A Risk Algorithm for the Persistence of Suicidal Thoughts and Behaviors During College

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ABSTRACT

Objective: The primary aims of this study are to (*a*) identify patterns of suicidal thoughts and behaviors (STB) during college among students with lifetime pre-matriculation STB and (*b*) develop a risk-screening algorithm for persistence of pre-matriculation STB during college.

Methods: Data come from the Leuven College Surveys, a series of prospective cohort studies of all incoming KU Leuven University freshmen. In the academic year 2012–2013, 4,889 incoming freshmen (73.2% response rate) provided baseline data on sociodemographic variables, childhood-adolescent traumatic experiences, 12-month stressful experiences, 12-month mental disorders, 12-month STB, and severity markers of pre-matriculation STB. A total of 2,566 students (69.3% conditional response rate) participated in 12- and 24-month follow-up surveys during the first 2 college years.

Results: Thirteen percent (weighted n = 535) of incoming freshmen reported lifetime pre-matriculation STB. Of those, 28.0% reported 12-month STB in 1 follow-up assessment, and another 27.7%, in both follow-up assessments. High persistence of STB (ie, 12-month STB in 2 follow-up assessments) was most strongly associated with severity markers of pre-matriculation STB, with odds ratios in the 2.4–10.3 range and population attributable risk proportions between 9.2% and 50.8%. When the aim was for less than 50% of false-positive cases (positive predictive value = 54.4%), a multivariate predictive risk algorithm (cross-validated area under the curve = 0.79) situated 59.9% of highly persistent cases among the 30% respondents with highest baseline predicted risk.

Conclusions: An individualized web-based screening approach is a promising strategy to identify students at the time of university entrance who may be at high risk for STB persistence during their academic career.

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Adolescence carries high risk for onset of suicidal thoughts and behaviors (STB).[1] Although STB decline during the transition into young adulthood,[2,3] many adolescents (21%–50%) continue to experience symptoms into their early twenties.[4,5] One potential prevention intervention for persistent STB is web-based screening upon college entrance.[6,7] 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 young adults for screening and referral to adequate care.[7] Web-based screening provides a practical alternative for suicidal individuals who may be less likely to seek clinical services,[8] and, further, it may offer personalized feedback[9] and access to online self-help interventions.[10]

Despite these potential advantages, it is currently unknown to what extent pre-matriculation onset STB persists into the college period. Of note, college student surveys suggest high lifetime STB prevalence (11%–34%),[11–13] and 12-month STB are comparable to those in same-aged peers (range, 4.2%–5.5%).[14] In addition, screening has been criticized for overwhelming counselors with false-positive cases[15] and imposing unrealistic demands on mental health centers.[16,17] Developing powerful risk screening algorithms for STB persistence may remediate this.[18] However, only 1 prior study developed such an algorithm, which was restricted to depressed adults 18 years or older.[19]

The present study addresses these shortcomings by examining persistence of pre-matriculation onset STB during the college years in a large longitudinal survey of college students (Leuven College Surveys [LCS],[20] part of the WHO World Mental Health Surveys International College Student project[21]). Consistent with recommendations to develop risk algorithms to target high-risk individuals for preventive interventions,[22] the current study examines the strength of multivariate associations in our model of baseline predictors to determine whether a well-defined subset of students at highest risk of persistent STB can be detected. Baseline risk factors assessed at college entrance were selected on the basis of available research on STB persistence and include previous STB,[22] childhood-adolescent trauma (eg, domestic violence),[23] number of stressful life events,[4] and mental disorders (eg, internalizing and externalizing disorders).[4]

METHODS

Procedures

Full procedures of the LCS have been reported previously.[24] Briefly, the LCS consists of a series of web-based self-report surveys of KU Leuven students. All 7,493 Dutch-speaking

Clinical Points

- There is a need for validated risk-screening algorithms to identify young adults with high risk for persistence of suicidal thoughts and behaviors (STB) against low amounts of false-positive cases.
- Web-based risk screening for a wide range of clinically relevant risk factors at college entrance is a promising approach to optimize the link between high risk for STB persistence and subsequent evidence-based care.

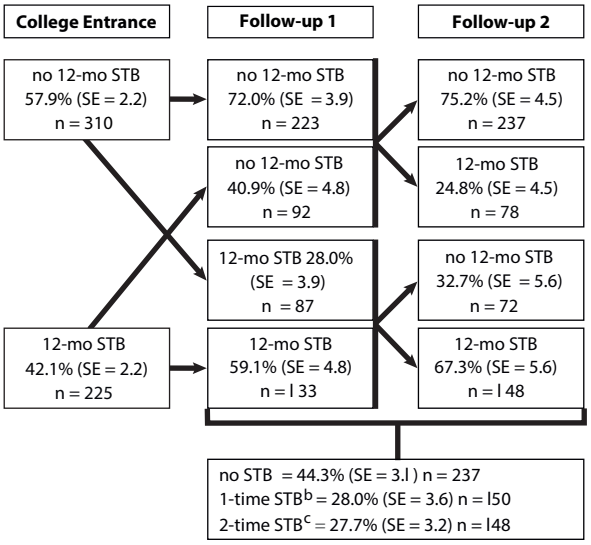
incoming freshmen aged 18 years or older were eligible for the baseline survey in the academic year 2012–2013. A total of 4,889 students completed the baseline survey (73.2% response rate after adjusting for nonparticipation due to college attrition). Students were contacted for the follow-up survey 12 and 24 months after the baseline assessment. A total of 2,566 of the original baseline respondents responded to at least 1 follow-up survey (69.3% conditional response rate after adjusting for nonparticipation due to college attrition). Informed consent was obtained from all subjects. Students with 12-month STB or nonsuicidal self-injury (NSSI) received links to local mental health resources. The study's protocol was approved by the University Hospital Leuven Biomedical Ethical Board.

Measures

Sociodemographic variables. The university's students' administration office provided sociodemographic characteristics, including gender, age, nationality, parents' financial situation, parents' education, parental familial composition, university group membership, and secondary school educational type. Survey items assessed sexual orientation and college living situation.

Suicidal thoughts and behaviors. Items from the Self-Injurious Thoughts and Behaviors Interview (SITBI)[25] assessed suicidal ideation ("Did you ever in your life have thoughts of killing yourself?"), suicide plans ("Did you ever think about how you might kill yourself [eg, taking pills, shooting yourself] or work out a plan of how to kill yourself?"), and suicide attempts ("Have you ever made a suicide attempt [ie, purposefully hurt yourself with at least some intent to die]?"). Baseline surveys assessed lifetime and 12-month STB ("In the past 12 months, did you think/have you made…"), whereas 12- and 24-month follow-up surveys each assessed 12-month STB to effectively cover the full follow-up period. At baseline only, pre-matriculation lifetime STB severity markers included (1) STB duration (> 5 years or more) and recency (remission at college entrance of 3 years or less) based on STB age-at-onset/offset measures; (2) proxy measures of intensity (eg, "How many days during that worst week did you have those thoughts?") and controllability of STB ("How easy was it for you to control those thoughts or push them out of your mind when you wanted to?"), referring to the week when STB was perceived as most severe[26]; and (3) STB-associated risk-taking behavior ("People who think about killing themselves sometimes do dangerous things as a way to tempt fate [eg, take a lot of drugs, drive too fast, volunteer for dangerous missions, or act recklessly]. How often in your life did you ever do dangerous things related to thinking about killing yourself?").[27]

Figure 1. Course of Suicidal Thoughts and Behaviors (STB) During College Among Students With a Prematriculation Lifetime History of STB (weighted n = 535)[a]



[a]Proportions indicate the number of participants that report (no) 12-month STB within the group where the arrow originates from. Groups with (no) 12-month STB in follow-up 1 were grouped together to calculate proportions in follow-up 2 (as indicated by the vertical bars).
[b]Reporting 1-time 12-month STB during 2-year follow-up.
[c]Reporting 2-time 12-month STB during 2-year follow-up.

