and attempt associated with them. The prevalence rates of tobacco and alcohol use with or without legal purchase age are shown in Additional file 1: Tables 5 and 6.

Covariates

The main confounding factors of interest included individual demographic characteristics, lifestyle factors, mental well-being, and country-based sociodemographic factors. The demographic characteristics included self-reported age, sex (either boy or girl), and body mass index (BMI). BMI was calculated from self-reported height and weight at survey time and was converted to z scores according to the World Health Organization (WHO) growth reference [30]. Lifestyle factors included physical activity and sedentary behavior habits [31]. Physical activity was defined as the number of days with at least 60 min of vigorous or moderate physical activity during the past week. Physical inactivity was defined as hours of sedentary behavior on a typical day (less than 1 h; 1 to 2 h; 3 to 4 h; 5 to 6 h; 7 to 8 h; more than 8 h). Mental health indicators included the self-reported presence of feeling lonely (yes/no) and feeling worried (yes/no) during the past 12 months. The country-level Sociodemographic Index (SDI) for the survey year, representing social and economic development, was obtained from the Global Burden of Diseases study (https://www.healthdata.org/research-analysis/gbd).

Statistical analysis

The demographic and behavioral characteristics of the study population were summarized using descriptive statistics. For continuous variables, we reported the mean and standard deviation (SD), and for categorical variables, we provided the frequency (proportion). The prevalence of tobacco and alcohol use among adolescents in 58 countries between 2013 and 2021 was displayed with a world map.

Then, binary logistic regression models were applied to analyze the independent associations of tobacco and alcohol use with suicide ideation, plan, and attempt adjusting for age, body mass index, country, insufficient physical activity (yes/no), long sedentary behavior (yes/no), survey weight, feeling lonely during the past 12 months (yes/no), feeling worried during the past 12 months (yes/no), and SDI. Additionally, we employed logistic regression models to further assess the interactive associations of tobacco and alcohol use with suicide ideation, plan, and attempt, where the exposure variables were categorized on the basis of the combination of tobacco and alcohol use: neither tobacco nor alcohol use (as the reference group), tobacco use only, alcohol use only, and both tobacco and alcohol use. Models were adjusted for age,

BMI, country, insufficient physical activity (yes/no), long sedentary behavior (yes/no), survey weight, feeling lonely during the past 12 months (yes/no), feeling worried during the past 12 months (yes/no), and SDI. With an ICC below 0.05, the influence of "country" on the variance in suicide ideation/plan/attempt is minimal, indicating that the "country" variable should be adjusted as a fixed effect, without using a random effects model [32]. The sex differences in each group were examined using the Wald test [33].

To analyze whether the purchase age restrictions played similar roles for both sexes and in countries with different suicide behavior risk (low or high, based on the country-level prevalence of each suicide behavior), the above analyses were conducted by sex and by country-level risk of suicide ideation, plan, and attempt. Participants were divided into four groups: participants who do not use tobacco (or alcohol) from countries without purchase age restrictions (reference group), tobacco (or alcohol) users from countries without purchase age restrictions, participants who did not use tobacco (or alcohol) from countries with purchase age restrictions, and tobacco (or alcohol) users from countries with purchase age restrictions. To analyze whether the purchase age restrictions played similar roles for both sexes and in countries with different suicide behavior risk (low or high, based on the country-level prevalence of each suicide behavior), the above analyses were conducted by sex and by country-level risk of suicide ideation, plan, and attempt. Models were adjusted for age, BMI, insufficient physical activity (yes/no), long sedentary behavior (yes/no), survey weight, feeling lonely during the past 12 months (yes/no), feeling worried during the past 12 months (yes/no), and SDI. The countries without available information on purchase age restrictions (Curacao, Mozambique, and Tokelau for tobacco products; Anguilla, Curacao, and Bahrain for alcohol) were not included in this part of the analysis.

Sensitivity analysis

Several sensitivity analyses were conducted. Firstly, we conducted a two-step random-effects meta-analysis to evaluate the association between the independent associations of tobacco and alcohol use with suicide ideation, plan, and attempt based on different countries. In the first step, we performed binary logistic regression models to calculate the effect estimates for each country, adjusting for age, BMI, insufficient physical activity (yes/no), long sedentary behavior (yes/no), survey weight, feeling lonely during the past 12 months (yes/no), and feeling worried during the past 12 months (yes/no). In the second step, a random effects meta-analysis was further performed to analyze the overall pooled estimated odds among the total participants as well as boys and girls. Secondly, to examine whether the frequency of tobacco and alcohol use contributed to higher odds of suicide ideation, plan, and attempt, interactions between tobacco and alcohol use on suicide ideation, plan, and attempt were conducted in those with moderate tobacco and alcohol users (1–5 days during the past month) and with frequent users (more than 5 days during the past month), respectively. Thirdly, countries with purchase age restrictions were further divided into two groups based on the age limit (≥ 18 years old or < 18 years old) to examine whether the restrictions that did not cover the entire study population (ages 12 to 17) were associated, to some extent, with a reduced odds of suicide ideation, plan, and attempt.

To obtain nationally representative results, sampling weights were taken into consideration (except for China, which did not include weight in the original design). All of the analyses were conducted for the overall participants and by sex group. All the statistical analyses were performed with R (version 4.3.1). Two-sided P values < 0.05 were considered statistically significant.

Results

Participant characteristics

A total of 211,022 adolescents (46.7% boys) from 58 countries were included in our analysis. The demographic and behavioral characteristics of the participants are displayed in Table 1. In total, the pooled prevalence rates for suicide ideation, plan, and attempt were 14.9%, 13.5%, and 11.1%, respectively. Among participants who used tobacco, the pooled prevalence rates of suicide ideation, plan, and attempt were 34.4%, 33.7%, and 36.9%, respectively, for boys, and 27.4%, 27.1%, and 29.0%, respectively, for girls. Among participants who used alcohol, the pooled prevalence of suicide ideation, plan, and attempt were 40.6%, 39.4%, and 41.7% in boys, and 42.7%, 42.8%, and 42.7% in girls, respectively.

