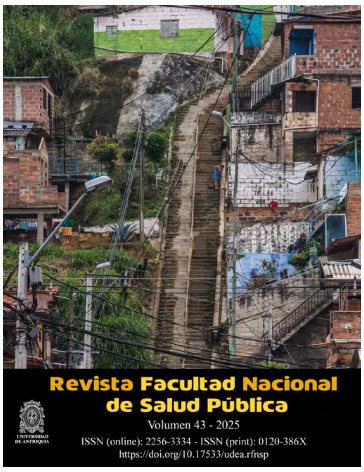

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Profile of psychoactive substance consumption associated with risk levels of suicidal behavior in Argentine adolescents

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Abstract

Objective: To identify the characteristics of psychoactive substance use associated with risk levels of suicidal behavior in Argentine adolescents.
Methods: Study based on the Argentine School Health Survey of 2018 as a secondary source, whose probabilistic sampling consisted of 56 981 schoolchildren aged 13 to 17. The three levels of suicidal behavior (ideation, planning, and attempt) were analyzed. A classification tree was made employing two categories: a) automatic detection of chi-square interactions, and b) a crude and adjusted odds ratio (OR) using binary logistic regression, sensitivity, specificity, and positive and negative predictive value.
Results: The overall frequency of suicidal ideation in the past 12 months was 21.50% (n = 11 962), while the frequency for suicidal planning was 17.30% (n = 9734); and for attempted suicide, at least once during the same period, was 15.10% (n = 8507). For suicidal ideation, planning, and attempt, the most common profile of association was a history of cigarette smoking, amphetamine/methamphetamine use, and drinking alcohol alone. Based on this profile, it was observed that for suicidal ideation, adolescents had an adjusted OR of 8.10 (95% CI = 5.22-10.55). The specificity was 99.11%, the positive predictive value was 63%, and the negative predictive value was 80%. For suicidal planning, adolescents had an adjusted OR of 7.13 (95% CI = 4.70 -9.84). Specificity was 99.10%, with a positive predictive value of 60%, and a negative predictive value of 83%. For suicide attempts, adolescents had an adjusted OR of 8.14 (95% CI = 5.69-10.64). Specificity was 99.80%, with positive and negative predictive values of 62% and 85%, respectively.
Conclusions: This research provides evidence of the strong association between solitary alcohol consumption, amphetamine/methamphetamine use, and smoking, and suicidal behavior in Argentine adolescents. Furthermore, it shows that smoking predisposes adolescents to the use of psychostimulants. The importance of developing preventive strategies and public policies to reduce this behavior in adolescents is highlighted.

----------*Keywords*: self-destructive behavior, psychoactive substance use, suicidal ideation, suicide attempts, substance-related disorders, adolescent health.

* This article arises from the research project "Profile of psychoactive substance use associated with risk of suicidal behavior in Argentine adolescents", registered at Universidad Científica del Sur. Start date: July 10, 2024. End date: August 3, 2024. Registration code: PI-15-2024-0662

Perfil de consumo de sustancias psicoactivas asociadas a niveles de riesgo de comportamiento suicida en adolescentes argentinos

Resumen

Objetivo: Identificar las características de consumo de sustancias psicoactivas asociadas a niveles de riesgo de comportamiento suicida en adolescentes argentinos.
Métodos: Estudio de corte basado en la Encuesta Mundial de Salud Escolar argentina del año 2018 como fuente secundaria, cuyo muestreo probabilista estuvo conformado por 56 981 escolares de 13 a 17 años. Se analizaron los tres niveles de comportamiento suicida (ideación, planeación e intento). Como instrumentos, se emplearon el árbol de clasificación mediante detección automática de interacciones de ji al cuadrado, la *Odds Ratio* (OR) crudo y ajustado por medio de regresión logística binaria, la sensibilidad, la especificidad, y el valor predictivo positivo y negativo.
Resultados: La frecuencia global de ideación suicida en los últimos 12 meses fue 21,50 % (*n* = 11 962), mientras que el 17,30 % (*n* = 9734) tuvo planeación suicida y el 15,10 % (*n* = 8507) intentó suicidarse al menos una vez durante el mismo periodo. Para ideación, planeación e intento suicida, el perfil común de mayor asociación fueron los antecedentes de fumar cigarros, consumir anfetaminas/metanfetaminas y tomar bebidas alcohólicas en solitario. Con base en este perfil, se observó que, para ideación suicida, los adolescentes tuvieron una OR ajustada de 8,10 (IC 95 % = 5,22-10,55). La especificidad fue del 99,11 %; el valor predictivo positivo, del 63 %, y negativo, del 80 %. Para la planeación suicida, los adolescentes presentaron una OR ajustada de 7,13 (IC 95 % = 4,70-9,84). La especificidad fue del 99,10 %, con valor predictivo positivo del 60 %, y negativo, del 83 %. En cuanto al intento suicida, los adolescentes tuvieron una OR ajustada de 8,14 (IC 95 % = 5,69-10,64). La especificidad fue del 99,80 %, con valor predictivo positivo y negativo de 62 y 85 %, respectivamente.
Conclusiones: Esta investigación aporta evidencia sobre la fuerte asociación entre el consumo de alcohol en soledad, el uso de anfetaminas/metanfetaminas y el tabaquismo con el comportamiento suicida en adolescentes argentinos. Además, el tabaquismo predispone al consumo de psicoestimulantes. Se destaca la importancia de elaborar estrategias preventivas y políticas públicas para reducir este comportamiento en adolescentes.

