NEW RESEARCH

Check for updates

Which Psychosocial Risks Are Necessary for Developing Depression During Adolescence? A Novel Approach Applying Necessary Condition Analysis

Igor Marchetti[a,*], PhD, PsyD, Ernst H.W. Koster[b], PhD, Benjamin L. Hankin[c], PhD

Objective: Although many factors predict adolescent depression, risks that operate as necessary conditions (ie, absence of the factor conveys absence of the outcome) have been largely unexplored. This study aimed to evaluate which psychosocial risk factors might serve as necessary conditions for future onset of depression across adolescence.

Method: At baseline, cognitive and personality risks, symptom severity, stressful events, and past depression history were assessed among 382 adolescents (225 girls; mean age = 12.6), who were then followed over 2 years with repeated diagnostic interviews to ascertain depression onset. An innovative statistical approach in mental health research, necessary condition analysis, was applied.

Results: Baseline rumination ($d = 0.50$), stressful events ($d = 0.37$), depressive symptoms ($d = 0.23$), and self-criticism ($d = 0.35$) all emerged as significant necessary conditions for adolescents to be diagnosed with a depressive disorder over the subsequent 24 months. Overall, 13.5% of the sample did not show all the necessary conditions (ie, they lacked 1 or more conditions) and were therefore virtually immune from experiencing 1 or more major depressive episodes over the follow-up, and 65.5% did not meet all those conditions for experiencing 3 or more major depressive episodes (ie, recurrent depression).

Conclusion: These findings can inform future theory building and testing as well as clinical applications via screening of necessary risk to future pediatric depression so that youth who may most benefit from effective interventions can be identified.

Plain language summary: This longitudinal study explored which factors are necessary (but not sufficient) for adolescents to develop depression. Authors analyzed data from 382 adolescents over two years and found rumination, stressful events, depressive symptoms, and self-criticism to be necessary for depression to occur. Only 13.5% of participants did not report all of these "necessary" factors and were nearly immune to developing one or more major depressive episodes (MDEs) over the follow-up. Conversely, 86.5% of the participants possessed all the necessary conditions for developing a major depressive disorder with 13.2% of these participants experiencing 1 or more MDEs over the 2-year follow-up.

Study preregistration information: The Necessary Conditions for Depressive Symptoms and Major Depression in Adolescence; https://osf.io/b5ced.

Diversity & Inclusion Statement: We worked to ensure race, ethnic, and/or other types of diversity in the recruitment of human participants. We worked to ensure sex and gender balance in the recruitment of human participants. One or more of the authors of this paper self-identifies as a member of one or more historically underrepresented sexual and/or gender groups in science.

Key words: adolescence; depression; necessary condition; risk factor

J Am Acad Child Adolesc Psychiatry 2025;64(10):1201-1209.

Overwhelming data highlight the high burden; morbidity; and economic, societal, and personal costs of major depressive disorder.[1] Adolescence represents a developmental period of elevated susceptibility to depression, especially first episodes that enhance the likelihood for depression recurrences later in life. Rates of depression surge considerably from mid-adolescence (age 15) to early adulthood (age 18), and recent epidemiological evidence shows that the prevalence of depression has increased over the last 20 years.[2] The rising prevalence of depression in youth, alongside the high morbidity and burden, led the US Surgeon General Vivek Murthy to consider this "the defining public health crisis of our time"[3] and prompted health and policy advocates to recommend screening for depression during adolescence.

Decades of research have identified dozens of factors that are concurrently and prospectively related to predict depression in youth.[4] However, the abundance of replicable, robust risk factors has not yet provided useful, actionable, translational information.[4] We suggest that evaluating the status of these multitudinous risk factors as necessary conditions for predicting future depression can help to address this problem and may advance psychopathology science via more precise, and falsifiable, theory-building efforts.[5,6] In this article, we highlight a novel approach via the application of necessary condition analysis (NCA),[7] which can be used to evaluate the status of empirically supported risks as necessary conditions.

How is a necessary condition for depressive risk defined? In their influential work, Abramson *et al.* defined a

necessary condition as "an etiological factor that must be present or have occurred in order for the symptoms to occur. The symptoms cannot occur if the etiological factor is absent."[8(p359)] Essentially, the authors described a deterministic necessary cause, indicating that if the necessary condition is not satisfied, the outcome will never happen (ie, if not X, then always not Y).[9] In the context of depression research, a deterministic necessary condition is a condition whose absence indicates the absence of future major depressive episodes (MDEs). However, the investigation of deterministic necessary risks for depression has been largely understudied, despite its crucial importance for advancing understanding of the fundamental nature of depression vulnerability in etiological theories and for practical clinical applications. Indeed, adjudicating whether particular risks have the status of necessary factors holds promise to yield progress for applied translational applications as well as basic scientific knowledge.

The extant body of evidence investigating prospective prediction of depression from risk factors over decades has used standard statistical approaches (eg, multiple regression and related analytical tools) to predict which participants are likely to experience a future depressive episode as a function of varying levels of various risk factors. By doing so, this dominant research paradigm has identified probabilistic sufficient causes, providing information about the likelihood that the presence of a sufficient cause will result in the outcome (ie, if X, then probably Y).[9] For example, within a multiple regression framework, a significant regression coefficient for childhood abuse indicates that increased levels of this risk factor are associated with a greater likelihood of experiencing elevated depressive symptoms. This example also helps to clarify that depression can result from a variety of different patterns of risk factors and many pathways (ie, equifinality). In fact, higher levels of one factor can compensate for lower levels of other risks (eg, low levels of rumination may be counterbalanced by high negative emotionality) and still eventuate in future depression.