The prevalence of tobacco and alcohol use across 58 countries is depicted in Additional file 1: Fig. S1. Among all the participants, 16.1% reported tobacco use within the past 30 days. The percentage of the population engaged in current tobacco use varied from 3.1 to 34.9%, with Lebanon having the highest prevalence and Cambodia having the lowest. Boys generally presented higher percentages than girls did. Similarly, the percentage of current alcohol use in the population ranged from 0.9% to 58.1%, with Argentina having the highest prevalence and Bangladesh having the lowest.

Table 1 Characteristics of the participants included in the analysis

Characteristics	Sample size		Suicide ideation			Suicide plan			Suicide attempt		
	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
BMI, kg/m^2, mean (SD)	98,457	112,565	21.92 ± 5.15	21.43 ± 4.99	22.18 ± 5.21	21.81 ± 5.11	21.29 ± 4.97	22.10 ± 5.17	21.72 ± 5.10	21.21 ± 4.97	22.04 ± 5.16
Age, years, mean (SD)			14.93 ± 1.40	14.94 ± 1.42	14.93 ± 1.38	14.89 ± 1.40	14.88 ± 1.43	14.90 ± 1.38	14.87 ± 1.40	14.91 ± 1.42	14.85 ± 1.38
Tobacco use, *N* (%)											
No	71,137	90,330	20,071 (70.19)	6555 (65.61)	13,516 (72.65)	18,195 (70.49)	6233 (66.28)	11,962 (72.90)	14,331 (67.89)	5209 (63.10)	9122 (70.97)
Yes	18,375	12,714	8524 (29.81)	3436 (34.39)	5088 (27.35)	7617 (29.51)	3171 (33.72)	4446 (27.10)	6777 (32.11)	3046 (36.90)	3731 (29.03)
Alcohol use, *N* (%)											
No	62,999	75,745	15,894 (58.00)	5515 (59.36)	10,379 (57.30)	14,294 (58.39)	5256 (60.61)	9038 (57.17)	11,722 (57.65)	4519 (58.29)	7203 (57.26)
Yes	23,032	23,680	11,508 (42.00)	3775 (40.64)	7733 (42.70)	10,188 (41.61)	3416 (39.39)	6772 (42.83)	8611 (42.35)	3234 (41.71)	5377 (42.74)
Insufficient physical activity[a], *N* (%)											
No	64,103	85,582	22,438 (73.48)	7399 (69.05)	15,039 (75.87)	20,266 (73.82)	7008 (69.80)	13,258 (76.13)	16,817 (73.70)	6176 (69.44)	10,641 (76.43)
Yes	31,720	24,101	8099 (26.52)	3317 (30.95)	4782 (24.13)	7189 (26.18)	3032 (30.20)	4157 (23.87)	6000 (26.30)	2718 (30.56)	3282 (23.57)
Daily sedentary behavior ≥ 5 h, *N* (%)											
No	76,948	85,505	21,013 (69.24)	7749 (73.00)	13,264 (67.21)	19,149 (70.24)	7378 (74.23)	11,771 (67.94)	16,550 (72.91)	6776 (76.76)	9774 (70.46)
Yes	18,517	23,979	9337 (30.76)	2866 (27.00)	6471 (32.79)	8115 (29.76)	2561 (25.77)	5554 (32.06)	6149 (27.09)	2051 (23.24)	4098 (29.54)
Feeling lonely, *N* (%)											
No	36,071	29,193	4931 (17.79)	2470 (25.22)	2461 (13.72)	5246 (20.56)	2720 (28.88)	2526 (15.69)	4140 (19.49)	2246 (27.76)	1894 (14.40)
Yes	53,007	74,410	22,794 (82.21)	7322 (74.78)	15,472 (86.28)	20,274 (79.44)	6697 (71.12)	13,577 (84.31)	17,106 (80.51)	5844 (72.24)	11,262 (85.60)
Feeling worried, *N* (%)											
No	37,969	32,118	5246 (18.80)	2639 (26.68)	2607 (14.48)	5503 (21.46)	2890 (30.46)	2613 (16.18)	4119 (19.28)	2191 (26.83)	1928 (14.61)
Yes	51,462	71,848	22,651 (81.20)	7251 (73.32)	15,400 (85.52)	20,140 (78.54)	6599 (69.54)	13,541 (83.82)	17,240 (80.72)	5976 (73.17)	11,264 (85.39)

SD standard deviation, *BMI* body mass index

[a] Insufficient physical activity time was defined as not reaching the current World Health Organization recommendation of being active for more than 60 min on ≥ 5 days per week

Table 2 Independent and interactive associations of tobacco use and alcohol use on suicide ideation, plan, and attempt

Tobacco and alcohol use	Suicide ideation		Suicide plan		Suicide attempt	
	OR (95%CI)	*P* for difference	OR (95%CI)	*P* for difference	OR (95%CI)	*P* for difference
Independent associations						
Tobacco use [a]						
Boys	1.97 (1.87,2.08)	< 0.001	1.98 (1.87,2.09)	< 0.001	2.39 (2.25,2.53)	< 0.001
Girls	2.46 (2.34,2.59)		2.47 (2.35,2.61)		2.94 (2.79,3.11)	
Alcohol use [b]						
Boys	1.43 (1.35,1.51)	< 0.001	1.37 (1.29,1.45)	< 0.001	1.66 (1.56,1.77)	0.082
Girls	1.67 (1.60,1.76)		1.74 (1.66,1.83)		1.78 (1.69,1.88)	
Interactive associations						
Neither						
Boys	Ref	Ref	Ref	Ref	Ref	Ref
Girls	Ref	Ref	Ref	Ref	Ref	Ref
Only alcohol use						
Boys	1.28 (1.19,1.38)	< 0.001	1.25 (1.15,1.35)	< 0.001	1.48 (1.36,1.61)	0.005
Girls	1.60 (1.52,1.69)		1.66 (1.57,1.76)		1.72 (1.62,1.83)	
Only tobacco use						
Boys	1.75 (1.60,1.91)	< 0.001	1.79 (1.63,1.96)	< 0.001	2.07 (1.88,2.27)	< 0.001
Girls	2.75 (2.50,3.02)		2.80 (2.54,3.08)		3.51 (3.18,3.87)	
Both use						
Boys	2.42 (2.25,2.61)	< 0.001	2.39 (2.21,2.58)	< 0.001	3.24 (3.00,3.51)	< 0.001
Girls	3.19 (2.98,3.40)		3.33 (3.11,3.57)		4.03 (3.75,4.33)	