Traumatic experiences in childhood or adolescence. Traumatic experiences occurring prior to the age of 17 years were assessed using 19 items adapted from the Composite International Diagnostic Interview (CIDI 3.0) childhood section,[28] the Adverse Childhood Experience Scale,[29] and the Bully Survey.[30] Items assessed parental psychopathology (ie, any serious mental or emotional problems, substance use problems, STB or death by suicide, criminal activities, or interpersonal violence), physical abuse, emotional abuse, sexual abuse, neglect, bully victimization (ie, either direct verbal or physical bullying, as well as indirect bullying [eg, spreading rumors], or cyberbullying), and dating violence. Response options consisted of 5-point Likert items ("never," "rarely," "sometimes," "often," and "very often"). Confirmatory factor analysis using our data showed excellent validity of the internal screener structure (root mean square error of approximation [RMSEA] = 0.019). To obtain dichotomously coded variables for population attributable risk proportion (PARP) analysis of risk factors, cutoff values consisted of "rarely" for all items, except bully victimization, which had a cutoff of "sometimes," in line with previous recommendation.[31]

Risk for 12-month mental disorders. Risk for 12-month mental disorders was assessed with the Global Appraisal of Individual Needs Short Screener (GAIN-SS)[32] including internalizing disorders, externalizing disorders, substance

Table 1. Sociodemographic Variables as Baseline Predictors for Adverse Clinical Patterns of STB During Follow-up[a]

	Prevalence			Bivariate Model[b]			
				One-Time STB[c]		Two-Time STB[c]	
	n (w)	% (w)	SE	OR (95% CI)	PARP, %	OR (95% CI)	PARP, %
I. Sociodemographic variables							
Being male	245	45.8	2.2	1.5 (0.8–2.6)	9.5	1.3 (0.7–2.2)	2.3
Age > 18 y	189	35.3	2.1	1.4 (0.8–2.6)	0.4	**2.3*** (1.2–4.4)	**16.5***
Non-Belgian nationality	58	10.8	1.4	1.2 (0.5–3.0)	0.9	1.1 (0.4–3.4)	0.5
Parents' financial situation difficult	138	25.7	2.1	1.1 (0.6–2.1)	1.4	1.0 (0.5–2.0)	−0.2
Parental education level[d]							
Both parents high	295	55.2	2.5	ref …	…	ref …	…
Only 1 parent high	135	25.3	2.1	1.2 (0.6–2.4)	2.6	1.2 (0.6–2.4)	2.3
No parent high	104	19.5	2.1	1.5 (0.7–3.4)	2.5	1.9 (0.9–4.2)	6.8
Non-intact familial composition[e]	180	33.6	2.2	1.2 (0.6–2.1)	1.6	1.2 (0.6–2.3)	3.3
Non-heterosexual orientation	78	14.7	1.9	1.2 (0.5–2.7)	−0.3	1.6 (0.7–3.8)	4.7
College-related sociodemographic variables							
University Group membership							
Human Sciences	318	59.4	2.1	ref …	…	ref …	…
Science and Technology	139	25.9	1.9	1.1 (0.6–2.0)	2.0	0.9 (0.5–1.7)	−2.4
Biomedical Sciences	78	14.7	1.5	1.2 (0.5–2.6)	1.1	1.1 (0.5–2.6)	0.8
Non-GSE pre-educational level	65	12.2	1.6	1.2 (0.4–3.4)	2.0	0.7 (0.2–2.8)	−2.2
Living with parents	174	32.5	2.4	1.2 (0.7–2.2)	4.7	1.0 (0.5–2.0)	−1.6

[a]Significant ORs and PARP values are shown in bold and are indicated by an asterisk (α = .05).
[b]Bivariate associations are based on a separate model for each row, with the variable in the row as the only predictor in the model.
[c]No STB during follow-up is the reference category.
[d]Defined as holding a bachelor's degree or more.
[e]Defined as parents being divorced or separated.
Abbreviations: GSE = general secondary education, OR = odds ratio, PARP = population attributable risk proportion, STB = suicidal thoughts and behaviors, w = weighted.

disorders, and crime/violence related disorders. The GAIN-SS subscreeners are very strongly correlated with the original corresponding subscales of the 60–120 minute *DSM-IV-TR*–based GAIN structured interview (Pearson $r = 0.84–0.93$[32]). Confirmatory factor analysis using our data showed a very good validity of the internal GAIN-SS structure (RMSEA = 0.032). For each screener, the recommended cutoff score for the highest probability of a 12-month diagnosis was used, that is, 3 or more positive 12-month symptoms. We also assessed risk for other mental disorders or symptoms, including 12-month mania/hypomania, intermittent explosive disorder, psychosis (using CIDI-3.0 items),[28,33] eating disorder (using Mini-International Neuropsychiatric Interview items[34]), and nonsuicidal self-injury (using the SITBI,[25] referenced above).

Stressful events experienced in the past 12 months. These events were assessed using 12 items taken from well-validated screeners[35–37] and included relevant stressful experiences among young adults, including life-threatening illness or injury of a family member or close friend,[38] accidents or death of a family member or close friend,[39] interpersonal events (eg, break-up with a romantic partner, serious betrayal by someone other than one's partner),[40] physical or sexual assault,[41,42] and legal problems (eg, time spent in jail).[43]

Analyses

Nonresponse propensity weights[44] adjusted for potential nonresponse bias, and multiple imputation by chained equations[45] adjusted for survey attrition and within-survey item nonresponse. All analyses were restricted to the 535 students who reported lifetime STB in the baseline survey. Adverse patterns of STB during the follow-up period were defined as 2-time STB (ie, reporting 12-month STB at both follow-up assessments) and 1-time STB (ie, reporting 12-month STB at 1 of the 2 follow-up assessments). Logistic regression analysis examined the strength of individual-level associations (ie, odds ratios [ORs]) between baseline risk factors with adverse patterns of STB. As this does not account for a population-level risk perspective[46] (ie, high-prevalence risk factors carrying low individual risk for STB [ie, low OR] may be equally or even more important to consider as low-prevalence risk factors carrying high risk for the affected individuals), PARP[47] were calculated, thus allowing the risk factors that potentially attribute most to the persistence STB in student populations to be identified.