A major implication of this approach is that the current quantification of effect sizes for associations between risk factors and future depression yields nearly no discernible information regarding the status of the risk as necessary. Without clear ascertainment of the status of risk factors, rigorous testing of risk models and potential falsification of etiological depression theories will falter.[10] Further, the applied translation of risk research to address vital clinical and public health needs will suffer because it is nearly impossible, unpractical, and excessively costly to screen individuals on all the possible probabilistic sufficient risks in meaningful ways.[11]

As traditional regression-based approaches inform risks as probabilistic sufficient conditions, a major gap exists regarding how best to identify deterministic necessary conditions (henceforth necessary conditions). NCA is a relatively novel analytical method[7] that has been applied successfully in several fields, includng economics, public health, business, and management,[12] but its application to mental health sciences has been limited so far.[13] NCA can detect, quantify, and provide statistical inference on necessary conditions in kind and in degree present in the data. Applied to the context of evaluating depression risk in youth, NCA has the potential to identify individuals who will not develop a depressive episode and can differentiate them from individuals who may or may not experience a depressive episode in the future. In contrast to sufficient risks, necessary conditions cannot be compensated for by other factors. In other words, individuals who do not exhibit the presence of a necessary risk for major depression will certainly not develop the disorder, even if other risk factors are present. Hence, the NCA approach holds promise to identify a smaller set of necessary risks for future depression. This knowledge can then be used to efficiently screen for depression (before implementing established prevention programs) and to promote innovative etiological theory development for depression that could reasonably be falsified.[10]

In this study, we applied NCA to evaluate well-established vulnerability factors for depression in youth.[4] Specifically, we examined the following cognitive/personality risks: self-criticism,[14] dependency,[14] hopelessness,[8] low self-esteem,[15] dysfunctional attitudies,[16] negative cognitive style,[17] and rumination.[18] Stressful life events and prior history of depression are additional well-known, established psychosocial predictors of future depression.[19] These factors are rooted in theories of depression risk within the broader vulnerability-stress paradigm,[8,14-18] which posits that these are important influences such that the absence of either vulnerability or stress could mean resilience from the onset of depression.[20] Although the causal status of these factors (whether they are necessary or sufficient conditions) has often not been explicitly clarified in depression models, or indeed in psychopathology theories more generally,[21] they are conceptually integrated within the vulnerability-stress framework. Therefore, it is plausible to consider that they may act as necessary conditions for the development of future depression. To test the extent if and to which all these factors function as necessary conditions for major depression, we followed 382 youths from early to mid-adolescence (10-15 years old) through mid- to late adolescence (13-18 years old) over a 2-year prospective period with multiple assessments.

METHOD

Participants

This study leveraged data from a 2-year longitudinal study comprising 382 adolescents (225 girls and 157 boys, mean age 12.6 years, age range 10-15 years) and a caretaker recruited from the general community in Montreal, Quebec, Canada, and Chicago, Illinois.[22] Participants were recruited through advertisements in local newspapers and the broader community, targeting individuals interested in a study on adolescent development. Inclusion criteria required that the child be between 10 and 15 years old and that the caretaker be willing to participate. Participants needed to be fluent in English, although their native language could be French (in Montreal) or Spanish (in Chicago). There were no exclusion criteria. The Montreal and Chicago samples were similar regarding adolescent gender composition ($\chi^2_1 = 0.42$, $p = .52$), adolescent age ($t_{380} = 0.62$, $p = .54$), adolescent grade ($t_{380} = 0.47$, $p = .64$), mother's highest level of education ($F_{1,380} = 2.10$, $p = .15$), father's highest level of education ($F_{1,330} = 0.62$, $p = .43$), and family income ($F_{1,380} = 0.24$, $p = .63$). However, the Chicago sample had a higher proportion of ethnic minority youth ($\chi^2_1 = 17.36$, $p < .001$) and more youth from single-parent households ($\chi^2_1 = 8.84$, $p = .003$). Sociodemographic details for the entire sample are presented in Table 1.

Given that no software for NCA power analysis was available at the time of preregistration, we based our sample size on previous literature.[12] Using current R resources, specifically the nca_power function from the R package NCA 4.0.1 (https://CRAN.R-project.org/package=NCA), an a priori power analysis would indicate that with an α of .05 and a power of 0.80, the minimum sample size required to detect a small effect ($d = 0.10$) is approximately 310 participants.Finally, this secondary analysis adhered to the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) reporting guidelines (https://www.strobe-statement.org/) (see Supplement 1, available online). The ethical approval for the secondary analysis was obtained from the Ethical Committee of University of Trieste.

TABLE 1 Sociodemographic Characteristics of Sample at Baseline (N = 382)

Variable	Value	
	%	
Child gender		
Female	58.8	
Male	41.2	
	Mean	**(SD)**
Child age, y	12.6	(1.1)
	%	
Child grade		
Fifth	3.4	
Sixth	28.2	
Seventh	30.9	
Eighth	25.6	
Ninth	11.8	
Child race/ethnicity		
Asian	12.4	
Black	12.4	
Hispanic	4.9	
Other/Native American	1.8	
White	68.5	
Parent marital status		
Married	70.2	
Divorced	15.1	
Widowed	1.3	
Single	13.3	
Mother's education		
Elementary school	2.6	
High school	15.8	
Community college	28.5	
University	31.9	
Graduate school	21.2	
Father's education		
Elementary school	4	
High school	14.8	
Community college	26.1	
University	32.2	
Graduate school	24.8	
Family income		
< $15,000	1.8	
$15,000-$29,999	13.3	
$30,000-$44,999	10.5	
$45,000-$59,999	17	
$60,000-$74,999	15.4	
$75,000-$89,999	10.7	
$90,000-$99,999	8.4	
≥ $100,000	22.8	

Procedure

In phase 1, each adolescent–parent pair was invited for a laboratory evaluation. During this session, they completed a series of questionnaires on demographics and psychosocial variables (see below) and participated in a clinical interview (Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime version [K-SADS-PL])[23] to determine the presence of current and past depressive episodes. Additionally, parents completed consent forms for themselves and their children, and the adolescents signed assent forms.