---------*Palabras clave*: conducta autodestructiva, consumo de sustancias psicoactivas, ideación suicida, intento de suicidio, trastornos relacionados con sustancias, salud del adolescente.

Profile of psychoactive substance consumption associated with risk levels of suicidal behavior in Argentine adolescents

Abstract

Objective: To identify the characteristics of psychoactive substance use associated with risk levels of suicidal behavior in Argentine adolescents.
Methods: Study based on the Argentine School Health Survey of 2018 as a secondary source, whose probabilistic sampling consisted of 56,981 schoolchildren aged 13 to 17 years. The 3 levels of suicidal behavior were analyzed (ideation, planning and attempt). The classification tree using automatic detection of chi-square interactions, the crude and adjusted Odds Ratio (OR) using binary logistic regression, sensitivity, specificity, and positive and negative predictive value were used.
Results: The overall frequency of suicidal ideation in the past 12 months was 21.50% (n = 11,962), while 17.30% (n = 9,734) had suicidal planning and 15.10% (n = 8,507) attempted suicide at least once during the same period. For suicidal ideation, planning and attempt, the most common profile of association was a history of cigarette smoking, amphetamine/methamphetamine use and drinking alcohol alone. Based on this profile, it was observed that for suicidal ideation, adolescents had an adjusted OR of 8.10 (95% CI = 5.22-10.55). The specificity was 99.11%; the positive predictive value was 63%; and the negative predictive value was 80%. For suicidal planning, adolescents had an adjusted OR of 7.13 (95% CI = 4.70-9.84). Specificity was 99.10%, with a positive predictive value of 60% and a negative predictive value of 83%. For suicide attempt, adolescents had an adjusted OR of 8.14 (95% CI = 5.69-10.64). Specificity was 99.80%, with positive and negative predictive values of 62% and 85%, respectively.
Conclusions: This research provides evidence of the strong association between solitary alcohol consumption, amphetamine/methamphetamine use, and smoking with suicidal behavior in Argentine adolescents. ¿Furthermore, smoking predisposes adolescents to the use of psychostimulants. The importance of developing preventive strategies and public policies to reduce this behavior in adolescents is highlighted.

----------*Keywords*: self-destructive behavior, psychoactive substance use, suicidal ideation, suicide attempts, substance-related disorders, adolescent health.

Introduction

Suicidal behavior involves three levels of risk: *suicidal ideation*, which refers to thinking about and considering suicide, and includes thoughts about wanting to die and ways of killing oneself; *suicide planning*, which involves the cognitive elaboration of a suicidal project that anticipates the occasion, means, and measures to prevent rescue; and *suicide attempt*, which constitutes an act of self-harm, involves intending own's death without resulting in it, represents a step beyond ideation and planning, and involves a concrete action to end one's life [1,2].

Risk factors may be health-related, such as previous mental disorders (depression, anxiety, bipolar disorder, personality disorders), environmental-social factors (chronic bullying and stress, school bullying or cyberbullying), adverse childhood experiences, personal and family history of suicide attempt [3], neurobiological susceptibility [4], and psychoactive substance use.

The use of psychoactive substances is considered a behavioral phenomenon that, in adolescents, can lead to depression and alterations in brain physiology. Currently, worldwide, it is estimated that around 284 million people between 15 and 64 years of age use some type of drug [5] and that, in adolescents, the use of psychoactive substances has increased, mainly in countries of low and middle-income, such as Argentina and Colombia, which have a higher prevalence of problematic alcohol use [6].

The use of psychoactive substances increases the likelihood of suicidal behavior in adolescents because, although they seek to use drugs in order to escape pain and emotional suffering, these substances induce depressive states, reduce inhibitions that prevent the consummation of the suicidal act, and increase the intensity of impulsive behaviors that lead to suicidal behavior. For example, tobacco causes debilitating and painful conditions that increase the likelihood of suicide because causes a decrease in levels of neurotransmitters such as serotonin and the enzyme monoamine oxidase, associated with mood [7].

As for amphetamines, their use causes personality changes, such as increased impulsivity and mood swings, and increases the risk of suicide to twice that of users of other drugs [8].

In regard to alcohol use, although it has been associated with suicidal behaviors, a direct relationship between the two has not yet been clarified [9]; however, it has been established that many alcohol consumers suffer from depression [10] and decreased self-control, which can incite suicidal behavior.

Drug use is also related to the "gateway" hypothesis, which holds that the use of legal substances (i.e., tobacco and alcohol) increases the risk of beginning the use of drugs such as cannabis, which, in turn, increases the likelihood of using other illegal substances [11].

Furthermore, recreational drug use can significantly increase the risk of suicide due to several factors. For instance, these substances can both cause or aggravate mental disorders, such as depression and anxiety, and reduce inhibitions and impulsivity, all of which facilitate suicidal behaviors. Similarly, drug use can lead to social isolation and serious physical and psychological problems, increasing feelings of hopelessness. The combination of these effects creates an environment in which risk factors for suicide are amplified, making people more likely to consider or attempt suicide [12].

The relationship between psychoactive substance use and suicidal behavior has been widely studied. Nonetheless, it is necessary to determine this association from an epidemiological point of view, i.e., finding the identity characteristics that build a risk profile in the adolescent population through the use of chi-square automatic interaction detector (CHAID) decision trees. This detector permits classifying and determining complex relationships between variables. To use it, it is necessary to know the profiles that characterize drug use and that are associated with levels of risk of suicidal behavior in adolescents. Hence, this study aimed to identify the characteristics of drug use associated with risk levels of suicidal behavior in Argentine adolescents.

