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Longitudinal development of risk-taking and self-injurious behavior in association with late adolescent borderline personality disorder symptoms

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ABSTRACT

Self-injurious behavior and risk-taking behaviors are associated with adolescent borderline personality disorder (BPD). Developmental trajectories of self-injurious and risk-taking behavior in predicting BPD have not been fully understood. The aim of the present study was to examine self-injurious and risk-taking behavior development and their prospective influence on BPD symptoms in adolescence. Data (n = 506; 62.06 % females, 14.53 years) from the German Saving and Empowering Young Lives in Europe cohort were analyzed. Self-injurious and risk-taking behaviors were assessed at baseline and one-year follow-up. BPD symptoms were assessed at two-year follow-up. In fully adjusted stepwise binominal regression analyses, recent onset, termination and maintenance of risky alcohol use and self-injurious behavior remained as significant predictors of BPD. Highest ORs were found for alcohol termination and maintenance of self-injurious behavior. Other facets of risk-taking behavior were not associated with increased ORs of BPD symptoms at two-year follow-up. These findings highlight the importance of self-injurious behavior and specific facets of risk-taking behavior in the development of adolescent BPD. Clinicians should focus on efforts in preventing adolescents from risk-taking and self-injurious behavior, since engaging in young age and therefore in potentially longer periods of these behaviors is associated with the highest risk of BPD.

1. Introduction

Risk-taking behaviors and self-harming behaviors are frequently occurring phenomena in adolescence (Kaess et al., 2014a,b). The term "deliberate self-harm" (DSH) serves as an umbrella term for a range of different self-damaging behaviors regardless of their suicidal intent; for example, non-suicidal self-injury (NSSI), suicide attempts, and self-injurious behavior. Risk-taking behaviors are defined as behaviors that may inflict on adolescents' physical wellbeing and psychosocial functioning and include a wide range of behaviors, including substance use, excessive media use, and promiscuity (Jessor, 2007). It has been reported that in addition to being a "normative" complex of behaviors in the general adolescent population, risk-taking behavior is associated with a range of psychological problems (Carli et al., 2014). Risk-taking behavior could thus be a marker for early identification of vulnerability to develop psychiatric disorders in adolescence (King et al., 2001). Self-injurious behavior is defined as the intentional act of direct deliberate destruction of one's own body tissue, including both nonsuicidal and suicidal self-injury (Brunner et al., 2014). Numerous population-based studies have shown that self-injurious behavior is often a transient

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phenomenon in adolescence that substantially decreases towards young adulthood (Moran et al., 2012), although a second peak of onset around the age of 20 to 24 was recently reported (Gandhi et al., 2018). Research based on non-clinical samples has shown that self-injurious behavior and NSSI are associated with other risk-taking behaviors among adolescents (Moran et al., 2015). Engagement in both self-injurious and risk-taking behaviors at the same time is known to be associated with higher psychopathology, e.g. suicidality (Turner et al., 2013). Self-injurious behavior and risk-taking behavior (e.g., substance use) are known to serve similar functions, such as regulating negative emotions like sadness, anger or emptiness and interpersonal aspects such as avoiding social rejection, both in clinical and non-clinical samples (Klonsky, 2007; Chapman et al., 2006). Further, self-injurious behavior was reported helpful in ending dissociation, avoiding the impulse to commit suicide and to generate exhilaration and excitement (Klonsky, 2007). Sensation seeking is also particularly known to be associated with adolescent risk-taking behavior (Charles et al., 2017). However, regulation of emotional internal states is the most important function of self-injurious behavior in adolescence (Jacobson and Gould, 2007). Even though the long-term negative effects of self-injurious behavior are known, the affective and socially reinforcing aspects of self-injurious behavior in the short-term – similar to risk-taking behavior – influence adolescents' temporary experience of distress (Zetterqvist, 2017). Acute symptoms of affective and behavioral dysregulation, primarily self-injurious behavior and risk-taking behaviors are diagnostic core features of adolescent borderline personality disorder (BPD) (Kaess et al., 2014a). Empirical evidence based on community samples of adolescents and adults shows that the presence and greater frequency of NSSI is associated with the endorsement of more BPD symptoms (Cerutti et al., 2011; Klonsky et al., 2003). Further, in the context of functions of NSSI, Vega et al. (2017) reported differential relationships between NSSI functions and specific BPD features (i.e. interpersonal functions of NSSI were associated to the BPD symptom of disturbed relatedness, whereas intrapersonal functions were associated with affective dysregulation in BPD). Adolescents with BPD engage in NSSI at an earlier age and report a longer history of NSSI compared to adolescents without BPD (Groschwitz et al., 2015). BPD symptoms in young adults are best predicted by continued engagement in NSSI over a 1-year period (Glenn and Klonsky, 2011).