Phase 2 of the study consisted of 8 telephone follow-up assessments conducted every 3 months over the 2 years

following the initial evaluation. During each follow-up assessment, a research assistant acquired information about depressive symptoms and negative life events for the adolescents. At the 6-, 12-, 18-, and 24-month follow-ups, a diagnostician gathered information about the adolescent's depressive symptoms over the past 6 months from both the parent and the adolescent using the K-SADS-PL. If a follow-up assessment with the K-SADS-PL was missed, the information for that period was collected during the next K-SADS-PL assessment. Parents and adolescents received $200 for participating in the study. Data collection began in 2003 and concluded in 2006. A flowchart of the study is show in Figure S1, available online.

Measures

Well-established personality and cognitive vulnerabilities for adolescent depression as well as negative life events were measured with self-report questionnaires. Information about personality traits, namely, dependency (Depressive Experiences Questionnaire Dependency subscale [DEQ-DEP]) and self-criticism (Depressive Experiences Questionnaire Self-Criticism subscale [DEQ-SC]), and cognitive risk factors, namely, dysfunctional attitudes (Children's Dysfunctional Attitudes Scale [CDAS]), negative cognitive style (Adolescent Cognitive Style Questionnaire [ACSQ]), hopelessness (Children's Hopelessness Scale [CHS]), rumination (Children's Response Styles Questionnaire [CRSQ]), and self-esteem (Self-Esteem Questionnaire [SEQ]), was acquired. The study also assessed baseline depression symptom severity (Children's Depression Inventory [CDI]), the presence of typical stressful events in adolescence (Adolescent Life Events Questionnaire [ALEQ]), and the number of previous depressive episodes over the youth's lifetime before baseline. Other measures present in the original study are not reported here. For more information about the constructs and the related questionnaires, see Table S1, available online.

Adolescent Depression Outcomes

The primary outcome of the study was the cumulative number of MDEs over the 2-year follow-up, which was calculated by summing all MDE onsets from each 6-month follow-up across the total span of 24 months. Information to make a diagnosis for MDE onset was acquired by administering the K-SADS-PL[23] to both adolescents and their caretaker separately, as informants, using *DSM-IV* major depressive disorder criteria.[24] At baseline, 6 adolescents met criteria for current depression, and 28 participants experienced past MDEs before the prospective follow-ups started. For more information about the instruments, see Table S1, available online.

Analytical Approach

The NCA is a novel method to investigate necessary conditions.[7] In detail, a scatterplot of each pair of dependent and independent variables is generated to quantify the area of empirically possible observations (ie, scope). The ceiling zone is defined as the area of interest without observation, located in the upper left corner of the scope when a high value of X is necessary for a high value of Y. In our study, we relied on the empirical scope, namely, the scope with observed minimum and maximum values of the condition and the outcome considered. The ratio between ceiling zone and empirical scope is considered the primary NCA effect size (d) and quantifies the degree of necessity that the independent variable exerts on the outcome (for more information, see Supplement 2, available online). The effect size can range from 0 to 1, where $0 < d < 0.1$ is considered small, $0.1 \leq d < 0.3$ is considered medium, $0.3 \leq d < 0.5$ is considered large, and ≥ 0.5 is considered very large.[12]

To define the ceiling zone, we relied on the ceiling envelopment–free disposal hull technique. This technique is a nondecreasing piecewise linear function, which connects all the highest values of the y-axis for each value on the x-axis, and it is recommended when conditions with few values are considered. In line with current guidelines,[12] we considered only the necessary conditions that reported an effect size $d \geq 0.10$ and an estimated p value $< .05$, after 10,000 permutated resamples. For the statistically significant conditions, we also reported bottleneck tables, where specific levels of necessary conditions for different levels of the outcome variable were shown. Given the bivariate nature of the NCA approach and the current uncertainty regarding the impact of data imputation on NCA results, pairwise deletion was used to manage any missing values.

In this study, we examined whether self-criticism and dependency, hopelessness, low self-esteem, dysfunctional attitudes, negative cognitive style, rumination, negative life events, and baseline depressive symptoms are necessary conditions for cumulative MDEs over a 24-month period. This analytical plan was preregistered (https://osf.io/b5ced).

RESULTS

Descriptive statistics for the baseline variables are presented in Table 2. Of 382 adolescents, 367 (retention rate = 96%) provided information on the main outcome measure (ie, K-SADS-PL).