Finally, a series of multivariate models was estimated. Predictors were entered in blocks, beginning with sociodemographic variables, followed by childhood-adolescent traumatic experiences, 12-month stressful experiences, 12-month risk for mental disorders, and finally severity markers of pre-matriculation STB. Individual-level predicted probabilities based on the multivariate equation were created, and area under the curve (AUC) values were calculated. 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 predefined proportions (eg, 10%) of respondents with highest predicted probabilities. Positive predictive value (PPV) was defined as the probability of effectively developing the outcome when being among predefined proportions (eg, 10%) of

Table 2. Childhood-Adolescent Traumatic Experiences and 12-Month Stressful Experiences as Baseline Predictors for Adverse Clinical Patterns of STB During Follow-up[a]

	Prevalence			Bivariate Model[b]			
				One-Time STB[c]		Two-Time STB[c]	
	n (w)	% (w)	SE	OR (95% CI)	PARP (%)	OR (95% CI)	PARP (%)
II. Traumatic experiences (age < 17 y)							
Parental psychopathology	286	53.5	2.6	1.4 (0.8–2.4)	4.3	1.7 (0.9–3.1)	15.4
Physical abuse	86	16.0	1.9	1.6 (0.7–3.9)	−0.1	**2.9*** (1.2–7.0)	**10.8***
Emotional abuse	209	39.1	2.5	1.1 (0.6–2.1)	−1.4	1.6 (0.9–3.0)	12.4
Sexual abuse	22	4.1	1.2	1.8 (0.3–10.8)	−0.8	**5.1*** (1.1–22.9)	**4.9***
Neglect	84	15.8	2.0	1.9 (0.8–4.5)	4.0	2.0 (0.8–5.0)	4.6
Bully victimization	332	62.2	2.6	1.3 (0.7–2.2)	6.9	1.2 (0.7–2.2)	3.9
Dating violence	74	13.9	1.9	1.1 (0.5–2.5)	0.4	1.1 (0.5–2.7)	1.0
Any traumatic experience	458	85.6	1.8	1.3 (0.6–3.0)	8.8	1.3 (0.6–2.9)	10.6
No. of traumatic experiences							
0	77	14.4	1.8	ref …	…	ref …	…
1	158	29.5	2.3	1.0 (0.4–2.5)	0.7	0.8 (0.3–2.0)	−3.7
2	116	21.7	2.2	1.5 (0.6–3.9)	4.7	1.3 (0.5–3.3)	1.4
3+	184	34.4	2.4	1.6 (0.6–3.9)	3.5	2.0 (0.8–4.9)	13.2
F test (*P* value)[d]				*F* = 0.32 (0.81)		*F* = 1.16 (0.32)	
III. Twelve-month stressful experiences							
Life-threatening illness or injury of a friend or family member	131	24.5	1.9	1.0 (0.5–1.9)	−0.4	1.0 (0.5–2.0)	0.9
Death of a friend or family member	117	21.9	1.9	1.3 (0.7–2.7)	−1.1	**2.3*** (1.1–4.8)	**12.0***
Breakup with a romantic partner	147	27.5	2.0	1.0 (0.5–1.9)	0.2	1.1 (0.5–2.1)	1.2
Romantic partner cheated	40	7.4	1.2	0.9 (0.3–2.7)	0.1	0.8 (0.3–2.3)	−1.1
Serious betrayal by someone other than partner	157	29.4	2.1	1.8 (1.0–3.4)	6.1	**2.1*** (1.1–4.1)	**11.1***
Serious ongoing arguments or breakup with friend or family member	187	34.9	2.2	1.4 (0.8–2.5)	0.8	**2.0*** (1.1–3.8)	**15.1***
Life-threatening accident	18	3.4	0.8	8.5 (0.4–166. 1)	1.8	10.0 (0.5–198.6)	2.6
Seriously physically assaulted	28	5.3	1.0	5.1 (0.5–57.1)	1.5	7.2 (0.4–123.9)	4.3
Sexually assaulted or raped	18	3.3	0.8	3.6 (0.6–21.9)	1.5	4.0 (0.7–22.8)	2.0
Any serious legal problem	38	7.0	1.2	1.6 (0.4–7.1)	−0.2	3.0 (0.6–13.7)	4.5
Any stressful event	389	72.7	2.0	1.6 (0.9–3.0)	9.9	**2.2*** (1.1–4.2)	**28.9***
No. of stressful experiences							
0	146	27.3	2.0	ref …	…	ref …	…
1	141	26.4	2.0	1.4 (0.7–2.9)	3.6	1.6 (0.7–3.2)	5.2
2	106	19.8	1.8	1.6 (0.7–3.7)	4.1	1.8 (0.8–4.2)	5.5
3+	141	26.5	2.0	1.9 (0.9–4.0)	2.6	**3.4*** (1.5–7.6)	**18.3***
F test (*P* value)[d]				*F* = 0.53 (0.66)		*F* = 2.52 (0.057)	

[a]Significant ORs and PARP values are shown in bold and are indicated by an asterisk (α = .05).
[b]The bivariate associations are based on a separate model for each row, with the variable in the row as the only predictor in the model.
[c]No STB during follow-up is the reference category.
[d]Cochran-Armitage trend test. The *F* test evaluates significance (α = .05) of 200 pooled Cochran-Armitage χ^2_3 linear trend tests.
Abbreviations: OR = odds ratio, PARP = population attributable risk proportion, STB = suicidal thoughts and behaviors, w = weighted.

respondents with highest predicted probabilities. We used the method of leave-one-out cross-validation[48] to correct for the overestimation of prediction accuracy when both estimating and evaluating model fit in a single sample.

RESULTS

Course of STB During College

The course of STB among the 535 students (13.0%; SE = 0.3) with lifetime STB is presented in Figure 1. Whereas about 4 out of 10 students (44.3%) show a pattern of remission during the 2-year follow-up period, about 3 out of 10 (28.0%) show 1-time STB (ie, 1-time 12-month STB during the 2 follow-up years), and 3 out of 10 (27.7%) show 2-time STB (ie, 2-time 12-month STB during the 2 follow-up years). The importance of the distinction between 1-time and 2-time STB is seen in the fact that 12-month prevalence of suicide plans is significantly higher among those with 2-time STB compared to those with 1-time STB in each of the 2 follow-up surveys (51.1% vs 14.1% in the first follow-up assessment; $\chi^2 = 16.1$; $P < .001$; and 78.9% vs 33.2% in the second follow-up assessment; $\chi^2 = 29.2$; $P < .001$). Few 12-month suicide attempts were reported: 8 at college entrance (2 in the 1-time STB group, 6 in the 2-time STB group), 3 during year 1 (1 in the 1-time STB group, 2 in the 2-time STB group), and 1 during year 2 (in the 1-time STB group).

Bivariate Models for Adverse Course of STB During College

Inspecting results across risk factor domains (Tables 1–3) reveals that risk factors are almost exclusively associated with 2-time STB, as opposed to 1-time STB. When we focus on 2-time STB, associations are strongest for severity

Table 3. Twelve-Month Mental Disorders and Severity Markers of Pre-Matriculation STB as Baseline Predictors for Adverse Clinical Patterns of STB During Follow-up[a]