These findings highlight the important role of the course of NSSI as a potential early risk marker for the development of BPD (Kaess et al., 2014a). Considering the role of risk-taking behavior in the development of BPD, there is empirical evidence that adolescent alcohol use predicts BPD symptoms in later life (Thatcher et al., 2005) and vice versa (Scalzo et al., 2017). Lazarus et al. (2016) assessed year-to-year changes in alcohol use and BPD symptoms in a large adolescent community sample and found that higher use of alcohol during the past year was associated with greater endorsement of BPD symptoms. The results remained significant even after controlling for comorbid psychopathology. In contrast to these results, Greenfield et al. (2015) found that substance use at the age of 14 (and older) was not a significant predictor of BPD at a 4-year follow-up. The authors interpreted their controversial findings in terms of an overrepresentation of risk-taking behavior among adolescents. Nakar et al. (2016) showed that while self-injurious behavior and suicidal behavior decrease during the course of adolescence, substance misuse increases in the same individuals, suggesting a symptom shift over time. Again, BPD symptoms were more common in affected individuals showing these shifting trajectories.

1.1. Aims of the study

Although the relationship between self-injurious behavior and BPD in adolescence has been well described (Groschwitz et al., 2015; Nakar et al., 2016), to the best of our knowledge, no longitudinal study has addressed changes of risk-taking behavior and self-injurious behavior and their predictive value for the development of BPD in adolescents. Identifying trajectories of self-injurious behavior and risk-taking behavior that might foster the development of BPD is important to enable prevention and intervention. Therefore, the aim of the present study was to address different courses of self-injurious behavior and risk-taking behavior as predictors of BPD symptoms in late adolescence in a two-year longitudinal study. The study further aimed to clarify the specificity of risk-taking behaviors and self-injurious behavior in predicting BPD.

2. Methods

2.1. General and sampling procedures

Data for the present analyses were drawn from the German cohort of the *Saving and Empowering Young Lives in Europe* (SEYLE) study, as well as its subsequent follow-up assessments. Details on the SEYLE study have been published elsewhere (Carli et al., 2013; Wasserman et al., 2010, 2015). SEYLE was approved by each national ethics committee and registered in the German Clinical Trials Registry (DRKS00000214). In Germany, a nationally representative sample of adolescents aged 13–17 years was recruited from randomly selected schools in the Heidelberg and Rhein-Neckar districts. The sampling procedures have been described in detail elsewhere (Carli et al., 2013). Informed and written consent was provided by both adolescents and their caregivers prior to inclusion in the study. A total of 1444 adolescents (mean age at baseline, 14.7 years; 52.1% female) participated in the baseline assessment, of which 1202 students (mean age, 15.6 years; 54.3% female) completed the one-year follow-up assessment. Baseline and one-year follow-up were school-based assessments using paper-and-pencil questionnaires. Of these 1202 students only 515 students (mean age, 16.6 years; 62.0% female) were available for a two-year follow-up as many students had finished school at the time of the last assessment or did not give consent for further research participation at baseline. The third and final assessment (two-year follow-up), conducted in January 2012, was carried out in Germany only. Assessment of BPD was conducted through an online-based self-report questionnaire or in some cases using a postal paper-pencil version. Diagnostic phone based interviews were conducted in a smaller sub-sample of these students. The current analyses focus solely on the self-report data. Only participants with completed data on self-injurious behavior (baseline and one-year follow-up), risk-taking behaviors (baseline and one-year follow-up), and complete data on all included covariates (baseline) were included (n = 506).

2.2. Adolescent measures

The German version of the *Structured Clinical Interview for DSM-IV-Axis II (SCID-II) Questionnaire* was used to assess BPD symptoms (Fydrich et al., 1997). Self-injurious behavior was assessed at baseline and one-year follow-up and measured by a modified version of the *Deliberate Self-Harm Inventory* (DSHI) (Gratz, 2001), as previously described elsewhere (Kaess et al., 2014a). In addition to self-injurious behavior, four domains of risk-taking behavior were assessed at baseline and one-year follow-up, including *alcohol consumption, drug use, smoking* (tobacco), and *excessive media use*. Single items for the respective assessment of domains were mainly taken from the *Global School-Based Student Health Survey* (GSHS; World Health Organization, 2009). Cut-offs to distinguish adolescents engaging in self-injurious behavior and risk-taking behavior on each domain were established during a consensus conference among the steering group and several child and adolescent psychiatrists and psychologists within the SEYLE consortium (Kaess et al., 2014a). A detailed description of the assessment of self-injurious behavior and risk-taking behaviors used for the statistical analyses and respective risk cut-offs is provided in Table 1. The total score of the *Strengths and Difficulties Questionnaire* (SDQ) was used to measure emotional and behavioral problems at

Table 1
Operationalization of self-injurious behavior and risk-taking behavior and respective cut-offs at baseline and one-year follow-up.

