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ORIGINAL CONTRIBUTION

A risk algorithm that predicts alcohol use disorders among college students

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Abstract

The first year of college may carry especially high risk for *onset* of alcohol use disorders. We assessed the one-year incidence of alcohol use disorders (AUD) among incoming first-year students, predictors of AUD-incidence, prediction accuracy and population impact. A prospective cohort study of first-year college students (baseline: N = 5843; response rate = 51.8%; 1-year follow-up: $n = 1959$; conditional response rate = 41.6%) at a large university in Belgium was conducted. AUD were evaluated with the AUDIT and baseline predictors with the Composite International Diagnostic Interview Screening Scales (CIDI-SC). The one-year incidence of AUD was 3.9% (SE = 0.4). The most important individual-level baseline predictors of AUD incidence were being male (OR = 1.53; 95% CI = 1.12–2.10), a break-up with a romantic partner (OR = 1.67; 95% CI = 1.08–2.59), hazardous drinking (OR = 3.36; 95% CI = 1.31–8.63), and alcohol use characteristics at baseline (ORs between 1.29 and 1.38). Multivariate cross-validated prediction (cross-validated AUC = 0.887) shows that 55.5% of incident AUD cases occurred among the 10% of students at highest predicted risk (20.1% predicted incidence in this highest-risk subgroup). Four out of five students with incident AUD would hypothetically be preventable if baseline hazardous drinking was to be eliminated along with a reduction of one standard deviation in alcohol use characteristics scores, and another 15.0% would potentially be preventable if all 12-month stressful events were eliminated. Screening at college entrance is a promising strategy to identify students at risk of transitioning to more problematic drinking and AUD, thus improving the development and deployment of targeted preventive interventions.

Keywords Alcohol use disorder · Hazardous drinking · University students · Risk algorithm · Incidence

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Introduction

The college years are a developmentally crucial period when students make the transition from late adolescence to emerging adulthood [1]. Apart from personal, social, and intellectual challenges and achievements, the college years are also a peak period for the prevalence of mental disorders [2, 3], with around one-third of incoming college students meeting criteria for a 12-month mental disorder [4, 5]. The prevalence of alcohol use disorders (AUD) among college students is lower than the estimates for some other mental disorders, with 12-month prevalence in students across 21 countries around 5% [6]. However, the college years, especially the first years, may carry especially high risk for *onset* of AUD as previous research suggests that up to 70% of AUD among college students has its onset *during* and not *prior* to college entrance [6]. AUD in college is associated with deleterious psychological, social, and physical health consequences [7], including violence [8], accidents and injuries [9], and risky sexual behaviors [10]. Additionally, over 90% of students with AUD do not perceive their symptoms to be a problem [11]. From a public health perspective, early and accurate identification of students that will make the transition from non-problematic alcohol use to a more severe level of alcohol consumption would facilitate effective deployment of targeted preventive interventions during college and thereby reduce the incidence, prevalence, severity, duration, and consequences of future AUD as well as of mental disorders that are influenced by AUD [12]. To guide allocation of resources and clinical decision-making, colleges need tools that accurately identify students at high risk of transitioning to more problematic drinking and developing AUD. Although there are many studies that estimate the prevalence of AUD in college, studies on the incidence of AUD, and predictors of incidence, among college students are scant. Using longitudinal data from the National Epidemiologic Survey on Alcohol and Related Conditions (NESARC), the incidence of AUD in the general population is estimated to be 1.45% per year, and approximately 4% among 20–29-year-olds, but they did not assess incidence specifically for college students who tend to be between 18 and 22 years of age [13].

Given the high availability of internet access and geographic proximity to centralized student services, college campuses may be ideally situated to access large groups of youth for screening and referral to adequate care [14]. Web-based screening provides a practical alternative for students with drinking problems who may be less likely to seek clinical services [15], and further, it may offer personalized feedback and access to online self-help interventions [16, 17]. Despite these potential advantages, it is currently unknown how many first-year college students effectively make the transition from non-problematic use of alcohol to a more problematic use of alcohol or to AUD, and how accurately these screening tools can identify the high-risk students that will make the transition, without identifying too many false-positive cases (a concern raised for the screening of suicidal behavior which limits the feasibility of screening [18]) that would put undue demands on college mental health centers. The development of powerful risk screening algorithms may remediate this.