The study contributes significantly to the advancement of theory and of public health practice by providing a deeper understanding of the relationship between psychoactive substance use and suicidal behavior in adolescents. Unlike previous studies that focused on individual or contextual factors in isolation, this study uses CHAID decision trees to identify and classify the complex interactions among multiple risk variables. This allows for more accurate identification of vulnerable groups and facilitates the development of more effective preventive and therapeutic interventions.

The results of this study not only expand theoretical knowledge about risk factors associated with levels of risk for suicidal behavior but also provide a solid basis for the implementation of public health policies aimed at the prevention and treatment of adolescent suicide.

Methods

This study was based on the analysis of secondary data from the Argentine Global School Health Survey (Encuesta Mundial de Salud Escolar [EMSE]), conducted in 2018. The methodology employed ensured the representativeness of the schooled adolescent population and allowed for the exploration of the relationship between different risk factors and the presence of suicidal

ideation, planning, and attempt in this population. The study design, the population analyzed, the variables included, and the statistical procedures used for data analysis are detailed below.

Design and population

A cutoff study, based on EMSE 2018 database, was conducted comprising a total of 56 students from Argentina, out of the 981, who were in the first to fifth year of secondary education [13]. The EMSE aimed to find data on health, risk, and protective factors in those students, in order to design health strategies and policies for children and adolescents at school [14].

The survey employed a multi-stage probability sampling method: first, schools were selected randomly; then, classrooms were selected within those schools; finally, students from the selected classrooms were invited to participate, thus ensuring a representative sample of the school students.

For the purposes of this investigation, the total available population was used without applying additional sampling techniques. The final database included 55 715 adolescents aged 13 to 17, who responded to the questions relevant to this research and were included in the CHAID decision tree (see Figure 1). However, due to data cross-linking, the number was reduced approximately to 30 000 students in the multivariate analysis, using binary logistic regression.

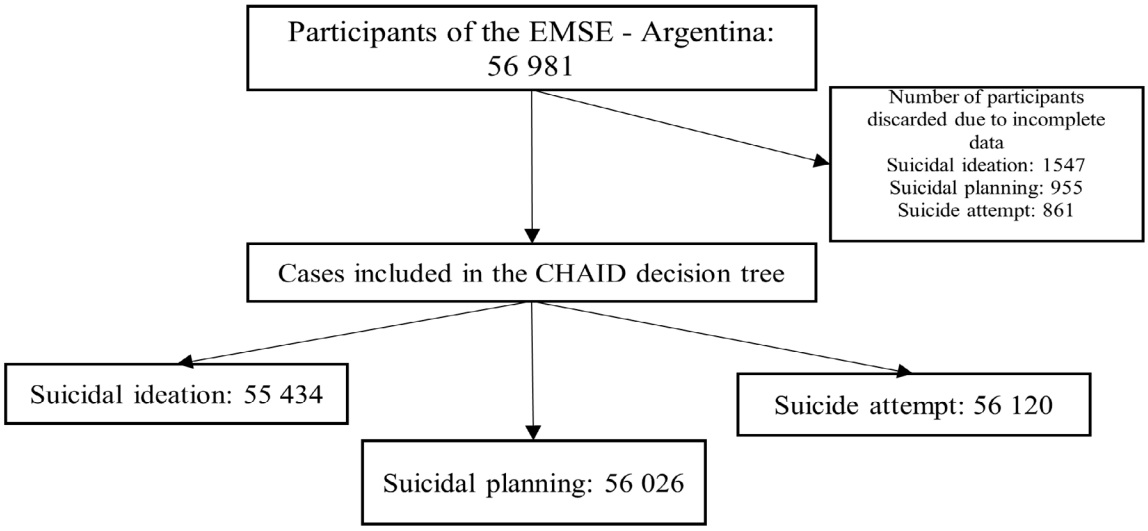

Figure 1. Cases included in the CHAID decision tree

Of the 56 981 participants in the EMSE, not all answered the three items on suicidal behavior. Some answered only one or two of them, which explains the difference in the final number of cases analyzed in each category (suicidal ideation, planning, and attempt).

Regarding data cleaning, incorrect data (such as decimals), misspelled variable entries, and inconsistent formatting of categories and numerical values were corrected. Duplicate data, outliers, null, and missing values were also searched for and found not to be a problem. The study did not include personal, institutional, or other data linkage between two or more databases.

This study followed the RECORD guidelines for the presentation of observational studies [15], ensuring transparency and quality in the presentation of methods and results.

Variables and measurements

The dependent variables were "ideation," "planning" and "suicidal attempt," which were defined in the database variables as: "if you have considered, planned, or attempted suicide during the last 12 months." Responses were dichotomized into "yes" or "no."

The independent variables included in the specification and analysis by the CHAID tree were the following: a) whether participants had tried cigarettes before age 14; b) whether they had drunk alcohol before age 14, among those who had drank more than a few sips; and c) whether they had ever been drunk in their lifetime. Participants were also asked whether they had used marijuana and amphetamines or methamphetamines at least once in their lifetimes. Additionally, they were asked a) whether participants had had alcoholic drinks;

b) whether they had drunk alcohol with friends; and c) whether they would be willing to drink alcohol if a friend offered it to them.