Domain	Question/Item	Response	Risk cut-off
Self-injurious behavior	Times in life of intentionally cutting, burning, scratching oneself, head banging, preventing wounds from healing and required medical treatment	a) never **b) once or twice**[a] **c) 3–4 times** **d) at least 5 times**	≥1 act of SIB
Alcohol	Times in life when drinking so much that really drunk? Times in life when had hangover from drinking?	a) never b) once or twice **c) 3–9 times**[a] **d) 10 or more times**	≥3 (any response: c or d)
Drugs	Times in life when used drugs	a) never b) once or twice **c) 3–9 times**[a] **d) 10 or more times**	≥ 3 (response: c or d)
Smoking (tobacco)	Cigarettes per day during last 6 months	continuous	≥ 2
Media	Typical time watching TV, playing PC or surfing on the Internet	a) less than 1 h per day b) 1–2 h per day c) 3–4 h per day **d) 5–6h per day**[a] **e) 7–8h per day** **f) more than 8h per day**	≥5 h (response: d–f)

[a] Risk cut-offs are represented in bold and define categories of risk-taking and self-injurious behavior with regards to content.

baseline (Goodman, 1997). Satisfactory internal consistency was reported for the total SDQ score with α = 0.72 – 0.84 in adolescent community samples (Muris et al., 2003; Malmberg et al., 2003; Van Roy et al., 2008), similar to Cronbach's α = 0.76 in the present sample.

2.3. Statistical analysis

Based on self-reports of self-injurious behavior and risk-taking behavior at baseline and one-year follow-up, the sample was split into four groups for self-injurious behavior and risk-taking behavior, respectively. Groups were formed distinguishing those not reporting self-injurious behavior at baseline or one-year follow-up (baseline and one-year follow-up: zero acts of self-injurious behavior; trajectory: never) and those falling below risk cut-offs for alcohol (<3 times really drunk or hungover), smoking (<2 cigarettes per day), drugs (<3 times in life), and media (<5 h per day) at baseline and one-year follow-up (trajectories: never); not reporting self-injurious behavior and falling below risk-taking behavior cut-off criteria at baseline but not at one-year follow-up (trajectories: onset); exceeding cut-off criteria for self-injurious behavior and/or risk-taking behavior at baseline but not at one-year follow-up (trajectories: termination); and those exceeding cut-off criteria for self-injurious behavior and risk-taking behavior at both baseline and one-year follow-up (trajectories: maintenance). The forming of the groups and study procedure is illustrated in Fig. 1.

Changes in risk-taking behaviors and self-injurious behavior from baseline to one-year follow-up were assessed using McNemar's chi-square (χ^2) for dichotomous variables (yes/no on self-injurious behavior and on domains of risk-taking behavior). Due to skewness of data, binominal regression analyses were conducted to investigate the predictive value of self-injurious behavior and risk-taking behavior trajectories on BPD symptoms at two-year follow-up. In the first step, we calculated unadjusted models for single trajectories of self-injurious behavior and risk-taking behaviors as the only predictor *(model 1)*. Subsequently, binominal stepwise regression analyses were calculated in order to remove predictors that did not explain significant variance to the model *(model 2)*. In the final step, the model was fully adjusted for age, sex, school type, and psychopathology (assessed via summary score of the SDQ) at baseline, controlling for individual levels of self-injurious behavior and risk-taking behavior at the first assessment *(model 3)*. Bonferroni–Holms method was used to correct *p*-values. Odds ratios (ORs) with 95% confidence intervals (CIs) for BPD at two-year follow-up were calculated. All analyses were performed using Stata/SE (Version 15.0; StataCorp LP, College Station, TX, US).