The present study addresses these shortcomings by examining the first onset of AUD during the college years in a large, longitudinal survey of college students (Leuven College Surveys (LCS) – see: www.mindmates.be/page.phpid28), a part of the WHO World Mental Health Surveys International College Student initiative (WMH-ICS initiative, see: http://www.hcp.med.harvard.edu/wmh/college_student_survey.php). We build on earlier work on the development of concentration-of-risk models that estimated and accurately predicted incidence or persistence of mental disorders and self-injurious thoughts and behaviors [19–21]. Consistent with recommendations to develop such risk algorithms to target high-risk individuals for preventive interventions [22, 23], we examine the strength of multivariate associations in our model of baseline predictors (socio-demographic factors, drinking patterns at college entrance, traumatic events in childhood or adolescence, stressful events in the 12 months prior to college entrance, and baseline mental disorders and self-injurious thoughts and behaviors) to determine whether a well-defined subset of students at highest risk of incidence of AUD as classified by the empirically determined risk algorithm can be detected.

Methods

Procedures

Full procedures of the LCS have been reported previously [5, 21]. Briefly, the LCS consists of a series of web-based self-report surveys of KU Leuven students. In the academic years 2014–2016, all 13,103 Dutch-speaking incoming freshmen aged 18 years or older were eligible for the baseline survey. A total of 5,844 students completed the baseline survey (51.8% response rate after adjusting for potential non-participation due to college attrition). Students were contacted for the follow-up survey 12 months after the baseline assessment. A total of 1959 of the original baseline respondents responded to the follow-up survey (corresponding to a 41.6% conditional response rate after adjusting for non-participation due to college attrition).

Measures

Baseline socio-demographic variables. The university's students' administration office provided socio-demographic characteristics, including gender, age, nationality, parents' financial situation, parents' education, parental familial composition, university group membership, student situation (full-time student versus other) and type of secondary school education.

Baseline and follow-up drinking patterns and alcohol use disorder was assessed using the Alcohol Use Disorders Identification Test (AUDIT) [24]. The AUDIT was developed to identify *hazardous drinking* (conceptualized as an alcohol consumption pattern that increases the risk of harmful consequences for the individual or others in the absence of an alcohol use disorder), *harmful drinking* (conceptualized as alcohol consumption that results in harmful mental and physical health consequences), and *alcohol dependence* (conceptualized as physiological, psychological and behavioral consequence of prolonged use, such as tolerance and withdraw) [25]. The AUDIT consists of a total score (range 0–40) and allows for the calculation of three subscales: the *consumption* subscale (consisting of three items assessing the frequency and quantity of alcohol use), the *dependence* subscale (consisting of three items assessing perceived control over drinking, failure to comply to normal expectations due to drinking, and withdrawal symptoms), and the *alcohol-related problems* subscale (consisting of four items measuring guilt or remorse after drinking, memory lapses after drinking, alcohol-related injuries, and concerns of family, friends or professionals regarding one´s drinking). Most research to identify alcohol use problems uses the total score with varying cut-offs [26, 27]. While this version of AUDIT scoring in college students has concordance with clinical diagnosis in the range AUC = 0.85–0.90 [26], more recent research has suggested more varied and less optimal sensitivity and specificity estimates for females and countries with lower prevalence [27]. For a more fine-grained algorithm that takes into account the dependence subscale as well as the total score, and in line with a prior recommendation [28], we defined alcohol use disorder (AUD) as either a total AUDIT score of 16 + or a total AUDIT score of 8–15 with a score of 4 + on the AUDIT dependence subscale. Those students who did not meet the criteria for AUD were divided into either a *hazardous drinking* group when they had a total AUDIT score of 8–15 with a score of 0–3 on the AUDIT dependence subscale, or a *no hazardous drinking* group as having a total AUDIT score of 0–7.