	Prevalence			Bivariate Model[b]			
				One-Time STB[c]		Two-Time STB[c]	
	n (w)	% (w)	SE	OR (95% CI)	PARP, %	OR (95% CI)	PARP, %
IV. Twelve-month mental disorders							
Risk for internalizing disorder	313	58.6	2.2	1.2 (0.7–2.1)	0.9	1.5 (0.8–2.7)	14.4
Risk for externalizing disorder	181	33.8	2.2	1.3 (0.7–2.4)	3.2	1.5 (0.8–2.9)	6.7
Risk for substance use disorder	57	10.6	1.4	1.7 (0.6–4.7)	1.6	1.9 (0.6–5.8)	3.4
Risk for crime/violence disorder	1	0.2	0.2	/ /	/	/ /	/
IED item positive	78	14.6	1.6	1.8 (0.8–4.4)	0.7	**3.1*** (1.1–8.3)	**9.6***
Mania/hypomania item positive	101	18.9	1.8	**3.4*** (1.5–8.1)	**7.0***	**4.2*** (1.5–12.1)	**12.1***
Any eating disorder item positive	104	19.4	1.8	1.3 (0.7–2.7)	0.6	1.8 (0.9–3.8)	7.1
Any psychotic item positive	56	10.4	1.4	1.9 (0.7–5.1)	2.9	1.9 (0.7–5.4)	2.7
Nonsuicidal self-injury	76	14.2	1.5	2.0 (0.8–4.6)	−0.5	**4.2*** (1.9–9.6)	**13.6***
Any positive screen	403	75.4	1.9	1.5 (0.8–2.8)	8.2	1.8 (0.9–3.6)	24.0
No. of positive screens							
0	132	24.6	1.9	ref …	…	ref …	…
1	142	26.5	2.0	1.0 (0.5–2.2)	−0.9	1.2 (0.6–2.5)	3.0
2	109	20.3	1.8	1.4 (0.6–3.2)	4.2	1.2 (0.5–2.7)	0.8
3+	153	28.6	2.0	**2.3*** (1.0–5.1)	**5.2***	**3.7*** (1.6–9.0)	**20.1***
F test (*P* value)[d]				*F* = 1.31 (0.27)		*F* = 2.78 (0.040)	
V. Severity markers of pre-matriculation STB							
Twelve-month STB at baseline	225	42.1	2.2	1.7 (0.9–3.1)	−1.8	**4.4*** (2.3–8.4)	**38.1***
Pre-matriculation lifetime STB							
No pre-matriculation suicide plans or attempts (ie, ideation only)[e]	236	44.1	2.2	ref …	…	ref …	…
Pre-matriculation suicide plans; no attempts	229	42.9	2.2	1.6 (0.9–2.9)	5.1	**2.4*** (1.3–4.7)	**19.7***
Pre-matriculation suicide attempts	69	13.0	1.5	**3.5*** (1.1–11.2)	**0.8***	**10.3*** (2.9–37.1)	**16.9***
STB characteristics in worst week of pre-matriculation lifetime STB							
Duration of STB 4 days or more per week	248	46.3	2.2	1.4 (0.8–2.5)	3.3	**1.9*** (1.1–3.4)	**17.3***
Duration of STB 5 hours or more per day	47	8.7	1.2	2.1 (0.7–6.3)	−0.7	**4.9*** (1.9–12.6)	**9.2***
Controlling STB very difficult/impossible	89	16.7	1.6	1.9 (0.9–4.0)	1.4	**3.1*** (1.5–6.4)	**11.0***
Any STB-associated risky behavior	167	31.2	2.0	1.2 (0.7–2.3)	0.4	1.7 (0.9–3.1)	9.8
Course of pre-matriculation lifetime STB							
Duration 5 years or more	141	26.4	2.0	1.4 (0.7–2.8)	−1.7	**2.9*** (1.5–5.7)	**18.4***
Remission at college entrance 3 years or less	423	79.0	1.8	1.4 (0.7–3.1)	−1.5	**3.4*** (1.3–9.0)	**50.8***

[a]Significant ORs and PARP values are shown in bold and are indicated by an asterisk (α = .05).
[b]The bivariate associations are based on a separate model for each row, with the variable in the row as the only predictor in the model.
[c]No STB during follow-up is the reference category.
[d]Cochran-Armitage trend test. The *F* test evaluates significance (α = .05) of 200 pooled Cochran-Armitage χ^2_3 linear trend tests.
[e]Students with a pre-matriculation history of ideation but not plans or attempts are the reference category for the 3-category predictor.
Abbreviations: IED = intermittent explosive disorder, OR = odds ratio, PARP = population attributable risk proportion, STB = suicidal thoughts and behaviors, w = weighted.
Symbol: / = could not be estimated.

markers of pre-matriculation STB (median OR = 3.2; median PARP = 17.9%; Table 3), including lifetime suicide attempts and 12-month STB at college entrance, but also STB duration (episodes spanning 5 years or more), recency (remission at college entrance for 3 years or less), perceived intensity (as determined by duration measures in worst week), and perceived controllability of STB. Considerable proportions of 2-time STB are also associated with baseline stressful experiences (PARP = 28.9%), as well as baseline risk for 3 or more mental disorders (PARP = 20.1%; Table 3). Specific risk factors identified in these risk domains include interpersonal stressors (serious betrayal by someone other than one's partner, serious ongoing arguments or breakup with friends of family members, death of a friend or family member [median OR = 2.1; median PARP = 12.0%]), as well as symptoms of dysregulated mood (intermittent explosive disorder symptoms, hypomania/mania symptoms) and NSSI (median OR = 4.2; median PARP = 12.1%). In contrast, population-level risk of childhood-adolescent traumatic experiences is nonsignificant, and individual-level associations are only significant for physical abuse (OR = 2.9) and sexual abuse (OR = 5.1).

Multivariate Models for Adverse Course of STB During College

Multivariate models (Supplementary eTables 1–3) also fit the data better for 2-time STB, as opposed to 1-time STB (drop in Akaike information criterion of 41.0% vs 18.0%). Significant predictors for 2-time STB in the final model adjusting for all risk domains (cross-validated AUC = 0.79 [SE = 0.04]) are lifetime suicide attempts (OR = 11.1 [1.4–87.4]; PARP = 7.2%) and 12-month STB (OR = 4.7 [1.4–15.9]; PARP = 12.3%). Of note, 12-month NSSI remains a strong independent risk factor (OR = 5.7 [1.7–18.5];

Table 4. Concentration of Risk of Persistent STB Cases in Different Proportions of Incoming Freshmen at Highest Predicted Risk Based on a Multivariate Model[a] Including All Risk Factors

	One-Time STB		Two-Time STB	
% at Highest Predicted Risk	Sensitivity, % (SE)[b]	PPV, % (SE)[c]	Sensitivity, % (SE)[b]	PPV, % (SE)[c]
100	100.0 (0.0)	28.0 (3.6)	100.0 (0.0)	27.7 (3.2)
90	90.1 (3.5)	27.9 (3.7)	98.7 (1.4)	30.3 (3.5)
80	80.8 (4.9)	28.1 (3.9)	96.2 (2.5)	33.2 (3.9)
70	71.9 (5.9)	28.6 (4.4)	92.8 (3.3)	36.5 (4.3)
60	62.4 (6.5)	28.8 (4.8)	87.6 (4.0)	40.0 (4.8)
50	53.3 (6.5)	29.4 (5.2)	80.6 (4.9)	44.1 (5.3)
40	43.4 (6.4)	29.8 (5.8)	71.6 (5.4)	48.8 (6.1)
30	33.5 (6.0)	30.4 (6.4)	59.9 (5.8)	54.4 (7.1)
20	23.0 (5.5)	31.1 (8.1)	45.4 (5.6)	61.6 (8.5)
10	12.0 (4.3)	31.9 (11.5)	27.1 (4.6)	73.1 (10.5)

[a]See Model 5 in the supplementary materials covering multivariate model construction (Supplementary eTables 1–3). Model-based area under the curve (AUC) values were 0.71 (SE = 0.03) for 1-time STB and 0.87 (SE = 0.03) for 2-time STB. Cross-validated AUC values were 0.52 (SE = 0.05) for 1-time STB and 0.79 (SE = 0.04) for 2-time STB.
[b]Sensitivity = proportion of persistent STB outcome cases found among the row % of responders at highest predicted risk, based on cross-validated predicted probabilities.
[c]Positive predictive value (PPV) = probability of effectively developing persistent STB when being among the row % at highest predicted risk, based on cross-validated predicted probabilities.
Abbreviation: STB = suicidal thoughts and behaviors.