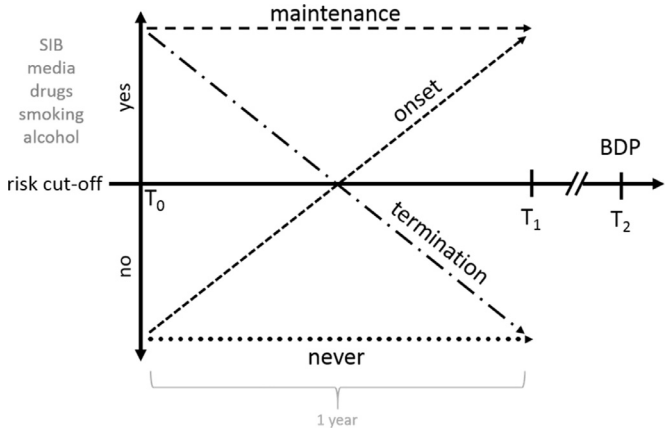

Fig. 1. Forming of the groups based on 4 trajectories of risk-taking behavior and self-injurious behavior (SIB) between baseline and one-year follow-up.

3. Results

3.1. Descriptive analyses

Mean age at baseline was 14.53 years (*SD* = 0.03; 62.1 % female); at one-year follow-up, it was 15.52 years (*SD* = 0.03), and at the time of online-based self-report (two-year follow-up), it was 17.12 years (*SD* = 0.03). *N* = 250 (49.4%) adolescents attended Gymnasium (8 years after primary school and general university entrance qualification), *n* = 161 (31.8%) Realschule (intermediate secondary school which takes 6 years after primary school) and *n* = 95 (18.8%) attended Hauptschule (secondary general school which takes 5 years after primary school). Among the participants, 59.1% (*n* = 299) had never engaged in self-injurious behavior at baseline or one-year follow-up, and most did not meet the risk cut-off criteria for risky alcohol use (*n* = 308, 60.9%), substance use (*n* = 472, 93.3%) or smoking (*n* = 382, 75.5%). 78.85% (*n* = 399), never used media for less than 5 h per day. Mean score in the SDQ was 11.38 (*SD* = 0.23) at baseline for the entire sample. The mean number of BPD criteria at two-year follow-up was 3.62 (*SD* = 0.10; range = 0–9). 160 adolescents met more than 5 criteria in the SCID II questionnaire. 3–4 criteria were met

Table 2
Sample characteristics for each developmental trajectory at baseline.