Traumatic experiences in childhood-adolescence (i.e. prior to the age of 17) were assessed using 19 items adapted from the Composite International Diagnostic Interview (CIDI 3.0) childhood section [29], the Adverse Childhood Experience Scale [30], and the Bully Survey [31]. Items assessed parental psychopathology (i.e., any serious mental or emotional problems, substance use problems, suicidal behaviors or death by suicide, criminal activities, or interpersonal violence), physical abuse, emotional abuse, sexual abuse, neglect, bully victimization (i.e., either direct verbal or physical bullying, as well as indirect bullying [e.g., spreading rumors], or cyberbullying), and dating violence. Response options consisted of five-point Likert items ("*never*", "*rarely*", "*sometimes*", "*often*", and "*very often*"). To obtain dichotomously coded variables (i.e., potential risk factors), cut-off values consisted of "*rarely*" for all items, except bully victimization which had a cut-off of "*sometimes*", in line with a previous recommendation [32].

Stressful events experienced in the 12 months before the baseline survey were assessed using items from well-validated screeners [33–35], and included relevant stressful experiences among young adults, including life-threatening illness or injury of a family member or close friend [36], accidents or death of a family member or close friend [37], interpersonal events (e.g., break-up with a romantic partner, serious betrayal by someone other than one's partner) [38], and other stressful experiences (e.g., physical or sexual assault, and legal problems, such as time spent in jail [39–41].

Mental disorders in the 12 months before the baseline survey were assessed using the Composite International Diagnostic Interview Screening Scales (CIDI-SC) [42] for major depressive episode, mania/hypomania (broad mania), generalized anxiety disorder (GAD), panic attacks, and drug use disorder (abuse or dependence either on cannabis, cocaine, or any other street drug, or on a prescription drug either used without a prescription or used more than prescribed to get high, buzzed, or numbed out). The CIDI-SC scales have concordance with blinded clinical diagnoses in the range AUC = 0.70–0.78. Items from the Self-Injurious Thoughts and Behaviors Interview (SITBI – see [43]) assessed 12-month non-suicidal self-injury, suicidal ideation, suicide plans, suicide attempts, and non-suicidal self-injury. We also assessed risk for other mental disorders or symptoms, including lifetime intermittent explosive disorder symptoms, lifetime post-traumatic stress disorder symptoms, and lifetime eating disorder symptoms (using MINI items – see [44]).

Analyses

Non-response propensity weights [45] were created to adjust for potential non-response bias. Multiple imputation by chained equations [46] was used to adjust for survey attrition and within-survey item non-response. One case was eliminated for analysis due to missing information on auxiliary variables necessary for calculating non-response weights, resulting in a final sample for analysis of $n = 5843$. Logistic

regression analysis examined the strength of individual-level associations (i.e., odds ratios [OR]) between baseline predictor variables and 12-month hazardous drinking or AUD at 12-month follow-up. Two series of models were constructed. A first series predicted AUD at 12-month follow-up among those 5,590 students without AUD at baseline; a second series predicted hazardous drinking or AUD at 12-month follow-up among those 4,381 students without hazardous drinking or AUD at baseline. Baseline predictor blocks in the multivariate models included the three AUDIT subscales (including a dummy variable for baseline hazardous drinking in the first series of models), sociodemographic variables, (number of) traumatic experiences in childhood-adolescence, (number of) stressful events experienced in the past 12 months, (number of) lifetime and 12-month mental disorders, and 12-month self-injurious thoughts and behaviors. Individual-level predicted probabilities based on the multivariate equations were created, and area under the curve (AUC) values calculated. The multivariate model with the highest AUC was selected for further evaluation of predictive accuracy. Predicted probabilities were discretized into deciles and cross-classified with observed cases to visualize the concentration of risk associated with high composite predicted probabilities. Sensitivity was defined as the proportion of cases found among pre-defined proportions (e.g., 10%) of respondents with highest predicted probabilities. Positive Predictive Value (PPV) was defined as the probability of effectively developing the outcome when being among pre-defined proportions (e.g., 10%) of respondents with highest predicted probabilities. We used the method of leave-one-out cross-validation [47] to correct for the over-estimation of prediction accuracy when both estimating and evaluating model fit in a single sample. Using summary measures of predicted probabilities calculated using coefficients from the final model, we estimated Potential Impact Fractions (PIF), representing the proportion of outcome cases potentially reduced after a change in the exposure of a related ordinal categorical predictor [48]. We use PIFs instead of the more commonly used Population Attributable Risk Proportion because PIFs are indicated in data where the lowest exposure of a risk factor (i.e. the use of alcohol) is non-zero.