TABLE 2 Descriptive Statistics

Variable	n	Mean	(SD)	Empirical range
Depressive symptoms (CDI) at baseline	375	8.82	(6.57)	0-35
Dependency (DEQ-DEP)	246	4.69	(2.02)	0-10
Self-criticism (DEQ-SC)	246	3.82	(1.84)	0-9
Hopelessness (CHS)	366	3.50	(2.57)	0-15
Low self-esteem (SEQ)	362	0.85	(0.46)	0-2.30
Dysfunctional attitudes (CDAS)	372	12.88	(5.97)	0-31
Cognitive style (ACSQ)	373	3.09	(0.78)	1-6.11
Rumination (CRSQ)	369	0.99	(0.59)	0-2.62
Number of previous episodes	381	0.26	(1.12)	0-17
Cumulative MDEs at 24-month follow-up	367	0.30	(0.93)	0-8
Depressive symptoms (CDI) at 6-month follow-up	356	7.47	(7.04)	0-44
Depressive symptoms (CDI) at 12-month follow-up	309	7.63	(6.77)	0-32
Depressive symptoms (CDI) at 24-month follow-up	318	6.86	(6.32)	0-41

Note: ACSQ = Adolescent Cognitive Style Questionnaire; CDAS = Dysfunctional Attitudes Scale; CDI = Children's Depression Inventory; CRSQ = Children's Response Styles Questionnaire; DEQ-DEP = Depressive Experiences Questionnaire Dependency subscale; DEQ-SC = Depressive Experiences Questionnaire Self-Criticism subscale; MDE = major depressive episode; SEQ = Self-Esteem Questionnaire.

TABLE 3 Necessary Condition Analysis (NCA) With Cumulative Major Depressive Episodes Over 2 Years as Outcome

	NCA	
Predictor (baseline)	CE-FDH effect size *d*	(*p*)
Depressive symptoms at baseline	0.23	(.048)
Dependency	0.33	(.189)
Self-criticism	0.35	(.048)
Hopelessness	0.15	(.200)
Low self-esteem	0.10	(.841)
Dysfunctional attitudes	0.27	(.247)
Negative cognitive style	0.22	(.634)
Rumination	0.50	(.001)
No. previous episodes	0.00	(1)
Stressful events	0.37	(.003)

Note: NCA CE-FDH effect size: $d < 0.1$ is considered small; $0.1 \leq d < 0.3$, medium; $0.3 \leq d < 0.5$ large; and $d \geq 0.5$, very large. CE-FDH = ceiling envelopment–free disposal hull.

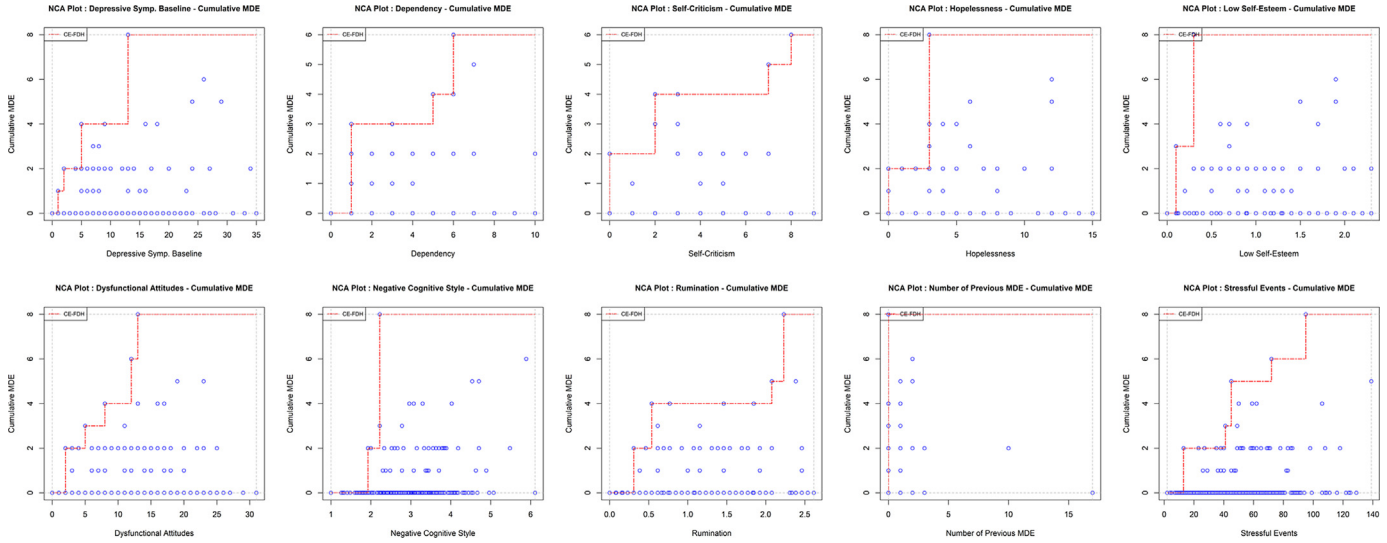
NCA for K-SADS-PL Outcome

Table 3 provides results of NCA showing that depressive symptoms at baseline ($d = 0.23$, medium effect, $p = .048$), self-criticism ($d = 0.35$, large effect, $p = .048$), rumination ($d = 0.50$, very large effect, $p < .001$), and stressful events ($d = 0.37$, large effect, $p = .003$) all were statistically significant and substantial necessary conditions for developing 1 or more MDEs over the subsequent period of 24 months (cumulative MDEs) (Table 3; Figure 1). The other personality and cognitive risk factors were not statistically significant necessary conditions.

Crucially, bottleneck analysis revealed that specific levels of rumination, depressive symptoms, and stressful events at baseline were necessary factors for potentially experiencing 1 or more MDEs during the subsequent 24 months (Table 4). In detail, an adolescent needed to report a value of at least 1 on the CDI (theoretical range: 0-54) at baseline, at least 0.307 on the rumination subscale of the CRSQ (theoretical range: 0-3), or at least 13 on the ALEQ (theoretical range: 0-288). These minimum scores were necessary conditions for adolescents to possibly receive at least 1 MDE diagnosis over time. At baseline, 46 adolescents reported no depressive symptoms (ie, CDI = 0), experienced low rumination (ie, below 0.307 on the CRSQ rumination subscale), or reported few stressful events (ie, events below 13 on the ALEQ), and none of them developed a major depressive disorder over the subsequent 24 months. In summary, 13.5% of the sample lacked at least 1 of the necessary conditions for depression and were virtually immune from experiencing 1 or more MDEs during the follow-up period. Conversely, 86.5% of the participants possessed all the necessary conditions for developing a major depressive disorder, with 13.2% of individuals both satisfying all the necessary conditions at baseline and experiencing 1 or more MDEs over the 2-year follow-up (Figure S2, available online).