PARP = 8.7%), an effect that is only attenuated (OR = 3.6 [0.9–14.9]; PARP = 4.9%) in the final model adjusting for all risk domains. Table 4 shows cross-validated sensitivity and PPV estimates for different proportions of students at highest predicted risk based on the final model. One possible trade-off between these measures is considering the top 30% at highest risk, as this includes 59.9% of subsequent cases of 2-time STB, with under 50% of false-positive cases (PPV = 54.4%).

DISCUSSION

In line with previous studies,[4,5,23,49,50] we identified a small proportion of young adults that repeatedly report STB during the early college years (ie, 2-time STB; 27.7% of incoming freshmen with lifetime pre-matriculation STB, 3.6% of all incoming freshmen). As expected, robust predictors were previous STB,[22] especially suicide attempts.[51] We now find this adverse course also predicted by a wider range of severity markers related to previous STB, such as long-lasting symptoms, high intensity of ideation, and perceived loss of control over ideation. In contrast with 1 previous clinical study,[52] these additional severity markers were no longer significant in a full multivariate model adjusting for previous STB, pointing out the need for additional studies. Since we did not assess severity of STB during follow-up, future research should also deliver a more fine-grained picture of patterns of STB severity over time. This should clarify to what extent we identified a subgroup of young adults with an uninterrupted course of severe suicidal symptoms from childhood-adolescence into the college years and to what extent these students are at risk for suicide. On the one hand, suicide attempts in our sample mainly occurred during childhood-adolescence and were almost nonexistent during follow-up in college. College attrition due to adverse mental health may explain this finding,[53,54] but it is also compatible with studies that show risk for suicide attempt to be highest in the year after onset of suicidal ideation.[55] On the other hand, tendency toward suicidal planning remained high among those with more persistent STB (51%–79%), and several prospective studies found a strong association between STB persistence and suicide attempts later in life.[5,56,57]

Surprisingly, we found childhood-adolescent trauma generally not related to persistence of STB into young adulthood. Notable exceptions were physical and especially sexual abuse, which is in line with the detrimental effects of these experiences on early-life mental health.[58] However, due to low prevalence, the contribution of these risk factors to the total amount of persistent STB cases was limited. In contrast, many such cases were potentially attributable to interpersonal stressful experiences and symptoms of dysregulated mood in the year before college entrance. This was especially the case for having arguments with family or friends, a risk factor ranking highest as precipitating event for suicide attempts.[59] When integrating these findings with existing research, one potential hypothesis is that earlier traumatic experiences initiate childhood-adolescent STB,[60] but also heightened levels of affective-behavioral dysregulation[61] and interpersonal stress sensitivity.[62] These traits, in turn, may be predictive for persistent STB into young adulthood, relatively independent from the earlier trauma that initiated them. If confirmed, we may have identified a group at risk for developing borderline personality disorder, given the strong association of this disorder with persistent STB,[63] as well as symptoms of mood instability,[64] interpersonal stressful experiences,[65] and physical or sexual trauma.[66] For some students, persistent STB was also strongly related to NSSI, which has been conceptualized as a coping mechanism to deal with heightened interpersonal stress and unwanted internal emotional states[67,68] and is also strongly associated with borderline personality characteristics.[69] In any case, these risk factors all emerged as important for persistence of childhood-adolescent STB into college, pointing to potential targets in college screening projects.

An important contribution of our study is the development of a prospective risk-screening algorithm that accurately predicts a persistent pattern of STB. Our algorithm performs equally well as those developed for other multifactorial diseases, including coronary heart disease,[70] common cancers,[71,72] diabetes,[57] and all-cause mortality.[73] Together with a recently developed risk algorithm for onset of college STB,[24] these results are very promising with regard to individualized approaches to screening for STB in unrestricted populations of young people. Indeed, we demonstrate that a powerful prediction algorithm may optimize the link between high risk for STB and referral for intervention. For example, an intervention targeting the top 30% of freshmen at highest risk could effectively reach 60% of highly persistent—and possibly severe—STB

cases during the following years. These percentages actually correspond to an estimated 80 students each academic year in our university, and they are realistic proportions of students to refer to evidence-based care like psychiatric assessment and psychotherapeutic interventions.[13,74] While false-positive cases may continue to be an issue (an expected 36 cases each academic year in our university), it is worth taking into consideration that our estimations are based on a large number (> 40) of clinically significant predictors. High cumulative risk for STB based on our model may signal a need for referral regardless of a subsequent development of persistent STB, safeguarding against an inadequate inflow of students to specialized care.

Several limitations of this study deserve attention. First, response rates in the 69.3%–73.2% range are good but do not rule out the possibility that we may have missed cases of STB in both baseline and follow-up assessments. However, our response rates (corrected for college attrition) are substantially higher than those of most cross-sectional web-based surveys (ie, around 40%[75]) or response rates in other recent large-scale college student surveys (39%–44%[13,76]). Second, it is unknown to what extent baseline risk for mental disorders established by using self-report measures effectively corresponds to mental disorders diagnosed by face-to-face clinical interviews. We addressed this limitation by selecting well-validated measures used in large surveys of the general population. Third, prediction accuracy measures were validated using the leave-one-out cross-validation technique, which delivers somewhat downward biased estimates of true prediction accuracy.[77] Therefore, cross-validated prediction accuracy measures in this study should be seen as underestimates, and future research should address this using larger sample sizes and better-equipped validation techniques.

CONCLUSION

We detected a small but significant proportion of students with a persistent pattern of STB, characterized by severe psychopathology and heightened sensitivity for interpersonal stressful experiences. Results are promising for accurately predicting highly persistent STB cases in a prospective way; however, results for relapsing-remitting STB were less favorable. Future research should address this by including additional risk and protective factors, by considering interactions between predictors, and by implementing machine learning techniques[78] to further improve prediction accuracy. Fortunately, the WHO World Mental Health Surveys International College Student project aims to collect prospective data on large samples of incoming freshmen worldwide, enabling these future endeavors.

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Editor's Note: We encourage authors to submit papers for consideration as a part of our Focus on Suicide section. Please contact Philippe Courtet, MD, PhD, at pcourtet@psychiatrist.com.

Supplementary material follows this article.

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Supplementary Material

Article Title: A Risk Algorithm for the Persistence of Suicidal Thoughts and Behaviors During College

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List of Supplementary Material for the article

Disclaimer

This Supplementary Material has been provided by the author(s) as an enhancement to the published article. It has been approved by peer review; however, it has undergone neither editing nor formatting by in-house editorial staff. The material is presented in the manner supplied by the author.

Supplementary Materials

Supplementary eTable 1. Multivariate individual-level associations between risk factors under study and adverse clinical patterns of STB during follow-up.

Supplementary eTable 2. Multivariate population-level associations between risk factors under study and adverse clinical patterns of STB during follow-up.

Supplementary eTable 3. Model fit statistics and prediction accuracy measures of multivariate prediction models for adverse clinical patterns of STB during follow-up

Supplementary eTable 1. Multivariate individual-level associations between risk factors under study and adverse clinical patterns of STB during follow-up.