Results

Description of the sample

The majority of the sample ($n = 5843$) was female (57.0%), 18 years of age (73.9%), only few participants (4.3%) were of non-Belgian nationality and 17.2% of the students indicated that they were raised in households with a difficult financial situation. For most students (62.0%), both parents had a college education, only a small proportion of students (15.4%) indicated that neither of their parents had a college education. More than half of all students met criteria for at least one of the three lifetime or five 12-month disorders (57.7%), and 25.3% reported exactly one, 15.0% exactly two, 8.7% exactly three, and 8.7% four or more mental disorders. More than half of the sample (58.4%) reported at least one traumatic experience prior to the age of 17, with 34.4% experiencing parental psychopathology as the most reported one, followed by bully victimization (32.4%). Every second student (57.6%) also reported at least one stressful life event in the past year, with the experience of life-threatening illness or injury of a close friend or family member most frequently reported (i.e. 20.6%).

Incidence of AUD

Prevalence of hazardous drinking and AUD at baseline and follow-up are shown in Table 1. Three findings stand out. First, 12-month prevalence of hazardous drinking and AUD at baseline was 21.6% and 4.7%, respectively. Second,

Table 1 Twelve-month hazardous drinking and alcohol use disorders at follow-up versus baseline

Baseline			12-month follow-up		
	n	% (SE)		*n*	% (SE)
No hazardous drinking or AUD	4381	73.7 (0.6)	No hazardous drinking or AUD	3675	83.4 (0.8)
			Hazardous drinking, no AUD	661	15.5 (0.8)
			AUD	46	1.1 (0.2)
Hazardous drinking, no AUD	1209	21.6 (0.6)	No hazardous drinking or AUD	319	26.0 (1.8)
			Hazardous drinking, no AUD	730	60.4 (2.0)
			AUD	160	13.6 (1.4)
AUD	253	4.7 (0.3)	No hazardous drinking or AUD	20	7.8 (2.3)
			Hazardous drinking, no AUD	104	40.8 (4.2)

persistence of hazardous drinking/AUD among college students (i.e. the proportion of those who meet criteria for hazardous drinking/AUD both at baseline and follow-up) was 60.4% and 51.5%, respectively. Third, the incidence of AUD among college students is estimated at 3.9% (SE = 0.4): an estimated 206 out of the 5,590 college students met criteria for AUD in follow-up while they did not meet criteria for AUD at baseline. More specifically, among those 4,381 students without 12-month hazardous drinking or AUD at baseline, only 1.1% made the transition to AUD one year later. By comparison, this was 13.6% among those 1,209 students with 12-month hazardous drinking (but no AUD) at baseline.

Bivariate and multivariate predictors of AUD incidence

Table 2 presents a summary of the baseline variables that significantly predicted AUD at follow-up first among the subsample of students without AUD at baseline and then among only students without hazardous drinking or AUD at baseline. First, among those without AUD at baseline, results from the bivariate analyses show that incidence of AUD at follow-up was associated with baseline hazardous drinking (OR = 14.20), alcohol use characteristics (ORs 1.76–2.35), being male (OR = 2.67), break-up with a romantic partner in the year prior to college entrance (OR = 2.05), serious betrayal by someone else than a romantic partner (OR = 1.53), and other stressful events in the year prior to college entrance (OR = 1.89). Especially those with two or more stressful events in the past year had higher odds for subsequent onset of AUD (ORs 1.54–2.17). Past 12-month drug use disorder and a lifetime eating disorder were also associated with incident AUD (ORs = 5.27 and 1.54, respectively). Second, among students without hazardous drinking or AUD at baseline, bivariate analyses to predict hazardous drinking or AUD at 12-month follow-up revealed similar results, though there were a few additional predictors, such as studying biomedical sciences (OR = 1.21) or screening positive for 12-month broad mania (OR = 2.31).

Table 2 also shows the final selected multivariate models, adjusting for all other risk domains included in those models. AUD at follow-up among those without AUD at baseline (cross-validated AUC = 0.887) was predicted by being male (OR = 1.53), a break-up with a romantic partner in the year prior to college entrance (OR = 1.67), hazardous drinking (OR = 3.36) and alcohol use characteristics at baseline (OR between 1.29 and 1.38). For the more restricted subset of only students without hazardous drinking or AUD at baseline (AUC = 0.785), predictors for hazardous drinking or AUD at 12-month follow-up were similar with a few additional predictors (i.e., studying biomedical sciences, 12-month panic attacks and 12-month broad mania; ORs in the 1.28–2.33 range).