Statistical analysis

Tables were used to determine descriptive statistics. The supervised learning method was used through the decision tree, by means of CHAID. This is an algorithm that generates segments and creates profiles with respect to the result through the automatic detection of interactions between variables by means of chi-square [16]. In each step, the independent variable having the highest interaction with the dependent variable was chosen, and the main *nodes* with the highest chi-square value were selected until reaching the terminal node; thus, obtaining variables with the highest interaction with the dependent variable [17].

The nodes of the CHAID tree were decision points where the data were divided into more homogeneous groups according to the characteristics of the independent variables. The root node contained the entire sample; the internal nodes performed divisions based on chi-square tests; and the leaf nodes represented the final groups with similar characteristics, helping to identify complex patterns and relationships in the data.

In addition, a 10-fold cross-validation method was used to estimate the risk of misclassification of the CHAID decision tree model. The resulting nodes were tested with tables for the estimation of the raw and adjusted odds ratio (OR, ORa) using binary logistic regression, a statistical method used to predict the outcome of a binary dependent variable (i.e., a variable with two possible outcomes, such as "yes" or "no") from one or more independent variables. This model estimates the probability of a given event occurring, using the logistic function to ensure that predictions are between 0 and 1.

The regression model included as explanatory variables sex; history of being bullied at school, history of being bullied on the Internet, being overweight, presence of obesity, consumption of high-fat food two or more times per day during the last 7 days, and consumption of salty food or snacks two or more times per day during the last 7 days.

Likewise, the sensitivity (S), specificity (S), positive predictive values (PPV), and negative predictive values (PPV) of the new variables for men and women were produced by the CHAID decision tree and used as diagnostic performance tests. Analysis and processing, including the use of machine learning methods, were performed using IBM® SPSS Statistics 25™ [18].

Ethical considerations

The data used in this study come from the EMSE 2018, which is open access and is publicly available through the website of the Argentine National Ministry of Health. These data were collected with the participants' informed consent and reaffirmation that they understood the purpose of the study, the procedures involved, and their rights. The latter included confidentiality and the option to withdraw at any time.

Since these data had already been reviewed and approved ethically prior to publication, no additional approval by an institutional ethics committee was required. The provisions of the Declaration of Helsinki regarding data handling and confidentiality of the participants [19] were also respected. The EMSE database, questionnaire, metadata, and codebook are available at [20].

Results

In the analysis of the characteristics of the population studied, important patterns related to the variables of interest were identified. The prevalence of suicidal ideation, planning, and attempts in the last 12 months showed a progressive decrease, with suicidal ideation being the most frequent. Likewise, use of substances such as tobacco, alcohol and drugs, together with factors such as bullying and nutritional status, stood out as relevant elements in the population studied. In terms of gender, a balanced distribution between men and women was observed. However, variables related to substance use showed worrying prevalences, such as a high percentage of adolescents trying tobacco or alcohol before age 14 and of adolescents using these substances in the company of friends.

On the other hand, although the use of illicit drugs, such as amphetamines and marijuana, was less frequent, their presence was still significant in certain subgroups. Factors related to bullying, both in and out of school, and on the Internet, were also recurrent and may be associated with risk behaviors, such as suicidal ideation and substance use. In addition, the analysis of nutritional status revealed prevalences of overweight and obesity that could influence the participants' perception of well-being and health.

Table 1 presents the results of the characteristics of the population studied. Differences in the sums of the frequencies within the table can be explained by the presence of missing data, the application of different denominators, and the design of the questionnaire. Indeed, not all participants responded to all the survey questions,

Table 1. Characteristics of the study population

Variable		Frequency	Percentage
Sex	Male	27 083	48
	Female	29 362	52
Has seriously considered suicide in the last 12 months	Yes	11 962	21.50
	No	43 666	78.50
Has planned to commit suicide (during the last 12 months)	Yes	9734	17.30
	No	46 483	82.70
Has attempted suicide at least once in the last 12 months	Yes	8507	15.10
	No	47 795	84.9
Has consumed ecstasy	Yes	1554	2.80
	No	54 541	97.20
Has tried cigarettes before age 14 (for the first time among those who smoked)	Yes	13 667	60.70
	No	8835	39.30
Has parents or caregivers who use some form of tobacco	Yes	18 490	32.90
	No	37 653	67.10
Drank alcohol before the age of 14 (among those who had ever drank more than a few sips)	Yes	25 583	62.80
	No	15 153	37.20
Has ever been drunk	Yes	20 680	37.60
	No	34 297	62.40
Has used marijuana (once or more in their lifetime)	Yes	7531	13.60
	No	47 847	86.40
Has used amphetamines or methamphetamines (once or more in their lifetime)	Yes	1437	2.60
	No	54 020	97.40
Has drunk alcoholic beverages	Yes	7644	22.60
	No	26 129	77.40
Has drunk alcohol with friends	Yes	27 317	80
	No	6847	20
Would drink alcohol if a friend offered it	Yes	33 662	60
	No	22 411	40
Has had sexual intercourse	Yes	23 303	43.20
	No	30 689	56.80
Has low body weight	Yes	1554	2.80
	No	54 541	97.20
Is overweight	Yes	10 675	29.60
	No	25 377	70.40
Presents obesity	Yes	2655	7.40
	No	33 397	92.60
Has frequently consumed salty food	Yes	4392	7.80
	No	52 236	92.20
Has frequently consumed high-fat food	Yes	4745	8.40
	No	51 692	91.60

Variable		Frequency	Percentage
Has been bullied at school	Yes	11 903	21.40
	No	43 839	78.60
Has been bullied outside of school	Yes	12 229	21.60
	No	44 263	78.40
Has been bullied on the Internet	Yes	12 197	21.60
	No	43 753	78.20

which generated variations in the totals for each variable. This might have been due to voluntary omissions, errors in data collection, or inconsistencies in recording. Besides, each variable analyzed was based on a different subset of the total sample, as some questions were only answered by those who met certain prior criteria. This may have affected the totals reported. Finally, certain questions were directed only at a specific group of participants. This may have influenced the number of responses available.