It is noteworthy that bottleneck analysis could also identify the necessary levels for recurrent depression (ie, 3 or more MDEs).[25] To potentially experience 3 or more MDEs, adolescents had to report at least low levels of baseline depressive symptoms (CDI = 5; theoretical range: 0-54), rumination (CRSQ = 0.538; theoretical range: 0-3), stressful events (ALEQ = 41; theoretical range: 0-288), or self-criticism (DEQ-SC = 2; theoretical range: 0-10). Overall, 65.5% of the sample did not meet all the necessary conditions for recurrent depression, and 34.5% did satisfy all these conditions, with only 2.1% of the sample both possessing the necessary conditions and experiencing 3 or more MDEs over the 2-year follow-up (Figure S2, available online).

FIGURE 1 Necessary Condition Analysis Scatterplot Between Risk Factors and Cumulative Major Depressive Episodes



Note: *MDE = major depressive episode; NCA = necessary condition analysis. Please note color figures are available online.*

DISCUSSION

Considerable research on risk for youth depression has identified numerous factors that influence prediction of depression during adolescence.[4] Yet at the same time, deeper theoretical understanding and translational application of the functional role of these many different depression risks have been limited. Results from this study yielded 2 sets of findings that advance knowledge in the field. First, we found that risk factors such as baseline depressive symptoms and rumination as well as stressful events all served as necessary conditions for adolescents to experience at least 1 depressive episode over a 2-year follow-up. Specifically, none of the participants who lacked 1 or more of the identified necessary conditions experienced a depressive episode in the subsequent 24 months. In other words, these findings identify which youth are at virtually negligible risk to develop a prospective MDE over time during the high-risk period of adolescence. Our analysis also indicated that experiencing at least 1 depressive episode during adolescence is a possibility for most youth. Approximately 86.5% of the sample exhibited all the necessary conditions for developing depression, and of this group about 13% both possessed the necessay conditions and experienced at least 1 MDE. In contrast, 13.5% of the adolescents did not meet all the necessary conditions and were thus virtually immune to depression.

Second, self-criticism, along with baseline depressive symptoms, rumination, and stressful events, also served as a

TABLE 4 Bottleneck Table of Significant Necessary Conditions for Cumulative Major Depressive Episodes (MDEs)

	Significant necessary conditions			
Outcome: cumulative no. MDEs over 24 mo	**Depressive symptoms at baseline (*d* = 0.23)**	**Self-criticism (*d* = 0.35)**	**Rumination (*d* = 0.50)**	**Stressful events (*d* = 0.37)**
0	NN	NN	NN	NN
1	1	NN	0.307	13
2	2	NN	0.307	13
3	5	2	0.538	41
4	5	2	0.538	45
5	13	7	2.077	45
6	13	8	2.231	72
7	13	NA	2.231	95
8	13	NA	2.231	95

Note: *NA = not applicable; NN = not necessary.*

necessary condition for experiencing 3 or more MDEs. Recurrent depression during adolescence often leads to significant societal and personal consequences, including an increased risk of suicide, substance abuse, and other forms of psychopathology,[26] and being able to detect individuals at risk is imperative. Although only about 2% of our participants both carried all the necessary conditions and experienced 3 or more MDEs, a substantial portion of the sample (approximately 34.5%) had all the necessary conditions for such a maladaptive trajectory. Conversely, the majority (approximately 65.5%) of the adolescents lacked at least 1 necessary condition and were not susceptible to recurrent depression.

Drawing strong clinical inferences based on a single study may seem premature, but the findings and approach used here may have major clinical implications when further strengthened by replication. First, our findings suggest that only a few key conditions are required for a reliable, valid, and practical screening to identify youth who might benefit from effective depression prevention. Clearly, replication with a larger sample is needed. Pending such replication, our results indicate that identifying youth who may (or may not) develop 1 MDE in the future would require 3 brief assessment measures (ie, depressive symptoms, rumination, and stressful events).

Conversely, when the objective is to identify youth who are virtually immune to developing major depression and therefore likely do not need any preventive intervention, each of the identified factors is virtually sufficient. In fact, failing to meet even 1 necessary condition makes the development of an MDE nearly impossible. For example, screening for minimal levels of rumination, rather than covering all known risk factors, provides a practical approach to meeting recommendations of public health experts for universal depression screening.

We can speculate that the current advocacy for universal adolescent depression screening[27] can help identify adolescents who do not report any depressive symptoms (eg, Patient Health Questionnaire-2 [PHQ-2], Patient Health Questionnaire-9 [PHQ-9], or Center for Epidemiologic Studies Depression Scale [CES-D]) and are at virtually no risk of developing an MDE in the future. Conversely, relying solely on depression-related measures seems to be less effective in predicting the future onset of depression, as meeting all the necessary conditions does not ensure the outcome (ie, 86% of the sample met all the necessary conditions for at least 1 MDE, but only 13% actually experienced the disorder).