	Never	Onset	Termination	Maintenance	*p*
Self-injurious behavior					
n (%)	299 (59.09)	41 (8.10)	75 (14.82)	91 (17.98)	
Females, *n (%)*	166 (55.52)	19 (46.34)	53 (70.67)	76 (83.52)	*<0.001*
Age, mean years (SD)	14.51 (0.68)	14.58 (0.77)	14.45 (0.64)	14.58 (0.86)	*0.644*
Schooltype, *n (%)*					*<0.001*
Hauptschule	37 (12.37)	12 (29.27)	22 (29.33)	24 (26.37)	
Realschule	87 (29.10)	16 (39.02)	17 (22.67)	41 (45.05)	
Gymnasium	175 (58.53)	13 (31.71)	36 (48.00)	26 (28.57)	
Number BPD criteria, mean (SD)	2.89 (1.92)	4.07 (2.40)	4.24 (1.92)	5.31 (2.13)	*<0.001*
SDQ, mean (SD)	9.76 (4.81)	11.00 (3.98)	12.93 (3.71)	15.58 (5.17)	*<0.001*
Alcohol					
n (%)	308 (60.87)	128 (25.30)	15 (2.96)	55 (10.87)	
Females, *n (%)*	201 (65.26)	71 (55.47)	10 (66.67)	32 (58.18)	*0.242*
Age, mean years (SD)	14.45 (0.67)	14.48 (0.70)	15.00 (0.85)	14.89 (0.85)	*<0.001*
Schooltype, *n (%)*					*0.003*
Hauptschule	59 (19.16)	21 (16.41)	5 (33.33)	10 (18.18)	
Realschule	97 (31.49)	31 (24.22)	9 (60.00)	24 (43.64)	
Gymnasium	152 (49.35)	76 (59.389	1 (6.67)	21 (38.18)	
Number BPD criteria, mean (SD)	3.32 (2.20)	3.80 (2.10)	4.73 (2.19)	4.56 (2.15)	*<0.001*
SDQ, mean (SD)	11.22 (5.19)	10.90 (5.31)	11.80 (3.65)	13.25 (4.86)	*0.033*
Drugs					
n (%)	472 (93.28)	19 (3.75)	13 (2.57)	2 (0.40)	
Females, *n (%)*	300 (63.56)	8 (42.11)	5 (38.46)	1 (50.00)	*0.076*
Age, mean years (SD)	14.48 (0.67)	15.00 (1.05)	15.31 (1.03)	14.50 (0.71)	*<0.001*
Schooltype, *n (%)*					*0.076*
Hauptschule	89 (18.86)	3 (15.79)	2 (15.38)	1 (50.00)	
Realschule	147 (31.14)	6 (31.58)	8 (61.54)	0 (0.00)	
Gymnasium	236 (50.00)	10 (52.63)	3 (23.08)	1 (50.00)	
Number BPD criteria, mean (SD)	3.57 (2.19)	4.47 (2.44)	4.08 (2.66)	3.50 (0.71)	*0.306*
SDQ, mean (SD)	11.28 (5.11)	11.89 (6.58)	13.69 (5.19)	13.00 (2.83)	*0.372*
Cigarettes					
n (%)	382 (75.49)	32 (6.32)	32 (6.32)	60 (11.86)	
Females, *n (%)*	228 (59.69)	23 (71.88)	20 (62.50)	43 (71.67)	*0.205*
Age, mean years (SD)	14.47 (0.63)	14.31 (0.82)	14.53 (0.67)	14.95 (1.03)	*<0.001*
Schooltype, *n (%)*					*<0.001*
Hauptschule	48 (12.57)	11 (34.38)	9 (28.13)	27 (45.00)	
Realschule	112 (29.32)	12 (37.50)	12 (37.50)	25 (41.67)	
Gymnasium	222 (58.12)	9 (28.13)	11 (34.38)	8 (13.33)	
Number BPD criteria, mean (SD)	3.25 (2.03)	4.84 (2.53)	4.25 (1.93)	4.98 (2.47)	*<0.001*
SDQ, mean (SD)	10.70 (4.81)	12.93 (5.63)	12.56 (5.14)	14.18 (6.02)	*<0.001*
Media					
n (%)	399 (78.85)	50 (9.88)	32 (6.32)	25 (4.94)	
Females, *n (%)*	263 (65.91)	25 (50.00)	14 (43.75)	12 (48.00)	*0.007*
Age, mean years (SD)	14.51 (0.70)	14.62 (0.81)	14.72 (0.85)	14.24 (0.60)	*0.0.64*
Schooltype, *n (%)*					*<0.001*
Hauptschule	33 (13.36)	5 (35.71)	36 (19.57)	21 (34.43)	
Realschule	68 (27.53)	6 (42.86)	63 (34.24)	24 (39.34)	
Gymnasium	146 (59.11)	3 (21.43)	85 (46.20)	16 (26.23)	
Number BPD criteria, mean (SD)	3.46 (2.21)	4.38 (2.47)	4.03 (1.77)	4.04 (1.86)	*0.018*
SDQ, mean (SD)	10.85 (5.00)	13.94 (6.31)	12.63 (4.02)	13.00 (5.00)	*<0.001*

Schooltype: after 4 years of elementary school the German school system divides into three types of secondary schools: 'Hauptschule' (secondary general school which takes 5 years after primary school), 'Realschule' (intermediate secondary school which takes 6 years). 'Gymnasium' (provides general university entrance qualification after 8 years of school).
BPD borderline personality disorder.
SDQ strengths and difficulties questionnaire.

by 166 adolescents. Detailed descriptive statistics on adolescents' risk-taking behavior and self-injurious behavior by trajectory group are provided in Table 2. Since data were derived from an intervention study, it was tested if the intervention arm had any impact on the findings. However, when the intervention arm was included in the following regression models the intervention arm had no predictive value.

3.2. Unadjusted models for single trajectories

In unadjusted binominal regression analyses *(model 1)* all trajectory pathways (onset, termination and maintenance) for risky alcohol and cigarette use and for engagement in self-injurious behavior resulted in significantly increased ORs for BPD. The greatest ORs for the development of BPD symptoms at two-year follow-up were found for maintenance of both self-injurious behavior and smoking and for termination and maintenance of alcohol use. Maintenance of self-injurious behavior was associated with the greatest OR for BPD symptoms at two-year follow-up with OR = 3.04 ($p < 0.001$). Results for self-injurious behavior trajectories were replicable even after excluding criterion 5 (self-injurious and suicidal behavior) out of total number of BPD criteria. Highest ORs were then found for maintenance of smoking (OR = 2.20, $p < 0.001$), termination of alcohol use (OR = 1.90, $p < 0.001$) and maintenance of alcohol use (OR = 1.76, $p < 0.001$). Only onset of substance use yielded a significant OR = 1.50 ($p < 0.05$), as well as onset (OR = 1.52, $p < 0.001$) of high media consumption. A more comprehensive overview of ORs for self-injurious behavior and risk-taking behaviors is provided in Table 3.