Models were adjusted for age, body mass index, country, insufficient physical activity (yes/no), long sedentary behavior (yes/no), survey weight, SDI, feeling lonely during the past 12 months (yes/no), and feeling worried during the past 12 months (yes/no)

[a] additionally adjusted for current alcohol use (yes/no)

[b] additionally adjusted for current tobacco use (yes/no)

Meta-analysis of the associations between tobacco use and alcohol use, and suicide ideation, plan, and attempt

The meta-analysis of the associations between tobacco use and alcohol use, and suicide ideation, plan, and attempt are presented in Additional file 1: Fig. S2–S4. Overall, tobacco use was related to an increased odds of suicide ideation, suicide plan, and suicide attempt, with ORs of 2.48 (95% CI 2.32 to 2.66), 2.39 (95% CI 2.24 to 2.56), and 3.46 (95% CI 3.10 to 3.86), respectively. The country with the highest associated odds for suicide ideation, plan, and attempt was Cambodia, with ORs of 6.90 (95% CI 3.90 to 12.21), 4.82 (95% CI 2.85 to 8.17), and 8.05 (95% CI 4.78 to 13.57), respectively.

The associations between alcohol use and elevated odds of suicide ideation, plan, and attempt were significant, with ORs of 1.71 (95% CI 1.54 to 1.89), 1.65 (95% CI 1.51 to 1.80), and 1.85 (95% CI 1.66 to 2.07), respectively. Among the countries, the highest estimates of odds for suicide ideation (OR = 3.69, 95% CI: 2.42 to 5.63) were observed in Honduras. Similarly, Samoa had the greatest odds for suicide plan (OR = 2.72, 95% CI: 1.59 to 4.64), and Nepal for suicide attempt (OR = 6.32, 95% CI: 3.91 to 10.21).

Independent and interactive associations of tobacco and alcohol use on suicide ideation, plan, and attempt

The independent and interactive associations between tobacco use, alcohol use, and suicide ideation, plan, and attempt are presented in Table 2. Girls who reported using tobacco were found to have significantly greater odds of suicide ideation (OR = 2.46, 95% CI 2.34 to 2.59, $P < 0.001$), suicide plan (OR = 2.47, 95% CI 2.35 to 2.61, $P < 0.001$), and suicide attempt (OR = 2.94, 95% CI 2.79 to 3.11, $P < 0.001$) than boys (suicide ideation: OR = 1.97, 95% CI 1.87 to 2.08, $P < 0.001$; suicide plan: OR = 1.98, 95% CI 1.87 to 2.09, $P < 0.001$; suicide attempt: OR = 2.39, 95% CI 2.25 to 2.53, $P < 0.001$, respectively). Similarly, the likelihoods of suicide ideation (OR = 1.67, 95% CI 1.60 to 1.76, $P < 0.001$), and suicide plan (OR = 1.74, 95% CI 1.66 to 1.83, $P < 0.001$) among girls who reported alcohol use was also significantly greater than boys (suicide ideation: OR = 1.43, 95% CI 1.35 to 1.51, $P < 0.001$; suicide plan: OR = 1.37, 95% CI 1.29 to 1.45, $P < 0.001$, respectively).

Compared with adolescents who used neither tobacco nor alcohol, those who used both tobacco and alcohol had the highest odds of suicide ideation (boys: OR = 2.42, 95% CI 2.25 to 2.61, $P < 0.001$; girls: OR = 3.19,

95% CI 2.98 to 3.40, $P<0.001$; $P_{difference}<0.001$), suicide plan (boys: OR = 2.39, 95% CI 2.21 to 2.58, $P<0.001$; girls: OR = 3.33, 95% CI 3.11 to 3.57, $P<0.001$; $P_{difference}<0.001$), and suicide attempt (boys: OR = 3.24, 95% CI 3.00 to 3.51, $P<0.001$; girls: OR = 4.03, 95% CI 3.75 to 4.33, $P<0.001$; $P_{difference}<0.001$).

Additionally, the interactive associations between the frequency of tobacco use and alcohol use, and suicide ideation, plan, and attempt are presented in Additional file 1: Table 7. Generally, we found similar interactive associations in both the moderate-frequency use and high-frequency use groups.

Associations of tobacco and alcohol use with suicide ideation, plan, and attempt, by sex and purchase age restrictions

The interactive associations of legal purchase age restrictions, tobacco use, and alcohol use on suicide ideation, plan, and attempt are presented in Fig. 2. In countries with a lower prevalence of suicide attempts, boys who use tobacco and are from countries with legal tobacco purchase age restrictions had lower odds of exhibiting suicide attempt (OR = 2.79, 95% CI 2.31 to 3.38) compared to those from countries without restrictions (OR = 4.54, 95% CI 3.41 to 6.04; $P_{difference}=0.006$).

In countries with a higher prevalence of suicide ideation, boys who use tobacco and from countries with legal age restrictions on tobacco purchases displayed lower odds of suicide ideation (OR = 2.15, 95% CI 1.90 to 2.43) compared to those from countries without such restrictions (OR = 2.93, 95% CI 2.44 to 3.50; $P_{difference}=0.006$). Similarly, girls who use tobacco from countries with legal age restrictions on tobacco purchases displayed lower odds of suicide ideation (OR = 2.37, 95% CI 2.14 to 2.63) compared to those from countries without such restrictions (OR = 4.22, 95% CI 3.43 to 5.19; $P_{difference}<0.001$). In countries with a higher prevalence of suicide plan, boys who use tobacco and from countries with legal age restrictions on tobacco purchases had lower odds of suicide plan (OR = 1.86, 95% CI 1.64 to 2.12) compared to those from countries without such restrictions (OR = 2.81, 95% CI 2.32 to 3.42; $P_{difference}=0.001$). Similarly, girls who use tobacco from countries with legal age restrictions on tobacco purchases displayed lower odds of suicide plan (OR = 2.20, 95% CI 1.98 to 2.45) compared to those from countries without such restrictions (OR = 4.61, 95% CI 3.65 to 5.83; $P_{difference}<0.001$).