The CHAID decision tree for factors associated with suicidal ideation had a total of 25 nodes, of which 15 were terminal nodes. The profiles associated with suicide attempts were found in those who drank alcohol alone and in those with a history of both amphetamine or methamphetamine use and cigarette smoking (nodes 14 - 5 - 1). The second profile with the highest association was drinking alcoholic beverages with friends, having consumed amphetamines, and having smoked cigarettes (nodes 15 – 5 -1) (see Figure 2).

Characteristics mainly associated with suicidal ideation in Argentine adolescent schoolchildren using the CHAID tree.

The CHAID decision tree for factors associated with suicidal planning had a total of 22 nodes, of which 13 were terminal nodes. The profiles associated with suicide attempts were found in those who drank alcohol alone and had a history of amphetamine or methamphetamine use and cigarette smoking (nodes 13-5-1). The second profile with the highest association was drinking alcoholic beverages with friends, having consumed amphetamines, and having smoked cigarettes (nodes 14-5-1) (see Figure 3).

Characteristics mainly associated with suicidal planning in Argentine adolescent schoolchildren using the CHAID tree.

The CHAID decision tree, for factors associated with attempted suicide, had a total of 21 nodes, of which 12 were terminal nodes. The profiles associated with attempted suicide were found in those who drank alcohol alone and had a history of amphetamine or methamphetamine use and cigarette smoking (nodes 13-5-1). The second profile with the highest association was drinking alcoholic beverages with friends, having consumed amphetamines, and having smoked cigarettes (nodes 14-5-1) (see Figure 4).

Characteristics mainly associated with suicide attempts in Argentine adolescent schoolchildren using the CHAID tree.

For suicidal ideation, adolescents at nodes 14 – 5 - 1 had a crude OR of 6.22 (95% CI = 4.58 - 7.45). After adjusting for other variables, the ORa was 8.104, which suggests an even stronger association, as adolescents with such nodes were 8.10 times more prone to suicidal ideation than those without these characteristics. The specificity was 99.11%, which indicates that the model correctly identified 99.11% of cases without suicidal ideation. The positive predictive value was 63%, which means that 63% of the adolescents identified as having suicidal ideation actually had it. The negative predictive value was 80%, which signifies that the 80% of adolescents identified as not suicidal in ideation were really not suicidal.

For suicidal planning, adolescents at nodes 14 – 5 - 1 had an OR of 7.13 (95% CI = 5.32 – 9.67). The ORa was 7.139, suggesting that the association remains significant after adjusting for other variables, as adolescents with such nodes were 7.13 times more likely to plan suicide than those without these characteristics. The specificity was 99.10%, indicating that the model correctly identified 99.10% of the cases without suicidal planning. The positive predictive value was 60%, which means that 60 % of the adolescents identified as having planned suicide actually had. The negative predictive value was 83%, indicating that 83% of the adolescents identified as not planning suicide did not actually plan it.

For suicide attempts, adolescents in nodes 13 – 5 - 1 had an OR of 9.50 (95% CI = 7.46 – 11.10). The ORa was 8.147, indicating a strong association after adjusting for other variables, as adolescents with such nodes were 8.14 times more likely to attempt suicide than those without these characteristics. The specificity was 99.80%, indicating that the model correctly identified 99.80% of cases without a suicide attempt. The positive predictive value was 62%, which means that 62% of adolescents identified as having attempted suicide had