Table 3
Unadjusted odd-ratios for BPD symptoms at two-year follow-up based on trajectory groups.

	OR	SE	Lower CI	Upper CI	P*
Self-injurious behavior**					
Onset	1.75	0.20	1.40	2.18	*0.000*
Termination	1.89	0.17	1.59	2.24	*0.000*
Maintenance	3.04	0.25	2.59	3.58	*0.000*
Alcohol					
Onset	1.25	0.09	1.09	1.44	*0.012*
Termination	1.90	0.34	1.34	2.69	*0.000*
Maintenance	1.76	0.17	1.45	2.14	*0.000*
Drugs					
Onset	1.50	0.23	1.10	2.04	*0.045*
Termination	1.26	0.24	0.87	1.82	*0.444*
Maintenance	0.97	0.47	0.37	2.50	*0.945*
Smoking					
Onset	2.06	0.25	1.62	2.63	*0.000*
Termination	1.58	0.20	1.24	2.02	*0.000*
Maintenance	2.20	0.21	1.83	2.64	*0.000*
Media					
Onset	1.52	0.15	1.24	1.84	*0.000*
Termination	1.30	0.16	1.02	1.65	*0.140*
Maintenance	1.30	0.18	0.99	1.71	*0.171*

Reference group 'never' with respective cut-offs for each risk-taking behavior and self-injurious behavior visible in *Table 1*; CI 95% confidence interval

* Bonferroni–Holms corrected *p*-values.

** ORs for self-injurious behavior onset and self-injurious behavior maintenance remain significant even after adjusting for overlap between predictor and outcome variable (criteria 5 of BPD diagnosis).

3.3. Stepwise binominal regression and adjusted model

In a stepwise binominal regression *(model 2)* analysis only self-injurious behavior and smoking (onset, termination and maintenance) remained as significant predictors of BPD symptoms. Finally, when further adjusting for age, sex, school type, and psychopathology *(model 3)* smoking was removed from the model and replaced by alcohol. Highest risk for BPD was found for self-injurious behavior maintenance (OR = 1.75, $p < 0.001$). In the alcohol group, termination of risky alcohol use was associated with the highest OR for BPD (OR = 1.67, $p = 0.01$). Further, female sex (OR = 1.43, $p = 0.001$) and psychopathology (OR = 1.08, $p < 0.001$) were associated with BPD at two-year follow-up. A more detailed overview of the ORs for the fully adjusted model is given in Table 4.

4. Discussion

The aim of the present study was to address intra-individual trajectories in risk-taking behavior and self-injurious behavior over 1 year and their associated OR of meeting BPD criteria 1 year later. First of all, unadjusted analyses showed that engagement in all investigated forms of risk-taking behavior and self-injurious behavior were significantly associated with a greater OR of showing BPD symptoms 1 year later. In stepwise regression analyses, however, only self-injurious behavior and smoking trajectories were kept in the model. When further adjusting the analyses for sex, school type, age, and psychopathology, only self-injurious behavior and alcohol trajectories, psychopathology at baseline, and female sex accounted for the best model. Importantly, maintenance of self-injurious behavior was associated with the highest ORs in all 3 models.

Table 4
Fully adjusted odd-ratios for BPD symptoms at two-year follow-up based on trajectory groups.

	OR	SE	Lower CI	Upper CI	P*
Self-injurious behavior					
Onset	1.57	0.18	1.25	1.98	*0.000*
Termination	1.39	0.13	1.16	1.67	*0.000*
Maintenance	1.75	0.16	1.46	2.10	*0.000*
Alcohol					
Onset	1.29	0.07	1.12	1.50	*0.003*
Termination	1.67	0.31	1.17	2.39	*0.010*
Maintenance	1.31	0.14	1.07	1.62	*0.010*
Sex	1.43	0.10	1.25	1.64	*0.000*
SDQ, total	1.08	0.01	1.06	1.09	*0.000*

Reference group 'never' with respective cut-offs for each risk-taking behavior and self-injurious behavior visible in *Table 1*; CI 95% confidence interval.

* Bonferroni–Holms corrected *p*-values.

First of all, results in all conducted models indicate that as soon as an adolescent engages in self-injurious behavior and risk-taking behavior the risk of BPD features later in life increases, a finding supported by empirical evidence (Glenn and Klonsky, 2011; Lazarus et al., 2016).