There were no subgroup differences in countries with or without legal alcohol purchase age restrictions in association with suicide behavior risk in countries with lower suicide behavior prevalence. In countries with higher prevalence, boys who use alcohol and are from countries with legal alcohol purchase age restrictions had higher odds of suicide ideation (OR = 2.93, 95% CI 2.29 to 3.74), suicide plan (OR = 2.13, 95% CI 1.74 to 2.62), and suicide attempt (OR = 2.35, 95% CI 1.92 to 2.87) compared to countries without restrictions (suicide ideation: OR = 1.68, 95% CI 1.14 to 2.47; suicide plan: OR = 1.47, 95% CI 1.09 to 1.98; suicide attempt: OR = 1.43, 95% CI 1.07 to 1.93). In countries with a higher prevalence of suicide attempts, girls who use alcohol and are from countries with legal alcohol purchase age restrictions had higher odds of suicide attempt (OR = 2.11, 95% CI 1.77 to 2.51) compared to countries without restrictions (OR = 1.38, 95% CI 1.05 to 1.80).

Additionally, we compared subgroups based on whether the legal purchase age restrictions for tobacco and alcohol use were set at 18 years. As detailed in Tables 3 and 4, we found similar associations of legal purchase age restrictions with the associations of tobacco, and alcohol use with suicide ideation, plan, and attempt among adolescents, by sex and purchase age restrictions. Specifically, in countries with a higher prevalence of suicide ideation and plan, boys and girls who use tobacco and from countries with legal age restrictions on tobacco purchases displayed lower odds of suicide ideation and plan compared to those from countries without such restrictions ($P_{difference}<0.05$). There were no subgroup differences in countries with or without legal alcohol purchase age restrictions in association with suicide behavior risk in countries with lower suicide behavior prevalence both boys and girls ($P_{difference}>0.05$). In countries with higher prevalence, boys who use alcohol and are from countries with legal alcohol purchase age restrictions had higher odds of suicide plan (OR = 6.10, 95% CI 2.12 to 17.52), and suicide attempt (OR = 8.15, 95% CI 2.89 to 22.97) compared to countries without restrictions (suicide plan: OR = 1.43, 95% CI 1.05 to 1.94; suicide attempt: OR = 1.39, 95% CI 1.02 to 1.89) among age of purchase restrictions < 18 years. Meanwhile, in countries with higher prevalence, girls who use alcohol and are from countries with legal alcohol purchase age restrictions had higher odds of suicide ideation (OR = 7.06, 95% CI 3.32 to 15.02) compared to countries without restrictions (suicide ideation: OR = 2.58, 95% CI 2.06 to 3.93) among the age of purchase restrictions < 18 years.

Discussion

On the basis of the most recent data from 58 countries collected between 2013 and 2021, we found that the pooled prevalence rates of suicide ideation, plan, and attempt were 14.9%, 13.5%, and 11.1%, respectively. Both tobacco and alcohol use are significantly associated with an increased odds of suicide ideation, plan, and attempt, with girls exhibiting significantly greater odds than boys. Among the adolescents, those who used both tobacco