Prediction accuracy

Table 3 shows cross-validated sensitivity and PPV for different proportions of students at highest predicted risk based on the final multivariate models described above. Multivariate cross-validated prediction (cross-validated AUC = 0.887) shows that an estimated 55.5% of incident AUD cases would occur among the 10% of students at the highest predicted risk and that an estimated 20.1% of these high-risk students would go on to meet criteria for AUD at follow-up compared to only 3.9% in the lowest risk subgroup. Among the subset without hazardous drinking or AUD, sensitivity among the 10% of students at the highest predicted risk was 33.1% and the positive predicted value 51.3% versus 16.6% in the lowest risk subgroup.

Population impact

In Table 4, we show adjusted PIFs of baseline predictors based on the final multivariate models described above. Four out of five students with incident AUD would hypothetically be preventable if baseline hazardous drinking was to be eliminated along with a reduction of one standard deviation in alcohol use characteristics scores, and another 15.0% would potentially be preventable if all 12-month stressful events were eliminated. Among the subset without hazardous drinking or AUD at baseline, alcohol use characteristic is attributable to 46.5% of new onset hazardous drinking/AUD and eliminating all 12-month stressful events would result in another 5.5% reduction, assuming a full causal relationship.

Discussion

Main findings

The aim of this study was to develop and evaluate the performance of a risk algorithm that aims to identify students at high risk of new onset AUD during the first year of college. We found a 3.9% one-year incidence of AUD (in line with the 4.0% reported for 20–29-year-olds in the general population [13]), that we could predict with a cross-validated AUC of 0.887 with three baseline variables: alcohol consumption scores, male gender, and having broken up with a romantic partner in the 12 months prior to college entrance. Using this algorithm, more than half of incident AUD cases would occur among the 10% of students at the highest predicted risk. If colleges were to evaluate incoming students with this algorithm and focus

Table 2 Summary of baseline predictors being significantly associated with 12-month hazardous drinking or AUD at follow-up

Baseline predictors	12-month AUD at follow-up among students with and without hazardous drinking (no AUD) at baseline ($n=5590$)				12-month hazardous drinking or AUD at follow-up among students without hazardous drinking or AUD at baseline ($n=4381$)			
	Median	Prevalence	Bivariate	Multivariate[b]	Median	Prevalence	Bivariate	Multivariate[c]
	Med (SE) [IQR]	% (SE)	OR (95%CI)	aOR (95%CI)	Med (SE) [IQR]	% (SE)	OR (95%CI)	aOR (95%CI)
AUDIT subscales								
AUDIT consumption score (0–12)	3.1 (0.0) [2.0–4.9]		1.76 (1.07–2.90)	1.29 (1.07–1.56)	2.5 (0.0) [1.8–3.8]		1.65 (1.05–2.60)	1.48 (1.05–2.09)
AUDIT dependence score (0–12)	0.0 (0.0) [0.0–0.5]		2.35 (1.11–4.96)	1.38 (1.09–1.75)	0.0 (0.0) [0.0–0.0]		2.44 (1.11–5.37)	1.51 (1.09–2.09)
AUDIT alcohol problems score (0–16)	0.0 (0.0) [0.0–1.2]		1.78 (1.06–2.99)	1.31 (1.06–1.61)	0.0 (0.0) [0.0–0.4]		1.84 (1.07–3.16)	1.43 (1.07–1.91)
Hazardous drinking (vs. no hazardous drinking)		22.7 (0.6)	14.20 (1.34–150.25)	3.36 (1.31–8.63)		0.0 (0.0)	/	/
Sociodemographic variables								
Being male		41.9 (0.7)	2.67 (1.27–5.62)	1.53 (1.12–2.10)		36.9 (0.8)	1.66 (1.14–2.43)	1.38 (1.08–1.76)
Human sciences		53.8 (0.7)	(ref)	(ref)		52.6 (0.8)	(ref)	(ref)
Science and technology		26.2 (0.6)	0.84 (0.46–1.54)	0.85 (0.44–1.64)		26.5 (0.7)	0.97 (0.73–1.29)	0.84 (0.52–1.34)
Biomedical sciences		20.0 (0.5)	1.00 (0.61–1.63)	1.18 (0.75–1.88)		20.9 (0.6)	1.21 (1.01–1.45)	1.28 (1.01–1.61)
Twelve-month stressful experiences								
Break-up romantic partner		17.9 (0.6)	2.05 (1.20–3.48)	1.67 (1.08–2.59)		16.4 (0.6)	1.65 (1.14–2.39)	1.58 (1.09–2.30)
Serious betrayal someone else		12.0 (0.5)	1.53 (1.03–2.27)	1.40 (0.80–2.45)		11.7 (0.5)	1.19 (0.93–1.52)	1.09 (0.71–1.65)
Any other stressful experiences		15.7 (0.5)	1.89 (1.17–3.04)	1.46 (0.95–2.24)		14.6 (0.6)	1.21 (0.97–1.52)	1.11 (0.78–1.57)
No stressful experience		43.2 (0.7)	(ref)	(ref)			(ref)	(ref)
Exactly 1 stressful experience		28.5 (0.7)	1.29 (0.91–1.82)	/		28.1 (0.8)	1.11 (0.91–1.34)	/
Exactly 2 stressful experiences		16.8 (0.6)	1.54 (1.01–2.37)	/		16.2 (0.6)	1.17 (0.91–1.51)	/
Exactly 3 stressful experiences		7.1 (0.4)	1.98 (1.13–3.46)	/		6.7 (0.4)	1.49 (1.10–2.02)	/
4 + stressful experiences		4.5 (0.3)	2.17 (1.20–3.91)	/		4.1 (0.3)	1.24 (0.80–1.91)	/