Results of both unadjusted and adjusted models highlight the particular importance of self-injurious behavior in adolescence. The results are in line with recent findings that NSSI (especially recurrent NSSI) in early adolescence is a risk marker for the incidence of mental illness (Wilkinson et al., 2018). Most interestingly, prior studies, reporting a strong association between self-injurious behavior and BPD (Kaess et al., 2014a), suggest that self-injurious behavior may be the most important predictor of adolescent BPD (Glenn and Klonsky, 2011). In particular, the present results confirm a previous study that found maintenance of self-injurious behavior to be the best predictor of adult BPD five to ten years later (Groschwitz et al., 2015). Consistent with our findings, Wilkinson et al. (2018) showed that both recurrent and sporadic NSSI, are important predictors for an increased risk of mental illness (in their study depression and anxiety) in adolescents. Unlike Wilkinson et al. (2018) we did not distinguish between sporadic and recurrent self-injurious behavior, but defined a risk-cut off ≥ 1. Since we did not assess the frequency of self-injurious behavior dimensionally we were not able to report on simple correlations. However, when comparing the self-harm group with the no self-harm group the mean number of BPD symptoms was 3.16 (CI 2.96–3.36) compared to 4.92 (CI 4.53–5.32). Empirical evidence based on community samples of adolescents and adults suggests that the presence and frequency of NSSI is associated with greater BPD symptoms (Brickman et al., 2014; Cerutti et al., 2011; Klonsky et al., 2003; Vega et al., 2017). It is known that single or occasional self-injurious behavior is related to psychosocial problems, similar to repetitive self- injurious behavior (Brunner et al., 2014, 2007). Similarly, as Wilkinson et al. (2018) mention in their limitations section, they were unable to conclude that recurrent NSSI has a stronger effect on mental health compared to sporadic NSSI. Therefore, a low-threshold cut-off for self-injurious behavior is crucial as risk marker for a wide range of psychiatric disorders including BPD. Studies show that while self-harm in adolescences decreases, misuse of tobacco, alcohol and illegal substances increases (Nakar et al., 2016) and that these adolescents are at increased risk of severe substance use in later life (Moran et al., 2015). Consistent to our results for alcohol trajectories in model 1 and 2, a study by Lazarus et al. (2016) found that adolescent alcohol use, persistent for 1 year, was associated with adolescents' concurrent BPD symptoms. In model 1 termination of alcohol was associated with the highest OR for BPD at two-year follow-up. However, all alcohol user groups (onset, maintenance and termination) were significantly associated with BPD symptoms at two-year follow-up. Post-hoc contrasts revealed that the alcohol termination group (similar to the maintenance and onset groups) significantly differed from the no-risk group. There was no difference in contrasts between onset, maintenance and termination, showing that as soon as an adolescent engages in excessive alcohol use – independent from terminating this specific behavior at some point – the risk for BPD symptoms increases. Termination in that specific time frame implies an earlier onset which might account for these findings. Alcohol is often involved in self-harm acts and associated with higher risk of mental illness (Larkin et al., 2017) and predicts self-harming behavior in adolescence (Tuisku et al.,

2012). Therefore symptom shifts from one impulsive behavior to another (e.g. disordered eating, frequent ruptures in interpersonal relationships etc.) are very likely (Turner et al., 2015). Further research on this topic is needed to better understand the underlying mechanisms and interaction between forms of risk-taking behaviors and self-injurious behavior that may place adolescents at risk for BPD and poor psychosocial outcomes.

Considering smoking habits, our results are in line with studies showing an association between poor physical health aspects including smoking and BPD diagnosis (Frankenburg and Zanarini, 2004). These findings emphasize that smoking is a risk-taking behavior with serious long-term consequences but distinguish smoking from more impulsive and less stable forms of risk-taking behaviors like binge drinking and substance abuse in adolescence. Underlying theories such as the *gateway theory* state that socially "accepted" risk-taking behaviors like smoking may progress into alcohol (Chen et al., 2002) or other illicit substance abuse (Fergusson et al., 2006). With respect to the present results, regular smoking in young adolescence might increase the associated risk for alcohol and substance use in later life. These behaviors in turn could be directly associated with self-injurious behavior and emotional dysregulation that are more specifically linked to BPD symptomatology. This could explain why smoking and media consumption were no longer associated as predictors for BPD symptoms at two-year follow-up in the final model.

Drug onset was associated with 1.5-fold increased OR ($p < 0.01$) for BPD symptoms at two-year follow-up. However, this finding is somewhat counterintuitive considering that termination and maintenance of substance use yielded no significant ORs. Therefore, the finding might be due to random effects in the context of a small cell size for the respective trajectory group and should be interpreted with caution. Nonetheless, the findings may also indicate that early engagement in substance use may point to a potential risk of BPD development, irrespectively of the trajectory of this behavior.