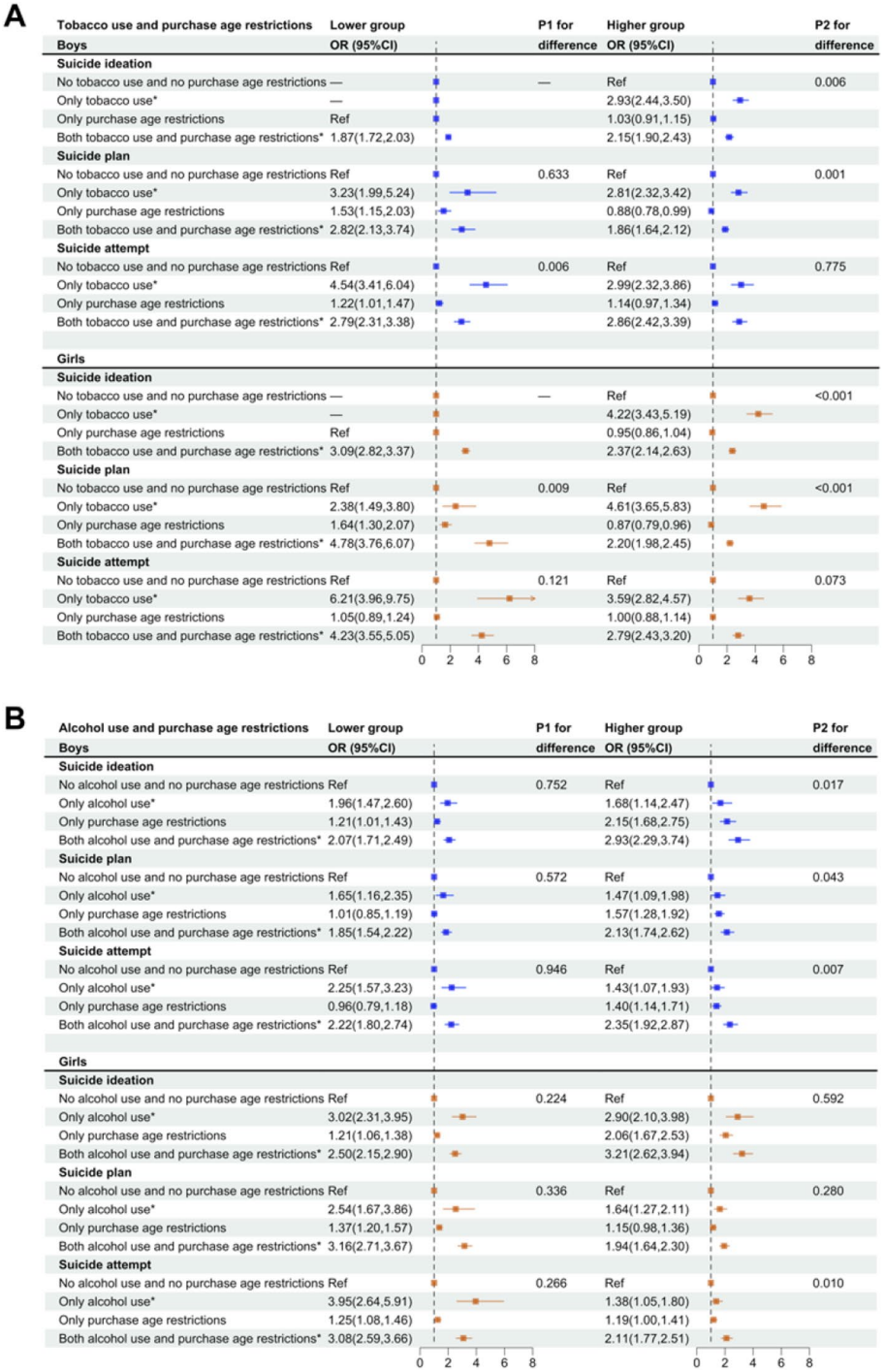

Fig. 2 Associations of tobacco and alcohol use with suicide ideation, plan, and attempt among adolescents in 58 countries, by sex, age of purchase restrictions, and the prevalence of suicide behaviors. Note: models were adjusted for age, body mass index, insufficient physical activity (yes/no), long sedentary behavior (yes/no), survey weight, SDI, feeling lonely during the past 12 months (yes/no), and feeling worried during the past 12 months (yes/no). *P*1 for difference indicates to differences of suicide ideation, plan, and attempt in tobacco use (or alcohol use) from countries with or without legal purchase age restrictions in countries with lower prevalence of suicide ideation, plan, and attempt; *P*2 for difference indicates to differences of suicide ideation, plan, and attempt in tobacco use (or alcohol use) from countries with or without legal purchase age restrictions in countries with higher prevalence of suicide ideation, plan, and attempt. Lower group refers to below the country-level prevalence of suicide ideation, plan, and attempt, respectively; higher group refers to above the country-level prevalence of suicide ideation, plan, and attempt, respectively. In **A**, there were no "No tobacco use and no purchase age restrictions" and "Only tobacco use" among the lower group

Table 3 Associations between tobacco use and suicide ideation, plan, and attempt among adolescents in 58 countries, by sex, age of purchase restrictions and the prevalence of suicide behaviors

Tobacco use and purchase age restrictions	Lower group OR (95%CI)	*P*1 for difference	Higher group OR (95%CI)	*P*2 for difference
Age of purchase restrictions ≥ 18 years[a]				
Boys				
Suicide ideation		—		0.006
No tobacco use and no purchase age restrictions	—		Ref	
Only tobacco use[a]	—		2.93 (2.44,3.50)	
Only purchase age restrictions	Ref		1.03 (0.91,1.15)	
Both tobacco use and purchase age restrictions[a]	1.86 (1.71,2.02)		2.15 (1.90,2.43)	
Suicide plan		0.658		< 0.001
No tobacco use and no purchase age restrictions	Ref		Ref	
Only tobacco use[a]	3.23 (1.99,5.23)		2.81 (2.32,3.42)	
Only purchase age restrictions	1.55 (1.17,2.06)		0.88 (0.78,0.99)	
Both tobacco use and purchase age restrictions[a]	2.84 (2.14,3.78)		1.86 (1.64,2.12)	
Suicide attempt		0.006		0.775
No tobacco use and no purchase age restrictions	Ref		Ref	
Only tobacco use[a]	4.54 (3.41,6.04)		2.99 (2.32,3.86)	
Only purchase age restrictions	1.23 (1.02,1.48)		1.14 (0.97,1.34)	
Both tobacco use and purchase age restrictions[a]	2.81 (2.32,3.40)		2.86 (2.42,3.39)	
Girls				
Suicide ideation		—		< 0.001
No tobacco use and no purchase age restrictions	—		Ref	
Only tobacco use[a]	—		4.22 (3.43,5.19)	
Only purchase age restrictions	Ref		0.95 (0.86,1.04)	
Both tobacco use and purchase age restrictions[a]	3.16 (2.89,3.46)		2.37 (2.14,2.63)	
Suicide plan		0.006		< 0.001
No tobacco use and no purchase age restrictions	Ref		Ref	
Only tobacco use[a]	2.39 (1.50,3.80)		4.61 (3.65,5.83)	
Only purchase age restrictions	1.69 (1.34,2.14)		0.87 (0.79,0.96)	
Both tobacco use and purchase age restrictions[a]	4.97 (3.91,6.32)		2.20 (1.98,2.45)	
Suicide attempt		0.138		0.073
No tobacco use and no purchase age restrictions	Ref		Ref	
Only tobacco use[a]	6.22 (3.96,9.77)		3.59 (2.82,4.57)	
Only purchase age restrictions	1.05 (0.89,1.24)		1.00 (0.88,1.14)	
Both tobacco use and purchase age restrictions[a]	4.31 (3.60,5.15)		2.79 (2.43,3.20)	

Models were adjusted for age, body mass index, insufficient physical activity (yes/no), long sedentary behavior (yes/no), SDI, feeling lonely during the past 12 months (yes/no), and feeling worried during the past 12 months (yes/no). *P*1 for difference indicates to differences of suicide ideation, plan, and attempt in tobacco use from countries with or without legal purchase age restrictions in countries with lower prevalence of suicide ideation, plan, and attempt; *P*2 for difference indicates to differences of suicide ideation, plan, and attempt in tobacco use from countries with or without legal purchase age restrictions in countries with higher prevalence of suicide ideation, plan, and attempt. Lower group refers to below the country-level prevalence of suicide ideation, plan, and attempt, respectively; higher group refers to above the country-level prevalence of suicide ideation, plan, and attempt, respectively. In the lower group, there were no "No tobacco use and no purchase age restrictions" and "Only tobacco use" groups