Table 2 (continued)

Baseline predictors	12-month AUD at follow-up among students with and without hazardous drinking (no AUD) at baseline ($n=5590$)				12-month hazardous drinking or AUD at follow-up among students without hazardous drinking or AUD at baseline ($n=4381$)			
	Median	Prevalence	Bivariate	Multivariate[b]	Median	Prevalence	Bivariate	Multivariate[c]
	Med (SE) [IQR]	% (SE)	OR (95%CI)	aOR (95%CI)	Med (SE) [IQR]	% (SE)	OR (95%CI)	aOR (95%CI)
Mental disorders								
12-month panic attacks		25.7 (0.6)	1.26 (0.94–1.71)	/		25.2 (0.7)	1.14 (0.96–1.36)	1.33 (1.05–1.68)
12-month broad mania		1.3 (0.2)	1.47 (0.37–5.75)	/		1.3 (0.2)	2.31 (1.34–3.99)	2.33 (1.05–5.17)
12-month drug abuse/dependence		0.4 (0.1)	5.27 (1.59–17.53)	/		0.2 (0.1)	2.78 (0.46–16.99)	0.93 (0.01–86.40)
Lifetime eating disorder		12.7 (0.4)	1.54 (1.06–2.23)	/		12.1 (0.5)	1.26 (1.04–1.53)	1.24 (0.93–1.66)
AUC[a]				0.887				0.785

AOR adjusted odds ratio, *AUD a*lcohol use disorder, *CI c*onfidence interval, *IQR* Interquartil range, *OR o*dds ratio, *SE s*tandard error

[a]AUC values corrected for potential over-estimation of prediction accuracy using the method of leave-one-out cross-validation

[b]The final selected multivariate model includes the three AUDIT subscales, the hazardous drinking dummy variable, all nine sociodemographic variables, and all seven 12-month stressful experiences under study

[c]The final selected multivariate model includes the three AUDIT subscales, all nine sociodemographic variables, all seven childhood-adolescent traumatic experiences, all seven 12-month stressful experiences, all eight mental disorders, and 12-month self-injurious thoughts and behaviours

Table 3 Concentration of risk for 12-month hazardous drinking or alcohol use disorder at follow-up in different proportions of incoming first year students at highest predicted risk at baseline based on the final multivariate model