	MULTIVARIATE MODEL 1[a]		MULTIVARIATE MODEL 2[a]		MULTIVARIATE MODEL 3[a]		MULTIVARIATE MODEL 4[a]		MULTIVARIATE MODEL 5[a]	
	One-time STB[b] OR (95%CI)	Two-time STB[b] OR (95%CI)	One-time STB[b] OR (95%CI)	Two-time STB[b] OR (95%CI)	One-time STB[b] OR (95%CI)	Two-time STB[b] OR (95%CI)	One-time STB[b] OR (95%CI)	Two-time STB[b] OR (95%CI)	One-time STB[b] OR (95%CI)	Two-time STB[b] OR (95%CI)
I. Socio-demographic variables										
Being male	1.6 (0.9-3.0)	1.3 (0.7-2.6)	1.7 (0.9-3.3)	1.7 (0.8-3.3)	1.7 (0.8-3.6)	1.5 (0.7-3.3)	1.7 (0.8-3.9)	1.9 (0.7-4.9)	1.7 (0.7-3.9)	2.0 (0.7-6.0)
Age > 18 years	1.4 (0.7-2.7)	**2.6*** (1.3-5.4)	1.5 (0.7-2.9)	**2.5*** (1.2-5.2)	1.5 (0.8-3.2)	**2.4*** (1.1-5.5)	1.5 (0.7-3.2)	2.3 (0.9-5.6)	1.5 (0.6-3.3)	2.3 (0.8-6.7)
Non-Belgian nationality	0.9 (0.3-2.7)	0.6 (0.2-2.2)	0.8 (0.3-2.3)	0.5 (0.1-2.0)	0.7 (0.2-2.4)	0.5 (0.1-2.1)	0.7 (0.2-2.5)	0.5 (0.1-2.8)	0.7 (0.2-2.8)	0.6 (0.1-4.9)
Parents' financial situation difficult	0.9 (0.4-1.8)	0.7 (0.3-1.7)	0.8 (0.4-1.7)	0.6 (0.3-1.6)	0.7 (0.3-1.7)	0.6 (0.2-1.8)	0.7 (0.3-1.8)	0.5 (0.2-1.8)	0.7 (0.3-1.8)	0.5 (0.1-1.8)
Parental education[c]										
- both parents high	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
- only one parent high	1.3 (0.6-2.5)	1.2 (0.6-2.5)	1.3 (0.6-2.6)	1.2 (0.5-2.5)	1.2 (0.6-2.5)	1.1 (0.5-2.6)	1.2 (0.5-2.5)	1.1 (0.4-2.8)	1.2 (0.5-2.7)	0.9 (0.3-2.6)
- none of parents high	1.7 (0.7-4.1)	2.0 (0.8-5.0)	1.7 (0.7-4.2)	2.0 (0.7-5.5)	1.5 (0.6-3.9)	2.0 (0.6-6.4)	1.6 (0.6-4.4)	2.2 (0.6-8.1)	1.8 (0.6-5.1)	3.1 (0.7-14.7)
Non-intact familial composition[d]	1.2 (0.6-2.3)	1.2 (0.6-2.5)	1.2 (0.6-2.4)	1.1 (0.5-2.4)	1.3 (0.6-2.7)	0.9 (0.4-2.2)	1.3 (0.6-3.0)	1.0 (0.4-2.6)	1.3 (0.6-3.0)	1.2 (0.4-3.7)
Non-heterosexual orientation	1.1 (0.4-2.7)	1.6 (0.6-4.3)	0.9 (0.3-2.3)	1.3 (0.4-3.8)	1.0 (0.4-2.7)	1.6 (0.5-4.9)	0.6 (0.2-2.0)	0.7 (0.2-3.2)	0.6 (0.2-2.0)	0.5 (0.1-3.1)
College-related socio-demographics										
University Group membership										
- Human Sciences	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
- Science & Technology	1.0 (0.5-2.0)	0.9 (0.4-1.8)	1.0 (0.5-2.0)	0.9 (0.4-1.8)	1.0 (0.5-2.1)	0.9 (0.4-2.0)	1.0 (0.4-2.1)	1.0 (0.4-2.4)	1.0 (0.5-2.3)	1.1 (0.4-2.9)
- Biomedical Sciences	1.3 (0.6-3.0)	1.3 (0.5-3.2)	1.3 (0.6-3.2)	1.3 (0.5-3.2)	1.3 (0.5-3.3)	1.2 (0.4-3.6)	1.2 (0.5-3.3)	1.2 (0.4-4.1)	1.4 (0.5-3.9)	1.6 (0.4-6.7)
Non-GSE pre-educational level	1.0 (0.3-3.1)	0.6 (0.1-2.6)	0.9 (0.3-3.1)	0.5 (0.1-2.8)	0.9 (0.3-3.2)	0.4 (0.1-2.7)	0.8 (0.2-3.2)	0.4 (0.0-3.2)	0.7 (0.2-3.0)	0.2 (0.0-2.6)
Living with parents	1.2 (0.6-2.2)	0.9 (0.4-1.9)	1.2 (0.6-2.2)	1.0 (0.4-2.2)	1.1 (0.6-2.1)	0.8 (0.3-2.0)	1.1 (0.6-2.4)	0.9 (0.3-2.5)	1.1 (0.5-2.4)	0.8 (0.2-2.8)
II. Traumatic experiences (< age 17)										
parental psychopathology			1.4 (0.7-2.7)	1.6 (0.7-3.5)	1.3 (0.6-2.8)	1.7 (0.7-3.9)	1.4 (0.6-3.0)	1.8 (0.7-4.7)	1.4 (0.6-3.2)	1.9 (0.7-5.6)
physical abuse			1.5 (0.5-4.4)	2.4 (0.8-7.4)	1.2 (0.4-3.9)	2.2 (0.7-7.4)	1.4 (0.4-5.1)	2.7 (0.7-10.8)	1.2 (0.3-4.8)	2.1 (0.5-9.7)
emotional abuse			0.8 (0.4-1.8)	0.9 (0.4-2.1)	0.7 (0.3-1.6)	0.7 (0.3-1.8)	0.6 (0.3-1.5)	0.6 (0.2-1.7)	0.6 (0.2-1.6)	0.6 (0.2-2.0)
sexual abuse			1.6 (0.2-12.3)	5.4 (1.0-30.5)	1.8 (0.2-15.0)	6.3 (0.9-44.2)	2.1 (0.2-19.7)	7.7 (0.9-66.7)	2.2 (0.2-23.1)	8.8 (0.8-96.9)
neglect			1.5 (0.6-4.1)	1.2 (0.4-3.7)	1.3 (0.4-3.7)	0.7 (0.2-2.5)	1.4 (0.4-4.3)	0.8 (0.2-3.4)	1.2 (0.4-4.1)	0.7 (0.1-3.3)
bully victimization			1.2 (0.7-2.3)	1.0 (0.5-2.0)	1.4 (0.7-2.7)	1.1 (0.5-2.3)	1.2 (0.6-2.5)	0.9 (0.4-2.1)	1.3 (0.6-2.7)	1.0 (0.4-2.5)
dating violence			0.9 (0.4-2.4)	0.8 (0.3-2.4)	0.8 (0.3-2.3)	0.6 (0.2-1.9)	0.7 (0.2-2.2)	0.4 (0.1-1.8)	0.6 (0.2-2.0)	0.3 (0.1-1.7)
III. Twelve-month stressful experiences										
life-threatening illness or injury of a friend or family member					0.9 (0.4-1.9)	0.6 (0.2-1.6)	0.8 (0.3-1.9)	0.6 (0.2-1.7)	0.7 (0.3-1.8)	0.5 (0.2-1.9)