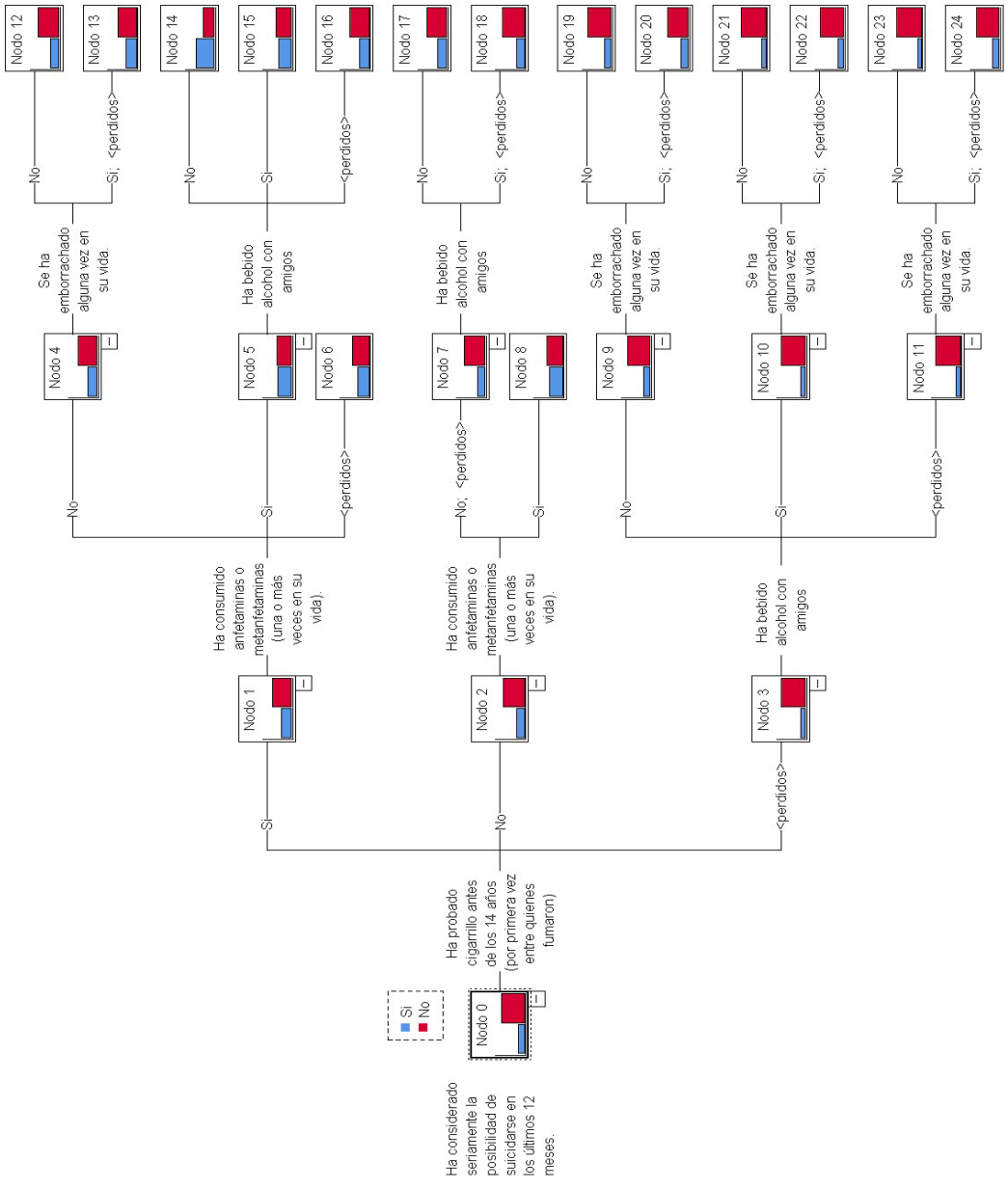

Figure 2. Characteristics mainly associated with suicidal ideation in Argentine adolescent schoolchildren using the CHAID tree