Second, another significant clinical implication of our study is the enhancement of primary, secondary, and tertiary prevention efforts. Rumination, stress exposure, current depressive symptoms, and self-criticism have been identified as necessary risks, and all of these are modifiable through evidence-based interventions.[4,28,29] Therefore, prevention strategies could actively target these psychosocial factors in vulnerable individuals who screen above the minimal necessary levels using brief, feasible, and practical means. According to causality theory,[9] lowering an individual's level below the necessary threshold is hypothesized to be sufficient to prevent the outcome (if not X, then always not Y).[9] In the context of depression, major depressive disorder could potentially be prevented or effectively treated by focusing on a single necessary cause through effective and personalized interventions. This represents a crucial practical consequence of the underlying theory, which warrants careful consideration and empirical evaluation. Overall, clinical opportunities should be used and targeted to deliver interventions that better address the mental health needs of youth, while optimizing relatively limited resources, such as trained mental health personnel, financial reimbursement, and time.

Important theoretical implications can be derived as well. First, our findings offer significant support for the central premise of the vulnerability-stress paradigm.[20] Specifically, rumination (ie, vulnerability) and stressful events (ie, stress) were both necessary for the onset of future MDEs. Second, from a theory-building perspective,[5,21] it is crucial to recognize that both necessary and sufficient conditions ultimately contribute to the onset of episodes (ie, embedded necessity theory).[30] Few depression or psychopathology theories explicitly address necessary conditions that lead to emergence of disorder. The results of our study pave the way for future research to explicitly assess the conceptual status of various risks (ie, necessary vs sufficient) and the associated types of causality (ie, deterministic vs probabilistic vs typical).[9] Using the most advanced theoretical and statistical developments, future research findings could rigorously evaluate and potentially falsify existing depression models.

Future research findings based on NCA can also iteratively guide future theory development based on findings from investigations, showing which risks function as deterministic necessary or probabilistic sufficient over the lifespan and in different ecological contexts. Knowing which risks serve as necessary conditions, as well as threshold values above which individuals may be vulnerable to future depression given particular necessary risks, can also be used to inform development and testing of computational models that more formally and precisely postulate etiological processes via mathematical models or simulation methods.[5,6] For example, findings from this study might suggest at least 1 possible specific model that could be formally simulated and further tested via computational

approaches. For instance, at minimum, exposure to stress and minimal levels of both rumination and depressive symptoms are needed for onset of 1 MDE, whereas additional, probabilistic sufficient factors must be present to elicit the onset of full-blown major depressive disorder.[31] We provide this example as 1 plausible model with these 3 necessary factors that empirical NCA shows are required for future MDEs. Clearly, other possible etiological models containing these 3 necessary risks could be formalized and tested to advance innovative theory building grounded in empirical risks. This approach would eventually result in a complex model, implying both the sufficiency and the necessity logic for explaining depressive onset (ie, embedded necessity theory).[30]

Some limitations should be mentioned. First, additional studies with larger samples and equivalent measures need to be conducted to further replicate and validate the current methodology. Second, given its bivariate nature, NCA currently cannot test the necessary patterns of multiple conditions, specifically, a necessary configuration of conditions that are not necessary on their own. Future theoretical and methodological developments should help clarify these advanced topics. Third, in the present study, we relied on psychosocial variables from literature on cognitive factors, personality traits, and stressful life events. Future work can apply NCA to variables across different levels of analysis (eg, biological, social, and other psychosocial levels). This step is crucial for enhancing our understanding of the additional factors required for the development of depression as well as for obtaining a more accurate quantification of the population's vulnerability to the disorder. Identifying the additional necessary factors will increase the percentage of individuals classified as not meeting all the conditions (ie, resilient to depressive onset), thereby providing a more reliable representation of the actual risk of the population. It is important to note, however, that the NCA approach demands a theoretical and logical basis for evaluating a variable as a potential necessary condition.[7] Consequently, important demographic factors related to adolescent depression, such as gender[32] and ethnicity/race,[33] are not suitable for this method, as it is unreasonable to propose that a particular gender or racial group could be virtually immune to depression. Fourth, although this approach carries implications for individuals, NCA studies usually depend on data at the group level. Future studies should consider the necessary conditions from an intrapersonal perspective, where the NCA approach might be fruitfully integrated with time-varying dynamic models.[34]

We advocate a wide use of the NCA approach for psychopathology and psychological science to advance understanding of the conceptual status of select depression risks as necessary. NCA could be usefully applied to also test and quantify deterministic sufficient causes (ie, if X, then always Y)[9] and even necessary and sufficient causes (ie, if not X, then always not Y, and if X, then always Y).[9] Considering that conducting experiments with randomization to risk conditions would often be unethical in risk research for psychopathology, NCA represents an invaluable approach for theory building in clinical science, where prospective samples could be followed for years, including multiple risks for development of psychopathology across levels and units of analysis.[35-39]

In conclusion, study results and the innovative methodology applied in this empirical investigation pave the way to new, important areas in mental health research. In particular, we posit that NCA could assist clinicians and researchers in elucidating the necessary factors contributing to the prospective development of mental disorders, across multiple levels of explanation (eg, psychosocial, neurobiological, genetic) and different forms of psychopathology beyond depression. Hence, this approach holds potential promise to advance knowledge on essential risks that could be screened broadly and then used to identify only susceptible adolescents who could benefit most from prevention efforts. Through screening based on knowledge obtained from NCA investigations, valuable resources (eg, personnel, time, effort) could be maximally applied to youth who could benefit from intervention as opposed to resilient individuals who exhibit neglible risk for future disorder.