[a] Only one country (Dominican Republic) had a restricted purchase age of < 18 years, therefore the stratified analysis was only conducted in countries whose restricted purchase ages were ≥ 18 years

and alcohol presented greater odds of suicide behaviors compared to those who used neither substance. Additionally, age restrictions on tobacco purchases are associated with decreased odds of suicide behaviors in both boys and girls, especially in countries with a high prevalence of suicide behaviors. On the other hand, alcohol purchase age restrictions are not related to lower odds of alcohol-related suicide behaviors. Our findings indicated that these associations remained robust regardless of whether the age of purchase restrictions was < 18 years or ≥ 18 years old. These findings, from a globalized perspective, suggest that tobacco and alcohol use are

Table 4 Associations between alcohol use and suicide ideation, plan, and attempt among adolescents in 58 countries, by sex, age of purchase restrictions, and the prevalence of suicide behaviors

Alcohol use and legal purchase age	Lower group OR (95%CI)	*P*1 for difference	Higher group OR (95%CI)	*P*2 for difference
Age of purchase restrictions ≥ 18 years				
Boys				
Suicide ideation		0.572		0.017
No alcohol use and no purchase age restrictions	Ref		Ref	
Only alcohol use	1.96 (1.47,2.60)		1.68 (1.14,2.47)	
Only purchase age restrictions	1.21 (1.01,1.43)		2.13 (1.66,2.73)	
Both alcohol use and purchase age restrictions	2.07 (1.71,2.49)		2.93 (2.30,3.75)	
Suicide plan		0.579		0.035
No alcohol use and no purchase age restrictions	Ref		Ref	
Only alcohol use	1.65 (1.16,2.35)		1.46 (1.08,1.97)	
Only purchase age restrictions	1.01 (0.85,1.20)		1.58 (1.29,1.93)	
Both alcohol use and purchase age restrictions	1.85 (1.54,2.22)		2.15 (1.76,2.64)	
Suicide attempt		0.979		0.006
No alcohol use and no purchase age restrictions	Ref		Ref	
Only alcohol use	2.26 (1.57,3.25)		1.43 (1.06,1.93)	
Only purchase age restrictions	0.96 (0.79,1.17)		1.40 (1.15,1.71)	
Both alcohol use and purchase age restrictions	2.25 (1.82,2.78)		2.36 (1.93,2.89)	
Girls				
Suicide ideation		0.224		0.668
No alcohol use and no purchase age restrictions	Ref		Ref	
Only alcohol use	3.02 (2.31,3.95)		2.90 (2.11,3.99)	
Only purchase age restrictions	1.21 (1.06,1.38)		2.04 (1.65,2.51)	
Both alcohol use and purchase age restrictions	2.50 (2.15,2.90)		3.15 (2.57,3.87)	
Suicide plan		0.430		0.274
No alcohol use and no purchase age restrictions	Ref		Ref	
Only alcohol use	2.55 (1.68,3.89)		1.64 (1.27,2.11)	
Only purchase age restrictions	1.37 (1.20,1.57)		1.15 (0.98,1.36)	
Both alcohol use and purchase age restrictions	3.06 (2.62,3.56)		1.94 (1.64,2.30)	
Suicide attempt		0.234		0.010
No alcohol use and no purchase age restrictions	Ref		Ref	
Only alcohol use	3.97 (2.65,5.95)		1.38 (1.05,1.80)	
Only purchase age restrictions	1.26 (1.08,1.47)		1.18 (1.00,1.41)	
Both alcohol use and purchase age restrictions	3.04 (2.55,3.62)		2.10 (1.76,2.51)	
Age of purchase restrictions < 18 years				
Boys				
Suicide ideation		—		0.192
No alcohol use and no purchase age restrictions	—		Ref	
Only alcohol use	—		1.68 (1.14,2.46)	
Only purchase age restrictions	Ref		2.76 (0.96,7.92)	
Both alcohol use and purchase age restrictions	1.81 (1.33,2.46)		3.39 (1.27,9.09)	
Suicide plan		0.754		0.010
No alcohol use and no purchase age restrictions	Ref		Ref	
Only alcohol use	1.67 (1.15,2.42)		1.43 (1.05,1.94)	
Only purchase age restrictions	0.73 (0.29,1.86)		4.29 (1.47,12.53)	
Both alcohol use and purchase age restrictions	1.43 (0.58,3.52)		6.10 (2.12,17.52)	
Suicide attempt		0.182		0.001
No alcohol use and no purchase age restrictions	Ref		Ref	
Only alcohol use	2.21 (1.50,3.26)		1.39 (1.02,1.89)	

Table 4 (continued)

Alcohol use and legal purchase age	Lower group OR (95%CI)	*P*1 for difference	Higher group OR (95%CI)	*P*2 for difference
Only purchase age restrictions	0.61 (0.21,1.74)		3.19 (1.06,9.58)	
Both alcohol use and purchase age restrictions	1.06 (0.39,2.91)		8.15 (2.89,22.97)	
Girls				
Suicide ideation		—		0.030
No alcohol use and no purchase age restrictions	—		Ref	
Only alcohol use	—		2.85 (2.06,3.93)	
Only purchase age restrictions	Ref		3.22 (1.44,7.23)	
Both alcohol use and purchase age restrictions	2.24 (1.65,3.03)		7.06 (3.32,15.02)	
Suicide plan		0.068		0.931
No alcohol use and no purchase age restrictions	Ref		Ref	
Only alcohol use	2.08 (1.34,3.23)		1.67 (1.28,2.16)	
Only purchase age restrictions	2.12 (0.96,4.72)		0.95 (0.32,2.76)	
Both alcohol use and purchase age restrictions	4.80 (2.20,10.51)		1.75 (0.61,4.97)	
Suicide attempt		0.596		0.548
No alcohol use and no purchase age restrictions	Ref		Ref	
Only alcohol use	3.30 (2.15,5.07)		1.44 (1.09,1.90)	
Only purchase age restrictions	1.57 (0.63,3.88)		1.19 (0.36,3.98)	
Both alcohol use and purchase age restrictions	4.29 (1.80,10.21)		2.07 (0.65,6.60)	