% Highest Risk	12-month AUD at follow-up among students with and without hazardous drinking (no AUD) at baseline ($n=5590$)				12-month hazardous drinking or AUD at follow-up among students without hazardous drinking or AUD at baseline ($n=4381$)			
	Sensitivity	SE	PPV	SE	Sensitivity	SE	PPV	SE
100	100.0	0.0	3.9	0.4	100.0	0.0	16.6	0.8
90	99.9	0.2	4.3	0.4	98.7	0.6	18.1	0.8
80	99.8	0.4	4.8	0.5	96.6	1.0	19.9	0.9
70	99.4	0.7	5.5	0.5	93.8	1.2	22.0	1.0
60	98.9	0.9	6.3	0.6	89.9	1.6	24.4	1.2
50	98.1	1.3	7.4	0.7	84.2	1.9	27.3	1.3
40	96.3	1.8	9.0	0.9	76.6	2.2	30.9	1.5
30	91.7	2.7	11.4	1.1	66.2	2.4	35.3	1.9
20	80.9	3.9	15.0	1.5	52.5	2.5	41.4	2.4
10	55.5	4.9	20.1	2.5	33.1	2.2	51.3	3.3

*AUD a*lcohol use disorder, *SE* Standard error

Sensitivity = proportion of risk for AUD disorder cases found among the row % of respondents at highest predicted risk, based on cross-validated predicted probabilities

Positive predictive value (PPV) = probability of effectively developing risk for AUD when being among the row % at highest predicted risk, based on cross-validated predicted probabilities

Table 4 Potential impact fractions of baseline predictors on risk for 12-month hazardous drinking or AUD at follow-up

	Difference distribution	12-month AUD at follow-up among students with and without hazardous drinking (no AUD) at baseline[a]		12-month hazardous drinking or AUD at follow-up among students without hazardous drinking or AUD at baseline[b]	
		aPIF%[c]	aPIF%[c]	aPIF%[c]	aPIF%[c]
AUDIT consumption score	− 1 Standard deviation	36.1	80.0	34.0	46.5
AUDIT dependence score	− 1 Standard deviation	15.6		6.4	
AUDIT alcohol-related problems score	− 1 Standard deviation	23.4		11.2	
Hazardous drinking	No hazardous drinking	50.8		/	/
All traumatic experiences	No traumatic experiences	/	/	0.0[d]	0.0[d]
All 12-month stressful events	No 12-month stressful events	15.0	15.0	5.5	5.5
All mental disorders	No mental disorders	/	/	0.0[d]	0.0[d]

AUD alcohol use disorder, *AUDIT* alcohol use disorders identification test

[a]The final selected multivariate model includes the three AUDIT subscales, the hazardous drinking dummy variable, all nine sociodemographic variables, and all seven 12-month stressful experiences under study

[b]The final selected multivariate model includes the three AUDIT subscales, all nine sociodemographic variables, all seven childhood-adolescent traumatic experiences, all seven 12-month stressful experiences, all eight mental disorders, and 12-month self-injurious thoughts and behaviours

[c]aPIF = adjusted Potential Impact Fraction. The PIF represents the number of outcome cases that are potentially impacted (reduced) after a change in the exposure of a related continuous of categorical predictor

intervention on the students in the highest 10% of predicted risk, they would be targeting more than half of the incident cases. Additionally, a high proportion of AUD incidence was attributable to baseline consumption patterns, which, if reduced by an intervention program during the first year of college, could conceivably decrease AUD incidence by as much as 80.0%. Preventing and/or helping students to cope effectively with stressful life events might also reduce AUD incidence by an additional 15.0%. This is consistent with the findings of Prince, Read and Colder [49] in which relatively small absolute differences in alcohol consumption in the first semester of college predicted large differences in alcohol-related consequences post-graduation. Similarly, Read et al. [50] observed that trauma and post-traumatic stress at matriculation predicted alcohol consequences at the end of the school year. Among the past-year stressful life events assessed, break-up with a romantic partner was the most predictive of increasing risk for AUD. This may be a particularly stressful event for incoming college students given that the transition to college already involves social network changes as many new relationships are formed and need to be balanced with older relationships [51]. In another prospective longitudinal study of emerging adults over 18 months, romantic relationship dissolution was associated with increased substance use, including heavy alcohol use [52].