CRediT authorship contribution statement

Igor Marchetti: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Ernst H.W. Koster:** Writing – review & editing, Writing – original draft, Supervision. **Benjamin L. Hankin:** Writing – review & editing, Writing – original draft, Supervision, Resources, Investigation, Funding acquisition, Data curation, Conceptualization.

Accepted November 1, 2024.

[a]University of Trieste, Trieste, Italy; [b]Ghent University, Ghent, Belgium; [c]University of Illinois-Urbana Champaign, Champaign, Illinois.

Igor Marchetti declares funding from the Italian Research Projects of National Relevance—NextGeneration EU (grants 2022AKTAK8 and P20223PTH4). Ernst H.W. Koster declares funding from Special Research Funds—Ghent University (grant BOF23/GOA/006) and an Applied Biomedical (TBM) grant of the Research Foundation—Flanders (FWO) (T000720N). Benjamin L. Hankin declares funding support from the National Institute of Mental Health (grant R01MH109662) and the National Heart, Lung, and Blood Institute (grant R01HL155744). The funders of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

The research was performed with permission from the Ethics Committee of the University of Trieste (Trieste, Italy).

Consent has been provided for descriptions of specific patient information.

This work has been prospectively registered: https://osf.io/b5ced.

Data Sharing: Senior author Benjamin L. Hankin, PhD, can be contacted for any data that are not included in the article or supplemental material. Data will be provided depending on the type of research request.

The authors thank the many staff members and students who assisted with data collection, interviewing, and project management. Also, the authors thank the families for their participation in this longitudinal study. Finally, the authors acknowledge the death of John R.Z. Abela, who was a co—principal investigator in the original study; his efforts, energy, and dedication were invaluable for the research the authors are grateful to conduct.

Disclosure: Igor Marchetti, Ernst H.W. Koster, and Benjamin L. Hankin have reported no biomedical financial interests or potential conflicts of interest.

*Correspondence to Igor Marchetti, PhD, Department of Life Sciences, University of Trieste, Edoardo Weiss 21 Street, 34128 Trieste, Italy; e-mail: imarchetti@units.it