Note: Its original Spanish translation is preserved

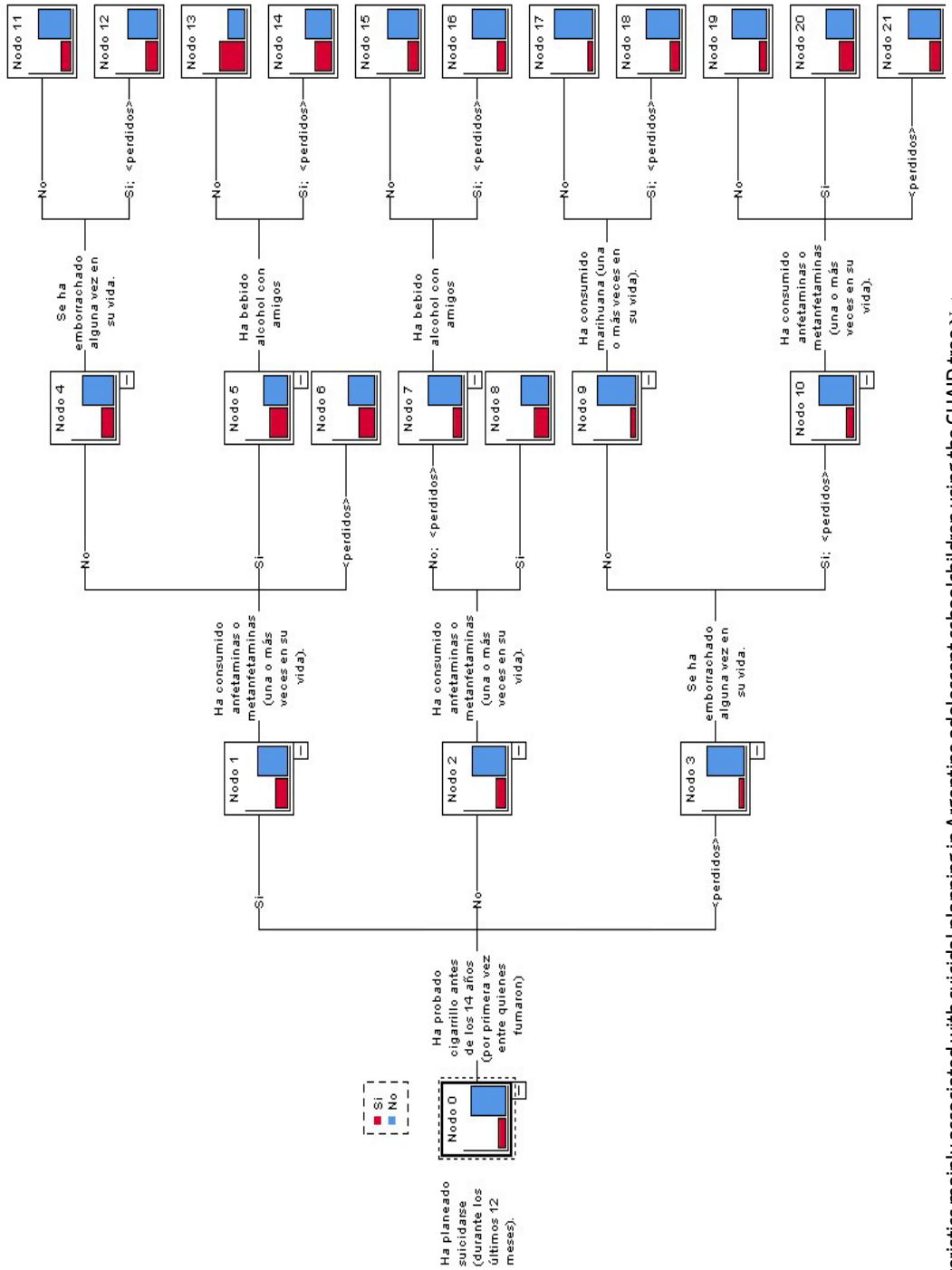

Figure 3. Characteristics mainly associated with suicidal planning in Argentine adolescent schoolchildren using the CHAID tree Note: *Note:* Its original Spanish translation is preserved

actually attempted suicide. The negative predictive value was 85%, indicating that 85% of adolescents identified as not having attempted suicide had not actually attempted suicide.

Table 2 presents the association and measures diagnostic between main nodes (CHAID tree) of suicidal ideation, planning and attempt in adolescent schoolchildren.

Table 2. Association and diagnostic measures between main nodes (CHAID tree) of suicidal ideation, planning and attempt in adolescent schoolchildren

Variable	Categories according to main nodes of the CHAID tree vs. other features	Crude OR (95% CI)	Adjusted OR (95% CI)	S (%)	E (%)	PPV (%)	NPV (%)
Suicidal ideation (n = 34 280)	Nodes 14 – 5 -1 (drinking alcohol alone, amphetamines/ methamphetamines use and cigarette smoking) (n = 175)	6.22 (4.58-7.45)	8.104 (5.223-10.550)	0.89	99.11	63	80
	Participants with other characteristics (n = 34 105)	1 (Ref.)	1 (Ref.)	-	-	-	-
Suicidal planning (n = 34 535)	Nodes 13 – 5 - 1 (drinking alcohol with friends, having consumed amphetamines/ methamphetamines, and smoking cigarettes) (n = 186)	7.13 (5.32-9.67)	7.139 (4.701-9.841)	0.90	99.10	60	83
	Participants with other characteristics (n = 34 349)	1 (Ref.)	1 (Ref.)	-	-	-	-
Suicide attempt (n = 34 537)	Node profile 13 – 5 -1 (drinking alcohol alone, having consumed amphetamines/ methamphetamines, and smoking cigarettes) (n = 282)	9.50 (7.46-11.10)	8.147 (5.698-10.649)	0.20	99.80	62	85
	Participants with other characteristics (n = 34 255)	1 (Ref.)	1 (Ref.)	-	-	-	-

E: Specificity; 95% CI: 95% confidence interval; OR: Odds ratio; Ref: Reference; S: Sensitivity; NPV: Negative predictive value; PPV: Positive predictive value.

Note:

1. The dependent variable for each analysis is suicidal ideation, suicidal planning, or suicidal attempt, as appropriate.

2. Explanatory variables include, as specified in the CHAID nodes: gender, bullied at school, bullied online, overweight, obese, consumed high-fat food two or more times per day (during the last 7 days), consumed salty food or snacks two or more times per day (during the last 7 days).

Discussion

In the CHAID decision tree, it could be observed that the profile with the highest association with levels of risk for suicidal behavior was that of adolescents who presented the following characteristics together: they drank alcoholic beverages alone, had used amphetamines/methamphetamines, and had smoked cigarettes. Tests of association found that this set of characteristics significantly increased the frequency of risk levels for suicidal behavior relative to other characteristics. This was reflected both in the specificity of almost 100% for the three aspects of suicidal behavior assessed in this research and in the negative predictive values that were equal to or greater than 80%. These results suggest that the joint use of several psychoactive substances increases the likelihood of suicidal behavior more than the individualized consumption of alcohol, amphetamines/ methamphetamines, and cigarettes.

In the tree, it could also be noted that having smoked cigarettes before age 14 was the parent node from which other substance use events, such as drinking alcohol, getting drunk, consuming amphetamines or methamphetamines, and consuming marijuana, occurred in the child nodes. This is consistent with the gateway hypothesis, which states that the use of legal drugs, such as alcohol or cigarette smoking (including electronic cigarettes), leads to the use of other substances [21].

Additionally, it was noticed that the main drug of initiation was tobacco, whose daughter nodes were the use of amphetamines or methamphetamines. This is consistent with the concept of "drug-drug specificity," related to the gateway hypothesis. Indeed, a previous study found that initial cigarette smoking is associated directly with the use of psychostimulants [22]. Hence, the adolescent smoking population is especially exposed to the use of psychostimulant drugs, which makes it necessary to a) implement strategies that discourage cigarette smoking; and b) develop intervention and prevention programs for the use of psychostimulants, such as amphetamines or methamphetamines, in those who have a past or present history of smoking.

The influence of co-consumption of substances on the risk levels of suicidal behavior has been studied by several authors. In a study conducted with high school students in South Korea, Cho, for example, found that those who consumed alcoholic beverages, tobacco, and coffee had a higher risk of suicide attempts than those who consumed one or two of the substances studied [23]. Also, in a study of South Korean adults, Jung found that habitual alcohol and tobacco use significantly increased the risk of suicide regardless of male or female sex [24]. Similarly, Rizk et al. reported that habitual use of alcoholic beverages and opioids increased the risk of suicidal ideation, suicide attempts, and death, due to the common effects these harmful substances have on neurobiological pathways which cause a negative predisposition to different levels of risk for affective states related to suicidal behavior [25].