Interestingly, meeting BPD criteria in those with a history of self-injurious behavior and alcohol was not just driven by psychopathological distress or female sex. However, both psychopathology and sex were independently associated with significantly increased OR of BPD symptoms 1 year later in the final model. Regarding the level of psychopathology, the mean SDQ total score of 11.38 in our student sample is consistent with other population-based studies in Europe (Rønning et al., 2004; Van Roy, Grøholt et al., 2006). Van Roy et al. (2006) reported an almost equal total mean score between 10.8 and 11.3 from early to late adolescence.

Since adverse childhood experiences are highly associated with elevated risk of BDP later in life (Zanarini et al., 2002), it is likely that underlying predispositions and psychological vulnerabilities are already present in those with elevated symptoms at baseline. Internalizing and externalizing problems in childhood are known precursors of suicidal behavior and BPD (Brezo et al., 2006; Laporte et al., 2011). Further, it is possible that adolescents who start engaging in self-injurious behavior and alcohol use developed psychopathology from baseline to one-year follow-up. Further, female sex was significantly associated with higher risk for BPD development. This finding is also known in the context of other psychiatric disorders, such as depression and post-traumatic stress disorders (Brewin et al., 2000; Galambos et al., 2004), presumably because women more often tend to present with internalizing symptoms.

Our study has several limitations. First, it is based on self-reports of self-injurious behavior, risk-taking behavior and BPD from a school-based sample. Improvement of assessment validity could have been achieved by combing self-report measures and external assessments, such as clinical interviews. Concerning BPD symptomatology $n = 160$ (31.6%) adolescents endorsed more than 5 BPD criteria in the SCID-II questionnaire. Prevalence rates of 0.9% (Lewinsohn et al., 1997) to 3% (Bernstein et al., 1993) among teenagers in community samples have been reported, with greater prevalence rates up to 14% (Chabrol et al., 2001) if lower thresholds are used. Similar, high prevalence rates of BPD around approximately 30% were only found in clinical samples of adolescents (Ha et al., 2014; Glenn and Klonsky, 2013). Therefore, the prevalence rate in our non-clinical sample seems to be over-representative, potentially due to loss of diagnostic accuracy within the self-report measure and should be emphasized as a clear limitation of the study. Since diagnostic BPD interviews were only assessed in a small non-representative sub-sample, we did not use these data. Second, as self-harming and suicidal behaviors as well as impulsive behavior are part of the diagnostic entity of BPD, there is a conceptual overlap between predictor and outcome variables. However, ORs for self-injurious behavior remained significant even after statistical adjustment for overlap between predictor and outcome variable. It is important to note that both were not assessed at the same time within a longitudinal design reducing the risk of overlap. Further, the study was based on a non-clinical sample, which makes it difficult to generalize the present results to (clinical) adolescents with full BPD symptomatology. Attrition rate from baseline to two-year follow-up is also a limitation of this study, which may be inherent in the community-based nature of the adolescent sample. We did not specify psychopathology in terms of diagnoses through more specific self-report measures or diagnostic interviews. Therefore, conclusions regarding the predictive influence of discrete psychiatric disorders (e.g., depression or anxiety) concerning risk-taking and self-injurious behavior cannot be made. Analyzing the relationship between self-injurious behavior and other forms of personality disorders would moreover be an interesting avenue for future research. Finally, our data were drawn from an intervention study. However, when controlling for potential intervention effect, we found no effect on our findings.

To conclude, adolescents engaging particularly in self-injurious behavior and risky alcohol use form a specific high-risk group for the development of BPD. Since BPD and even subthreshold BPD is associated with severe psychosocial impairments and problems in health-related quality of life (Kaess et al., 2017; Zanarini et al., 2010), early detection of BPD symptoms is crucial in order to provide early intervention. For the early detection of adolescent BPD symptoms, risk markers such as self-injurious and risk-taking behavior seem to be of great clinical value. Particularly, the course of self-injurious behavior should be used as an important risk marker in the prediction of BPD, as demonstrated by the present findings. Clinicians should especially focus on preventive efforts to keep adolescents from engaging in self-injurious behavior and risky alcohol use since 1 act of engagement carries prognostic influence. Yet, maintenance of self-injurious behavior is associated with the highest OR, therefore specific interventions to reduce the time of engagement in self-injurious behavior are needed.

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Declaration of interest

The authors were independent of the funders in all aspects of study design, data analysis, and writing of this manuscript and have no conflict of interest to declare.

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