https://doi.org/10.1016/j.jaac.2024.11.001

REFERENCES

1. Kessler RC. The costs of depression. Psychiatr Clin North Am. 2012;35(1):1-14. https://doi.org/10.1016/j.psc.2011.11.005
2. Daly M. Prevalence of depression among adolescents in the US from 2009 to 2019: analysis of trends by sex, race/ethnicity, and income. J Adolesc Health. 2022;70(3):496-499. https://doi.org/10.1016/j.jadohealth.2021.08.026
3. Peetz C. Kids' declining mental health is the 'crisis of our time,' surgeon general says. EducationWeek. Accessed February 6, 2024. https://www.edweek.org/leadership/kids-declining-mental-health-is-the-crisis-of-our-time-surgeon-general-says/2023/04
4. Hankin BL, Griffith JM. What do we know about depression among youth and how can we make progress toward improved understanding and reducing distress? A new hope. Clin Child Fam Psychol Rev. 2023;26:919-942. https://doi.org/10.1007/s10567-023-00437-4
5. Robinaugh DJ, Haslbeck JM, Ryan O, Fried EI, Waldorp LJ. Invisible hands and fine calipers: a call to use formal theory as a toolkit for theory construction. Perspect Psychol Sci. 2021;16(4):725-743. https://doi.org/10.1177/1745691620974697
6. Haslbeck JMB, Ryan O, Robinaugh DJ, Waldorp LJ, Borsboom D. Modeling psychopathology: from data models to formal theories. Psychol Methods. 2022;27(6):930-957. https://doi.org/10.1037/met0000303
7. Dul J. Necessary condition analysis (NCA) logic and methodology of "necessary but not sufficient" causality. Organ Res Methods. 2016;19(1):10-52. https://doi.org/10.1177/1094428115584005
8. Abramson LY, Metalsky GI, Alloy LB. Hopelessness depression: a theory-based subtype of depression. Psychol Rev. 1989;96(2):358372. https://doi.org/10.1037/0033-295X.96.2.358
9. Dul J. A different causal perspective with Necessary Condition Analysis. J Bus Res. 2024;177:114618. https://doi.org/10.1016/j.jbusres.2024.114618
10. Meehl PE. Theoretical risks and tabular asterisks: Sir Karl, Sir Ronald, and the slow progress of soft psychology. J Consult Clin Psychol. 1978;46(4):806-834. https://doi.org/10.1037/0022-006X.46.4.806
11. Kieling C, Adewuya A, Fisher HL, *et al*. Identifying depression early in adolescence. Lancet Child Adolesc Health. 2019;3(4):211-213. https://doi.org/10.1016/S2352-4642(19)30059-8
12. Dul J, Hauff S, Bouncken RB. Necessary condition analysis (NCA): review of research topics and guidelines for good practice. Rev Manag Sci. 2023;17(2):683-714. https://doi.org/10.1007/s11846-023-00628-x
13. Luther L, Bonfils KA, Firmin RL, *et al*. Metacognition is necessary for the emergence of motivation in people with schizophrenia spectrum disorders: a necessary condition analysis. J Nerv Ment Dis. 2017;205(12):960-966. https://doi.org/10.1097/NMD.0000000000000753
14. Blatt SJ, Zuroff DC. Interpersonal relatedness and self-definition: two prototypes for depression. Clin Psychol Rev. 1992;12(5):527-562. https://doi.org/10.1016/0272-7358(92)90070-O
15. Brown GW, Harris T. Social origins of depression: a reply. Psychol Med. 1978;8(4):577-588. https://doi.org/10.1017/S0033291700018791
16. Beck AT. Cognitive models of depression. J Cogn Psychother. 1987;1(1):5-37.
17. Hankin BL, Abramson LY. (2002). Measuring cognitive vulnerability to depression in adolescence: reliability, validity, and gender differences. J Clin Child Psychol. 2002;31(4):491-504. https://doi.org/10.1207/153744202320802160
18. Nolen-Hoeksema S. Responses to depression and their effects on the duration of depressive episodes. J Abnorm Psychol. 1991;100(4):569-582. https://doi.org/10.1037//0021-843x.100.4.569
19. Thapar A, Eyre O, Patel V, Brent D. Depression in young people. Lancet. 2022;400(10352):617-631. https://doi.org/10.1016/s0140-6736(22)01012-1
20. Monroe SM, Simons AD. Diathesis-stress theories in the context of life stress research: implications for the depressive disorders. Psychol Bull. 1991;110(3):406-425. https://doi.org/10.1037/0033-2909.110.3.406
21. Kent JS, Markon K, MacDonald IIIAW. Theories of psychopathology: introduction to a special section. J Psychopathol Clin Sci. 2023;132(3):223-227. https://doi.org/10.1037/abn0000824
22. Abela JR, Hankin BL. Rumination as a vulnerability factor to depression during the transition from early to middle adolescence: a multiwave longitudinal study. J Abnorm Psychol. 2011;120(1):259-271. https://doi.org/10.1037/a0022796
23. Kaufman J, Birmaher B, Brent B, Rao U, Ryan N. The Schedule for Affective Disorders for School-Age Children. Pittsburgh, PA: University of Pittsburgh Medical Center; 1996.
24. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders. 4th ed, text rev. Washington, DC: American Psychiatric Association; 2000.
25. Monroe SM, Anderson SF, Harkness KL. Life stress and major depression: the mysteries of recurrences. Psychol Rev. 2019;126(6):791-816. https://doi.org/10.1037/rev0000157
26. Birmaher B, Arbelaez C, Brent D. Course and outcome of child and adolescent major depressive disorder. Child Adolesc Psychiatr Clin N Am. 2002;11(3):619-637. https://doi.org/10.1016/S1056-4993(02)00011-1
27. Mangione CM, Barry MJ, Nicholson WK, *et al*. Screening for depression and suicide risk in children and adolescents: US Preventive Services Task Force recommendation statement. JAMA. 2022;328(15):1534-1542. https://doi.org/10.1001/jama.2022.16946
28. Eckshtain D, Kuppens S, Ugueto A, Ng, *et al*. Meta-analysis: 13-year follow-up of psychotherapy effects on youth depression. J Am Acad Child Adolesc Psychiatry. 2020;59(1):45-63. https://doi.org/10.1016/j.jaac.2019.04.002
29. Merry S, McDowell H, Hetrick S, Bir J, Muller N. Psychological and/or educational interventions for the prevention of depression in children and adolescents. Cochrane Database Syst Rev 2004;(1):CD003380. https://doi.org/10.1002/14651858.CD003380.pub2
30. Bokrantz J, Dul J. Building and testing necessity theories in supply chain management. Journal of Supply Chain Management. 2023;59(1):48-65. https://doi.org/10.1111/jscm.12287
31. Hankin BL, Abramson LY. Development of gender differences in depression: an elaborated cognitive vulnerability–transactional stress theory. Psychol Bull. 2001;127(6):773-796. https://doi.org/10.1037/0033-2909.127.6.773
32. Bone JK, Lewis G, Lewis G. The role of gender inequalities in adolescent depression. Lancet Psychiatry. 2020;7(6):471-472. https://doi.org/10.1016/S2215-0366(20)30081-X
33. Monroe P, Campbell JA, Harris M, Egede LE. Racial/ethnic differences in social determinants of health and health outcomes among adolescents and youth ages 10–24 years old: a scoping review. BMC Public Health. 2023;23(1):410. https://doi.org/10.1186/s12889-023-15274-x
34. Bringmann LF, Vissers N, Wichers M, *et al*. A network approach to psychopathology: new insights into Clinical Longitudinal Data. PLoS One. 2013;8(4):e60188. https://doi.org/10.1371/journal.pone.0060188
35. Lewinsohn PM, Hops H, Roberts RE, Seeley JR, Andrews JA. Adolescent psychopathology: I. prevalence and incidence of depression and other DSM-III-R disorders in high school students. J Abnorm Psychol. 1993;102(1):133-144. https://doi.org/10.1037/0021-843x.102.1.133
36. Michelini G, Perlman G, Tian Y, *et al*. Multiple domains of risk factors for first onset of depression in adolescent girls. J Affect Disord. 2021;283:20-29. https://doi.org/10.1016/j.jad.2021.01.036
37. Ormel J, Oldehinkel AJ, Sijtsema J, *et al*. The TRacking Adolescents' Individual Lives Survey (TRAILS): design, current status, and selected findings. J Am Acad Child Adolesc Psychiatry. 2012;51(10):1020-1036. https://doi.org/10.1016/j.jaac.2012.08.004
38. Morken IS, Viddal KR, Von Soest T, Wichstrøm L. Explaining the female preponderance in adolescent depression—a four-wave cohort study. Res Child Adolesc Psychopathol. 2023;51(6):859-869. https://doi.org/10.1007/s10802-023-01031-6
39. Zinbarg RE, Mineka S, Craske MG, *et al*. The Northwestern-UCLA youth emotion project: associations of cognitive vulnerabilities, neuroticism and gender with past diagnoses of emotional disorders in adolescents. Behav Res Methods. 2010;48(5):347-358. https://doi.org/10.1016/j.brat.2009.12.008