Models were adjusted for age, body mass index, insufficient physical activity (yes/no), long sedentary behavior (yes/no), survey weight, SDI, feeling lonely during the past 12 months (yes/no), and feeling worried during the past 12 months (yes/no). *P*1 for difference indicates to differences of suicide ideation, plan, and attempt in alcohol use from countries with or without legal purchase age restrictions in countries with lower prevalence of suicide ideation, plan, and attempt; *P*2 for difference indicates to differences of suicide ideation, plan, and attempt in alcohol use from countries with or without legal purchase age restrictions in countries with higher prevalence of suicide ideation, plan, and attempt. Lower group refers to below the country-level prevalence of suicide ideation, plan, and attempt, respectively; higher group refers to above the country-level prevalence of suicide ideation, plan, and attempt, respectively. In purchase age restrictions (< 18 years) countries, there were no "No tobacco use and no purchase age restrictions" and "Only tobacco use" groups among the lower group

associated with adverse mental health outcomes. Age restrictions on tobacco purchases may be associated with a lower risk of tobacco-related suicide behaviors, particularly among girls and in countries with a high prevalence of such behaviors.

Smoking and alcohol use have been found to be associated with suicide ideation, plan, and attempt in numerous population-based studies. One study involving more than 30,000 adolescents from China and the USA reported that both alcohol and tobacco use are associated with increased suicide ideation and attempts [11]. Studies in Korean adolescents reported similar findings and further reported that both conventional and electric smoking were associated with an increase in suicidal behavior, with a greater frequency of smoking associated with a greater risk of suicidal behavior [34, 35]. Since these substance use factors are potentially modifiable risk factors for suicidal behaviors, targeted intervention strategies with prioritization are integral for suicide prevention [36]. Some studies have reported a greater risk of suicide among adolescents who use both tobacco and alcohol [37–39]. One study conducted in the USA revealed that for students who had suicidal ideation or suicide plans, alcohol use was not associated with suicide attempts, whereas cigarette smoking was associated with suicide attempts [19]. Our study contributes to the existing body of related research by providing global validation of the above studies, which were conducted in the USA. Specifically, we confirmed the association between smoking and an increased risk of all suicide-related behaviors, emphasizing the importance of addressing tobacco control in adolescent suicide prevention efforts. In addition, our findings suggest that tobacco use is associated with greater odds of suicide-related behaviors in girls than in boys. Although the self-reported rates of tobacco and alcohol use are lower among girls, considering that they constitute more than 70% of reported suicide behaviors, girls who engage in smoking and drinking behaviors may constitute the highest risk group for suicide mortality. On the one hand, girls may experience more interpersonal problems and other social pressures that are closely related to substance use and mental health risks including suicidal behavior [40, 41]. The hormonal differences between sexes, particularly the effects of estrogen, could

also contribute to the greater risk of suicidal behaviors related to tobacco and alcohol use in girls. The interaction between estrogen and nicotine could potentially enhance the mood-altering effects of nicotine, making females more susceptible to its depressive or dysphoric effects, which could contribute to an increased risk of suicide-related behaviors [42, 43]. Therefore, special attention should be given to developing targeted approaches and strategies for intervention efforts in this subgroup.

Research on physiological mechanisms has confirmed that tobacco and alcohol consumption are associated with an increased risk of suicide in adults. Rapid nicotine uptake into the brain through any form of smoking, including inhalation of conventional cigarettes, or electronic cigarettes, or through passive smoking, can facilitate long-term sensitization and short-term impulsivity, both of which impair regulatory action and predispose individuals to negative effects and suicidal behaviors [44]. Further analysis of the 50-year observational study utilizing Swedish medical, criminal, and pharmacy registries revealed a potential association between drinking disorders and suicidal behavior, particularly among women, along with evidence of family aggregation [45]. In addition to reducing suicide-related deaths, strengthening the implementation of the tobacco control framework (SDG Health Target 3.a) and preventing harmful alcohol abuse (SDG Health Target 3.5) are important goals consistent with SDG 3 "Ensuring healthy lives and promote well-being for all at all ages" [46]. Adolescents should undoubtedly be the focus of these initiatives to build a sustainable future for generations. However, until 2022, 2.3 billion people still lived in countries that did not adopt a single tobacco control measure, and passive smoking killed 1.3 million nonsmokers a year [47]. Six of the 58 countries we studied have no age restrictions on purchasing tobacco, and seven have no age restrictions on purchasing alcohol. These countries are located in South America, Southeast Asia, the Western Pacific, Africa, and the Eastern Mediterranean Region, and their adolescent population is unprotected from tobacco and alcohol harm. Inequalities in health promotion policies between countries also contribute to the high prevalence of suicidal behaviors among adolescents in these areas and the extreme inequality of data accessibility. Moreover, sometimes, even if the government imposes age restrictions on the purchase of certain tobacco or alcohol products, adolescents from some countries still have easy access to alternate tobacco and alcohol products, such as cigars and hookahs [48–50]. In our current analysis, the countries with the greatest risks of tobacco-related and alcohol-related suicidal behaviors also had age restrictions on tobacco or alcohol purchases. In addition to these policies, the lack of comprehensive life skills education for young people and some socioenvironmental factors such as conflict conditions and social transition might have a greater influence on suicide behaviors [51–53]. Moreover, in societies where tobacco and alcohol use are culturally embedded, age restrictions alone may not be sufficient to reduce consumption among adolescents and young adults, thereby failing to mitigate associated risks [54]. While our findings suggest that legal purchase age restrictions may be associated with lower suicide risks related to tobacco use among adolescents, it is important to recognize that these restrictions often coexist with broader public health policies, such as anti-tobacco campaigns, school-based prevention programs, and mental health initiatives. For example, in countries like Australia, legal age restrictions are part of a comprehensive tobacco control framework that includes plain packaging laws and public education efforts, which together may amplify the protective effects against tobacco-related harms, including suicide risks. Future studies should aim to disentangle the specific contributions of legal purchase age restrictions from the cumulative impact of these broader public health measures [46].