death of a friend or family member	1.2 (0.5-2.8)	2.2 (0.8-6.1)	1.2 (0.5-3.0)	2.2 (0.7-6.6)	1.1 (0.4-2.8)	1.8 (0.5-6.2)
break-up with a romantic partner	0.9 (0.4-2.0)	1.0 (0.3-2.7)	0.9 (0.3-2.2)	0.9 (0.3-2.7)	0.9 (0.3-2.3)	0.9 (0.2-3.4)
romantic partner cheated	0.7 (0.2-3.0)	0.5 (0.1-2.6)	0.7 (0.1-3.3)	0.6 (0.1-3.3)	0.6 (0.1-3.2)	0.4 (0.0-3.0)
serious betrayal someone else than partner	1.8 (0.8-3.9)	1.9 (0.8-4.5)	1.4 (0.6-3.4)	1.6 (0.6-4.3)	1.4 (0.6-3.5)	1.7 (0.5-5.6)
serious ongoing arguments/break-up with friend or family	1.1 (0.5-2.4)	1.6 (0.7-3.6)	1.1 (0.5-2.6)	1.8 (0.7-4.6)	1.1 (0.5-2.6)	1.6 (0.5-4.8)
life-threatening accident	7.1	7.1 (0.2-294.6)	6.5	7.1 (0.1-417.8)	7.2	12.0 (0.1-1418)
seriously physically assaulted	3.7 (0.3-50.2)	4.7 (0.2-124.4)	3.3 (0.2-50.3)	4.0 (0.1-133.8)	3.7 (0.2-65.0)	4.3 (0.1-345.2)
sexually assaulted or raped	5.5 (0.6-50.6)	2.2 (0.2-28.6)	4.2 (0.4-46.3)	1.5 (0.1-24.6)	5.5 (0.4-72.2)	0.9 (0.0-36.5)
any serious legal problem	1.0 (0.2-6.2)	3.3 (0.5-23.0)	1.2 (0.2-8.0)	3.3 (0.4-30.6)	1.2 (0.2-9.4)	4.3 (0.3-62.3)
IV. Twelve-month mental disorders						
risk for internalizing disorder			1.0 (0.5-2.1)	0.9 (0.3-2.4)	0.8 (0.4-1.8)	0.5 (0.2-1.6)
risk for externalizing disorder			1.2 (0.5-2.7)	1.0 (0.3-3.0)	1.3 (0.5-3.1)	1.0 (0.3-3.7)
risk for substance use disorder			0.9 (0.2-3.7)	0.9 (0.2-5.2)	1.1 (0.2-4.7)	1.7 (0.2-13.1)
IED item positive			1.4 (0.4-4.3)	1.6 (0.4-6.8)	1.1 (0.3-3.8)	1.2 (0.2-5.7)
(hypo)mania item positive			3.0 (1.0-8.9)	4.2 (0.9-20.0)	3.2 (1.0-10.6)	4.2 (0.7-24.7)
any eating disorder item positive			0.9 (0.3-2.6)	1.2 (0.4-3.9)	0.8 (0.3-2.4)	1.0 (0.3-3.8)
any psychotic item positive			1.0 (0.3-3.6)	0.8 (0.2-3.8)	1.0 (0.3-3.7)	0.8 (0.1-4.8)
non-suicidal self-injury			2.3 (0.7-7.2)	**5.7*** (1.7-18.5)	1.8 (0.5-6.2)	3.6 (0.9-14.9)
V. Severity markers of pre-matriculation STB						
Twelve-month STB at baseline					1.8 (0.7-4.4)	**4.7*** (1.4-15.9)
Pre-matriculation lifetime STB						
- no pre-matriculation suicide plans or attempts (i.e., ideation only)[d]					(ref)	(ref)
- pre-matriculation suicide plans; no attempts					1.7 (0.8-3.6)	2.5 (1.0-6.5)
- pre-matriculation suicide attempts					3.5 (0.7-18.6)	**11.1*** (1.4-87.4)
STB characteristics in worse week of pre-matriculation lifetime STB						
duration STB 4 days or more/week					0.9 (0.4-2.0)	0.7 (0.2-2.0)
duration STB 5 hours or more/day					1.4 (0.3-6.6)	2.2 (0.4-13.5)
control STB very difficult/impossible					1.0 (0.3-3.1)	0.9 (0.2-3.8)
any STB-associated risky behavior					0.8 (0.3-1.8)	0.7 (0.2-2.2)

Course of pre-matriculation lifetime STB		
duration 5 years or more	1.2 (0.5-2.9)	1.5 (0.5-4.9)
remission at college entrance 3 years or less	1.1 (0.4-2.9)	2.0 (0.5-9.1)

Note: significant OR are shown in bold and are marked with * (α=0.05).

[a] The multivariate associations are based on a model including all predictors shown in the corresponding column.

[b] no STB during follow-up is the reference category

[c] High degree of parental education defined as holding a college bachelor degree or more.

[d] Non-intact familial composition defined as parents being divorced or separated.

[e] Students with a pre-matriculation history of ideation but not plans or attempts are the reference category for the 3-category predictor

Abbreviations: STB = GSE = general secondary education; IED = intermittent explosive disorder; OR = Odds ratio; Suicidal Thoughts and Behaviors.

Supplementary eTable 2. Multivariate population-level associations between risk factors under study and adverse clinical patterns of STB during follow-up.