The findings of this study suggest that the use of alcohol, cigarettes, and amphetamines/methamphetamines has a higher level of association with suicidal behavior than the use of one or two of these substances, and that the association is stronger when adolescents drink alcohol without other people. Creswell et al. found that solitary drinking from adolescence and young adulthood was associated with alcohol use disorders in adulthood [26]. Solitary drinking suggests underlying problems, such as depression or short- and long-term social adjustment problems [27], and may be indicative of addictions developed for the purpose of coping with negative emotions and situations. This makes solitary drinking a red flag indicating the need to investigate possible addictions and underlying social problems in adolescents. The strong vulnerability of this group to different levels of suicidal behavior also makes it necessary that questions directed towards the frequency and quantity of use of alcohol and other psychoactive substances go beyond the individualized study of each addiction to include aspects related to possible problems of social adaptation.

The use of amphetamines or methamphetamines was a feature that had a frequent association with risk levels for suicidal behavior in CHAID, even in the absence of alcohol consumption or smoking. These stimulant drugs (mainly methamphetamines, as they are more potent) may promote maladaptive behaviors since they cause dysregulation in the secretion of neurotransmitters, such as dopamine, serotonin, or norepinephrine; reduce their concentrations; and influence the presence of suicidal behavior [28].

Alcohol use, both alone and in the company of others, presented the strongest associations, together with amphetamine/methamphetamine use and smoking. Its relationship with suicidal behavior is not only influenced by sociocultural factors but also by its neurobiological impact. In particular, alcohol affects the regulation of 5-hydroxytryptamine receptors in the ventral prefrontal cortex, decreasing serotonergic activity. This reduction in serotonergic innervation contributes to the development of affective disorders associated with suicidal thoughts [29].

Regarding cigarette smoking, its main component, nicotine, acts on brain nicotinic cholinergic receptors for the release of neurotransmitters, such as dopamine, serotonin, noradrenaline, acetylcholine, gamma-aminobutyric acid, and glutamate. Therefore, the consumption of alcohol, cigarettes, and amphetamines/methamphetamines may increase the risk levels of suicidal behavior due to an accelerated depletion of the neurobiological pathways of affective regulation.

In that sense, the findings of the multivariate analyses provided significant evidence on the association between risk factors as a whole —such as lone alcohol consumption, history of amphetamine/methamphetamine use, and cigarette smoking—, and different levels of suicidal risk (suicidal ideation, planning, and attempt) in adolescents.

The ORa indicated a risk substantially elevated for each level of risk for suicidal behavior. For example, for suicide attempts, the ORa was 8.147 (95% CI = 5.698 – 10.649), implying that adolescents with these factors were eight times more likely to attempt suicide compared with those without these factors. This pattern was also present in suicidal ideation (ORa: 8.104; 95% CI = 5.223 – 10.550) and suicidal planning (ORa: 7.139; 95% CI = 4.701 – 9.841), suggesting that these factors may play a key role in the progression of suicidal thoughts to more severe behavioral risk levels.

Furthermore, although sensitivities are low (< 1%), specificities are remarkably high (> 99%), reflecting that these nodes are effective in identifying adolescents who are not at risk, but have limitations in detecting all those who are.

These results highlight the relevance of addressing substance use as a preventive strategy. Factors such as solitary alcohol drinking or drug use, such as amphetamine use, could function as early markers to identify vulnerable adolescents. The identified nodes suggest that targeted interventions in at-risk groups, especially

in those with multiple substance use, could be particularly effective in reducing the burden of suicidal behavior in adolescents.

The limitations of this study were several. The first was related to information bias and classification, since the source was a secondary database on which it was not possible to verify that the data were correctly recorded. There were neither biochemical nor anthropometric parameters. In addition, although the database consisted of 72 variables included in the CHAID tree, this study did not explore all of them, because the inclusion of too many variables could cause an overfitting of the model and would imply the incorporation of patterns of less relevance, and data related to the objectives of this research could be lost. In consequence, variables unrelated to the objectives of this article, such as anthropometric and dietary factors, were omitted.

Another limitation was the non-application of psychometric tests of suicidal ideation to obtain the results, which were based on individual questions. A third set of limitations has to do with its cross-sectional design, the use of self-reports, a sample limited to school students, the possible existence of confounding variables not considered, the lack of generalization to other populations, and the presence of missing data. It is necessary to take these limitations into account when interpreting the results and planning future research.

In conclusion, the pathological profile formed by solitary drinking, using amphetamines or methamphetamines, and smoking is strongly associated with suicidal behavior in Argentine adolescents with respect to those exposed to only one or two of these substances.

It is recommended to implement prevention and early education programs to discourage tobacco use, develop targeted interventions to identify and support at-risk adolescents, and conduct public awareness campaigns on the dangers of substance use. In addition, it is crucial to strengthen access to mental health services and train health professionals to treat at-risk adolescents.

Public policies should regulate access to substances such as alcohol and cigarettes and support families in the creation of healthy and safe environments. They should also require the implementation of longitudinal studies to monitor trends and of public policies related to such regulation. These actions would help reduce the incidence of suicidal behavior in adolescents.

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Author Contributions

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