Strengths and limitations

We present a novel approach to risk prediction by estimating the concentration of risk in different proportions of incoming students at highest predicted risk based on a multivariate model of baseline predictors, and using PIF to simulate population impact of transitions to more harmful drinking patterns with a large longitudinal sample of college students. The inclusion of baseline AUDIT consumption scores in the prediction algorithm allows a simple cost-effective tool for universities to predict transitions to more harmful consumption and eventual AUD. Some limitations, however, should be considered when interpreting the results. First, the response rates were modest (51.8% at baseline and 41.6% at follow-up) but consistently higher than those reported in other recent large-scale surveys of college students (39–44%) [3, 53]. Additionally, we used cutting-edge missing data techniques [46] to increase the representativeness of the data. Because the sample was drawn from one university in Belgium, replicating the findings at other universities represents an important goal for future research. The sample size lacked power to predict AUD exclusively at follow-up among students without hazardous drinking or AUD at baseline. A further limitation is the self-administered self-report assessment of AUD and other mental disorders, rather than a clinician diagnosis based on face-to-face interviews.

However, our measures of AUD and other mental disorders were well-validated screening scales used in many prior general populations surveys, and have shown high diagnostic concordance with clinical diagnoses [26, 54]. Finally, while we included a range of baseline predictors (sociodemographic, consumption patterns, life events and mental disorders), there are other predictors which might increase predictive accuracy in the future, such as personality traits like sensation-seeking, urgency, and low constraint [11], family history of problem drinking [55], and protective factors (e.g., emotion regulation competencies [56]). However, it will be important for future research to identify the fewest number of predictors possible that provides the optimal level of accuracy to reduce respondent burden and increase the feasibility of evaluating all incoming students.

Clinical and policy implications

Alcohol use is a large problem across college campuses worldwide. Screening algorithms, such as the one in this study based on integrative multivariate prediction models, may be a useful resource (and one that is low-cost and can be easily implemented in the college context) for detecting high-risk students and tailoring interventions to those students based on population-level estimates of the factors that contribute the most to overall incidence, namely baseline consumption patterns and effects of romantic relationship break-up. Thus college mental health prevention efforts could be more selective regarding the students targeted for intervention as well as the exposures targeted, thus optimizing limited resources. Our findings, along with those of others [49], suggest that future AUD can be predicted in the first year of college with reasonable precision and this early detection could be beneficial for college counselors to implement timely preventive strategies. Several promising interventions have been evaluated in this regard for college students [57–59]. However, it may be particularly challenging to get students with alcohol use problems into treatment as prior research has shown that students with AUD are less willing to seek treatment [15] and do not perceive their symptoms to be a problem [11]. Digital risk screeners with subsequent normative feedback, including information about potential preventive options, might be a promising approach to motivate at risk students for preventive interventions [17]. Perhaps interventions that stem from student orientation or activities that address recognition of the problem and are presented less as traditional modes of treatment delivery would be more acceptable for these students [60]. Increasingly, online interventions, which have the potential to reach a greater number of students at a low cost to university administrators, have shown promise in general community and healthcare settings [61, 62] though initial results in college students have been mixed [63–65]. The current study provides data to suggest who and what to target in such interventions and the importance of targeting those students during their first year of college.

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Compliance with ethical standards

Conflict of interest In the past 3 years, Dr. Kessler received support for his epidemiological studies from Sanofi Aventis, he was a consultant for Johnson & Johnson Wellness and Prevention, Shire and Takeda, and served on an advisory board for the Johnson & Johnson Services Inc. Lake Nona Life Project. Dr. Kessler is a co-owner of DataStat, Inc., a market research firm that carries out healthcare research. Dr. Demyttenaere has served on advisory boards for Boehringer Ingelheim Eli Lilly, Lundbeck, Johnson&Johnson, Livanova, Servier, and has research grants from Eli Lilly, foundation 'ga voor geluk', Fonds voor Wetenschappelijk Onderzoek Vlaanderen. Dr. Ebert reports to have received consultancy fees/served in the scientific advisory board from several companies, such as Sanofi, Novartis, Minddistrict, Lantern, Schoen Kliniken, and German health insurance companies (BARMER, Techniker Krankenkasse). He is also a stakeholder of the Institute for health training online (GET.ON), which aims to implement scientific findings related to digital health interventions into routine care. The other authors have no interests to declare.

Ethical approval The study's protocol was approved by the University Hospital Leuven Biomedical Ethical Board and complies with the ethical standards of the Helsinki Declaration of 1975, as revised in 2008.

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