	MULTIVARIATE MODEL 1[a]		MULTIVARIATE MODEL 2[a]		MULTIVARIATE MODEL 3[a]		MULTIVARIATE MODEL 4[a]		MULTIVARIATE MODEL 5[a]	
	Two-time STB[b] PARP	One-time STB[b] PARP	Two-time STB[b] PARP	One-time STB[b] PARP	Two-time STB[b] PARP	Two-time STB[b] PARP	One-time STB[b] PARP	Two-time STB[b] PARP	One-time STB[b] PARP	Two-time STB[b] PARP
I. Socio-demographic variables										
Being male	-3.8	2.6	-3.5	5.2	-3.8	3.4	-3.1	5.3	-3.0	4.5
Age > 18 years	0.7	**12.7***	0.5	**11.6***	0.5	**10.2***	0.7	8.7	0.7	7.4
Non-Belgian nationality	-0.4	-2.6	-0.3	-3.3	-0.3	-3.6	-0.3	-3.5	-0.2	-1.8
Parents' financial situation difficult	0.4	-2.5	0.6	-3.8	0.8	-2.8	0.8	-3.2	0.8	-4.4
Parental education[c]										
- both parents high	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
- only one parent high	-1.2	1.3	-1.1	1.3	-0.9	1.2	-0.7	0.9	-1.0	0.5
- none of parents high	-1.2	4.6	-1.2	4.6	-0.8	3.8	-0.7	3.8	-0.6	4.5
Non-intact familial composition[d]	-0.7	2.3	-0.7	0.3	-1.4	-1.7	-1.5	-1.4	-1.4	-0.6
Non-heterosexual orientation	0.5	4.0	0.8	2.6	0.8	3.4	1.2	-1.1	1.1	-2.2
College-related socio-demographics										
University Group membership										
- Human Sciences	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
- Science & Technology	-0.1	-0.9	-0.1	-1.3	-0.1	-1.2	-0.2	-0.3	-0.3	0.5
- Biomedical Sciences	-0.6	1.6	-0.7	1.4	-0.6	0.9	-0.5	0.5	-0.5	1.4
Non-GSE pre-educational level	-0.7	-3.5	-0.6	-3.5	-0.8	-4.3	-0.7	-4.3	-0.8	-4.5
Living with parents	-1.7	-2.6	-1.2	-1.4	-1.2	-3.4	-1.3	-2.5	-1.3	-2.8
II. Traumatic experiences (< age 17)										
parental psychopathology			-1.6	6.2	-1.6	6.1	-1.7	6.0	-1.6	5.8
physical abuse			0.2	5.6	0.5	4.4	0.4	4.7	0.4	2.6
emotional abuse			1.3	-0.4	1.6	-2.9	1.9	-3.9	1.6	-3.7
sexual abuse			0.2	3.9	0.3	3.7	0.2	3.4	0.2	3.4
neglect			-1.4	0.1	-1.3	-2.5	-1.2	-1.7	-1.3	-2.3
bully victimization			-2.5	-0.5	-2.5	1.2	-2.4	-0.5	-2.7	-0.5
dating violence			-0.1	-1.2	0.0	-2.6	0.2	-3.5	0.3	-3.8
III. Twelve-month stressful experiences										
life-threatening illness or injury of a friend or family member					0.1	-4.7	0.3	-4.0	0.3	-4.2
death of a friend or family member					0.7	7.6	0.7	6.7	0.7	4.2
break-up with a romantic partner					0.4	-0.6	0.2	-1.3	0.2	-0.8
romantic partner cheated					0.3	-1.6	0.3	-1.4	0.2	-2.1
serious betrayal someone else than partner					-2.7	4.0	-2.1	1.8	-2.1	1.6
serious ongoing arguments/break-up with friend or family					0.9	5.5	0.8	6.1	0.8	4.1

life-threatening accident	-0.5	1.0	-0.5	0.8	-0.5	1.0
seriously physically assaulted	-0.4	2.1	-0.3	1.6	-0.3	1.3
sexually assaulted or raped	-0.6	1.1	-0.5	0.8	-0.6	0.3
any serious legal problem	0.7	3.6	0.7	3.4	0.6	2.9
IV. Twelve-month mental disorders						
risk for internalizing disorder			1.0	-0.3	0.7	-5.1
risk for externalizing disorder			-0.9	-0.4	-1.2	-0.3
risk for substance use disorder			0.1	-0.5	0.3	1.2
IED item positive			0.1	3.2	0.2	1.1
(hypo)mania item positive			-2.1	6.0	-2.2	5.3
any eating disorder item positive			0.6	1.3	0.5	-0.8
any psychotic item positive			-0.4	-1.6	-0.4	-1.3
non-suicidal self-injury			-0.2	**8.7***	-0.1	4.9
V. Severity markers of pre-matriculation STB						
Twelve-month STB at baseline					0.5	**12.3***
Pre-matriculation lifetime STB						
- no pre-matriculation suicide plans or attempts (i.e., ideation only)[d]					(ref)	(ref)
- pre-matriculation suicide plans; no attempts					-1.9	7.9
- pre-matriculation suicide attempts					-0.1	**7.2***
STB characteristics in worse week of pre-matriculation lifetime STB						
duration STB 4 days or more/week					-1.0	-3.0
duration STB 5 hours or more/day					0.5	2.4
control STB very difficult/impossible					-0.6	-1.0
any STB-associated risky behavior					1.1	-2.1
Course of pre-matriculation lifetime STB						
duration 5 years or more					0.3	3.6
remission at college entrance 3 years or less					1.1	4.7

Note: significant PARPs are shown in bold and are marked with * (α=0.05).

[a] The multivariate associations are based on a model including all predictors shown in the corresponding column.

[b] no STB during follow-up is the reference category

[c] High degree of parental education defined as holding a college bachelor degree or more.

[d] Non-intact familial composition defined as parents being divorced or separated.

[e] Students with a pre-matriculation history of ideation but not plans or attempts are the reference category for the 3-category predictor

Abbreviations: STB = GSE = general secondary education; IED = intermittent explosive disorder; OR = Odds ratio; Suicidal Thoughts and Behaviors.

Supplementary eTable 3. Model fit statistics and prediction accuracy measures of multivariate prediction models for adverse clinical patterns of STB during follow-up.

	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
	One-time STB	Two-time STB	One-time STB	Two-time STB	One-time STB	Two-time STB	One-time STB	Two-time STB	One-time STB	Two-time STB
Akaike Information Criterion	482.37	459.60	467.36	427.10	441.93	380.37	418.25	333.22	395.37	271.15
Bayes Information Criterion	533.49	510.63	546.00	505.62	559.90	498.14	567.68	482.40	580.19	455.66
Nagelkerke pseudo-R^2 (%)	4.5	10.1	6.9	17.4	11.4	28.0	14.1	37.4	16.9	51.9
Area-under-the-Curve (SE)[a]	0.60 (0.03)	0.66 (0.04)	0.63 (0.03)	0.71 (0.04)	0.67 (0.04)	0.77 (0.03)	0.69 (0.04)	0.81 (0.03)	0.71 (0.03)	0.87 (0.03)
Area-under-the-Curve (SE)[b]	0.50 (0.05)	0.59 (0.05)	0.51 (0.05)	0.64 (0.05)	0.53 (0.05)	0.69 (0.04)	0.53 (0.05)	0.72 (0.04)	0.52 (0.05)	0.79 (0.04)
Sensitivity (SE)[a,c]	16.8 (4.3)	19.5 (4.2)	18.4 (4.5)	23.5 (4.4)	20.8 (4.6)	26.8 (4.5)	21.7 (4.6)	29.4 (4.6)	22.9 (4.6)	32.9 (4.7)
Sensitivity (SE)[b,c]	10.9 (4.5)	15.3 (4.3)	11.4 (4.4)	19.0 (4.5)	12.5 (4.4)	21.6 (4.6)	12.4 (4.3)	23.4 (4.6)	12.0 (4.3)	27.1 (4.6)
Positive Predictive Value (SE)[a,d]	43.2 (9.8)	51.3 (10.2)	47.8 (10.2)	63.1 (10.3)	54.9 (10.4)	72.2 (9.8)	57.6 (10.3)	79.1 (9.1)	60.8 (10.3)	88.3 (7.0)
Positive Predictive Value (SE)[b,d]	28.1 (11.0)	40.4 (11.1)	29.8 (11.1)	51.3 (11.9)	33.1 (11.4)	58.2 (11.7)	33.0 (11.3)	63.2 (11.4)	31.9 (11.5)	73.1 (10.5)

[a] calculated with cross-validated predicted probabilities obtained through leave-one-out cross-validation

[b] calculated with cross-validated predicted probabilities obtained through leave-one-out cross-validation

[c] Sensitivity = Proportion of (high-)persistent STB outcome cases found among the 10% of respondents with highest predicted probabilities.

[d] Positive Predictive Value = Probability of effectively developing (high-)persistent STB when being among the 10% of respondents with highest predicted probabilities.