The main strength of our study is that we used a standardized questionnaire for the measurement of tobacco use, alcohol use, and suicidal ideation, plan, and attempt. This study utilized data from three different datasets including the GSHS, YRBSS, and the China survey. The study timeframe, study design, and questionnaire on exposures and outcomes in the two databases (YRBSS and GSHS datasets) were the same. The study design, population, definitions of exposures and outcomes, and data collection procedures in the China survey were also consistent with the two databases, to ensure comparability across different countries. All of the data had the same design and sampling strategy and therefore provided directly comparable results across the 58 countries. There are several limitations to the present study. First, most of the data (except for data from the USA) were collected prior to the COVID-19 pandemic, during which time adolescents experienced enormous strain specifically. The instant and long-term impacts of pandemics on both substance abuse and psychosocial wellness are difficult to estimate and require longitudinal observations [55]. Second, although we have successfully examined the combined effect of tobacco and alcohol use on suicidal behavior from a global perspective, the cross-sectional design of our study limits our ability to establish causal relationships between these behaviors and suicidal outcomes. Therefore, there is a need for

higher-quality longitudinal studies to be conducted in regions where data are lacking to further explore these associations. Third, all exposures and outcome measures were collected through self-administered questionnaires. While questionnaires have demonstrated good reliability and validity among adolescents worldwide, it is important to acknowledge that the possibility of adolescents providing responses that do not accurately reflect their true circumstances cannot be entirely ruled out. Factors such as misunderstanding, intentional concealment, or other motivations might introduce bias to some extent in the study results. Owing to approximately 10% missing data in this study, we opted for a deletion approach to handle these cases. Additionally, the analysis was conducted using data from the GSHS across 58 countries, all countries with available exposure and outcome variables were included, but those with small sample sizes or no valid effect estimates (14 out of 58 countries) were included only in the logistic regression analyses and excluded from two-step meta-analyses. This approach was necessary to maintain the robustness of country-specific results, but might limit the generalizability of our findings to countries excluded. Fourth, the lack of original sampling weights in the Chinese dataset being limited to two provinces, which may limit the understanding for the broader Chinese population. This limitation could affect the findings' effectiveness and representativeness for the broader Chinese population. Additionally, age restriction data for tobacco and alcohol purchases were collected from government websites during January 2024 and may not reflect the regulations in the country during which the individual data were collected. Further research is needed to track the long-term impact of tobacco and alcohol-related laws and regulations on adolescent suicidal behaviors. Sixth, owing to the absence of individual socio-economic information in the GSHS survey, this study could not further consider the potential confounding effects of socio-economic information on the associations. Finally, the exposures (tobacco and alcohol use) in this study were assessed based on their use in the past 30 days, whereas the outcomes (suicidal ideation, plan, and attempt) were assessed on the basis of their occurrences in the past year. This inconsistency in the timing of the survey questions introduces a limitation, as it is possible that the suicidal behaviors could have preceded substance use. This limitation suggests potential bidirectional associations, such as alcohol use following suicidal ideation as a coping mechanism.

Conclusions

In conclusion, our study provides a novel global perspective of tobacco and alcohol use in adolescent suicide ideation, plan, and attempt. This study revealed that tobacco and alcohol consumption are strongly associated with the risk of suicide behaviors among adolescents, particularly among girls. Additionally, the existence of tobacco purchasing age restrictions may be associated with a lower prevalence of suicide behaviors among adolescents. Country-level tobacco control strategies may have the potential to reduce risks of suicide behaviors associated with tobacco use among adolescents.

Abbreviations

BMI	Body mass index
GDP	Gross domestic product
GSHS	Global School-based Student Health Survey
SD	Standard deviation
SDGs	Sustainable Development Goals
SDI	Socio-demographic Index
WHO	World Health Organization
YRBSS	US Youth Risk Behavior Surveillance System

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12916-025-03983-6.

Additional File 1: Tables S1-S7. Table S1. Questionnaire details and definitions of exposures and outcomes. Table S2. Legal age restrictions on tobacco purchase among included countries. Table S3. Legal age restrictions on alcohol purchase among included countries. Table S4. Sample size of each country and the prevalence of suicide ideation, plan, and attempt. Table S5. The prevalence of tobacco use with or without legal purchase age. Table S6. The prevalence of alcohol use with or without legal purchase age. Table S7. Interactive associations between tobacco use and alcohol use, and suicide ideation, plan, and attempt among different frequency use. Figures S1-S4. Fig. S1. Prevalence of tobacco use and alcohol use among adolescents in 58 countries between 2013 and 2021. Fig. S2. Meta-analysis of tobacco use, alcohol use, and suicide ideation, plan, and attempt among overall adolescents in 58 countries. Fig. S3. Meta-analysis of tobacco use, alcohol use, and suicide ideation, plan, and attempt among boys in 58 countries. Fig. S4. Meta-analysis of tobacco use, alcohol use, and suicide ideation, plan, and attempt among girls in 58 countries.

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Data sharing statement

The raw data from the GSHS can be accessed from the World Health Organization website (http://www.who.int/ncds/surveillance/microdata). The latest YRBSS data can be accessed from the Centers for Disease Control and Prevention of the USA at https://www.cdc.gov/healthyyouth/data/yrbs/data.htm. The Chinese data from the student health survey in Jiangxi and Jiangsu Provinces are available upon reasonable request to Professor Zhiyong Zou.

Authors' contributions

Z.Z. had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. M.C. and X.W. conducted and are responsible for the data analysis and drafting of the manuscript. Concept and design were Z.Z., Y.J., and W.L. Acquisition, analysis, or interpretation of data were M.C., X.W., J.G., H.W., and J.L. Administrative, technical, or material support were J.L., Z.Z., and Y.J.. Supervision was Z. Z., Y.J., and W.L.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Declarations
Ethics approval and consent to participate.
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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