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Association of body mass index with progression from binge-eating behavior into binge-eating disorder among adolescents in the United States: A prospective analysis of pooled data

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ABSTRACT

The association between body mass index (BMI) and binge-eating disorder (BED) is well-established. However, data on the extent to which BMI is associated with progression from binge-eating behavior into BED among adolescents are limited, which was the aim of this investigation. Participants were 9964 U.S. adolescents from the Adolescent Brain Cognitive Development (ABCD) Study, aged 9–13 at the time of study enrollment. A computerized parent-reported assessment was used to establish adolescents' binge-eating behaviors and BED. Cox proportional hazards models adjusting for sociodemographic covariates were used to examine prospective associations between BMI and likelihood of BED onset among a) adolescents with binge-eating behavior, and b) adolescents with no binge-eating behavior. Of 975 adolescents who met the study criteria for binge-eating behavior, 89 (9.1%) subsequently met the study criteria for BED. Of 8989 adolescents with no binge-eating behavior, 82 (0.9%) subsequently met the study criteria for BED. BMI percentile was significantly associated with the likelihood of BED onset in participants with (adjusted HR = 1.03, 95% confidence interval [CI] 1.00, 1.06) and participants without (adjusted HR = 1.05, 95% CI 1.03, 1.07) binge-eating behavior. Results were also significant when examining BMI as a dichotomous predictor (above and below 85th percentile) among those with (adjusted HR = 2.60, 95% CI 1.00, 6.68) and those without (adjusted HR = 6.01, 95% CI 3.90, 11.10) binge-eating behavior. Overall, results indicate that elevated BMI is prospectively associated with a greater risk for BED onset among U.S. adolescents with or without binge-eating behavior. Adolescents with a higher BMI may benefit from screening for binge eating, and prevention/early intervention strategies to mitigate the risk for developing BED.

1. Introduction

Binge-eating disorder (BED) is characterized by recurrent (at least

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once per week for three months) episodes of consuming large amounts of food within a short time period along with loss of control regarding eating (Sarmiento & Lau, 2020). These binge-eating episodes occur in

Abbreviations

ABCD	Adolescent Brain Cognitive Development Study
BED	Binge-eating disorder
BMI	Body mass index
KSADS-5	Kiddie Schedule for Affective Disorders and Schizophrenia
LOC	Loss of control

the absence of recurrent inappropriate compensatory behaviors and are associated with marked distress and characterized by several possible features (e.g., eating much more rapidly than normal, feeling disgusted or guilty after eating, eating in the absence of hunger). BED is the most common eating disorder in the United States (U.S.), with an estimated prevalence of 3–5% in the general population (Udo & Grilo, 2018). Individuals with BED are at higher risk for severe psychological and medical sequelae including depression (Araujo et al., 2010), suicidality, and cardiometabolic diseases (Barakat et al., 2023; Marzilli et al., 2018; Stice et al., 2013; Swanson et al., 2011). Furthermore, social and economic consequences of BED include significant treatment costs, loss of productivity of individuals and caregivers, and substantial negative impacts on wellbeing (Streatfeild et al., 2021). Notably, individuals also may engage in binge-eating behavior that does not meet the criteria for BED, including at a lower frequency or duration, or lacking the requisite number of associated features (Sarmiento & Lau, 2020). Such presentations of binge-eating behavior likely increase the risk for the later onset of BED (Herle et al., 2020). Given that a shorter duration for untreated eating disorders may promote better outcomes (Austin et al., 2021), understanding binge-eating behavior and BED risk factors, particularly in early adolescents, is necessary to identify high-risk groups and support the implementation of prevention/early intervention strategies to curtail the adverse consequences of BED.

The prevalence of binge-eating behavior in the U.S. has been reported to be 2.5% among adolescents (Swanson et al., 2011). Furthermore, previous studies reported that 10–28% of U.S. adolescent girls experience progression from binge-eating behavior into BED over time (Glazer et al., 2019; Stice et al., 2013), highlighting the importance of adolescence as a timeframe in relation to BED onset (Kjeldbjerg & Clausen, 2023; Kotler et al., 2001). This developmental period is characterized by substantial physical and psychosocial changes (e.g., pubertal onset, salience of peer influences) that may impact the risk for binge eating (Farley & Kim-Spoon, 2014; Flament et al., 2015; Klump et al., 2017), and heightened stress arising from such changes may also exacerbate BED risk due to binge-eating behavior serving as a maladaptive coping mechanism (Nagata et al., 2023).

It is well documented that higher body mass index (BMI) is a common correlate of BED. Indeed, consistent with leading theories of the onset and maintenance of binge eating, higher BMI may serve as a risk factor for the onset or exacerbation of binge eating. For example, both the dual-pathway model and the transdiagnostic cognitive-behavioral theory of eating disorders propose that body image disturbances (i.e., dissatisfaction, overvaluation of shape/weight) promote increased risk for binge-eating behavior in response to dieting/weight-control behavior, and these processes may be especially salient for individuals with a higher BMI (Fairburn et al., 2003; Rohde et al., 2015). Furthermore, a recently elaborated developmental framework for BED highlights the salience of loss-of-control (LOC) eating (i.e., subjective loss of control over eating, regardless of the amount of food consumed) as a

vulnerability factor in youth, with such behaviors posited as increasing risk for development of binge-eating behavior and excess weight gain (Sonneville et al., 2013; Tanofsky-Kraff et al., 2005). Consistent with this theory, both any (i.e., at least one past-month episode) and regular (i.e., at least one weekly episode for three months) occurrence of LOC-eating behavior has been found to be more common in adolescents compared to any and regular occurrence of binge-eating behavior (Derks et al., 2022). Moreover, the presence (versus absence) of LOC-eating episodes has been found to be prospectively associated with increased weight gain among youth over time ((Tanofsky-Kraff et al., 2009).

Among adolescents specifically, studies have found positive associations between BMI and binge-eating behavior (De Zwaan, 2001; Derks et al., 2022; Olsen et al., 2021). For example, a cross-sectional study among Danish adolescents aged 16 years reported a significant association between BMI and self-reported BED symptoms (Olsen et al., 2021). Moreover, a longitudinal, population-based study found that youth who had a higher BMI at age 10 were significantly more likely to exhibit binge-eating behavior (versus no BED symptoms) at age 14 (Derks et al., 2022).

While research has explored the association of BMI with BED or binge-eating behavior, data on the prospective association of BMI with the risk of progression from binge-eating behavior into BED are more limited. Such information would provide greater insight into the prospective risk for BED onset associated with higher body weight among adolescents, which would inform the utility of screening, prevention, and early intervention strategies. Therefore, we used data from a large sample of U.S. adolescents enrolled in the Adolescent Brain Cognitive Development (ABCD) Study, in which parents completed a computerized assessment to establish adolescent binge-eating behaviors and BED. The current investigation examined the prospective association of BMI with: a) risk for progression into BED among adolescents with binge-eating behavior, and b) risk for onset of BED among adolescents with no binge-eating behavior. We hypothesized that BMI would be associated with a greater risk for BED onset among both those with and without binge-eating behavior.

2. Method

2.1. Participants

The ABCD study is an ongoing longitudinal epidemiological study of brain development and child health in the U.S. It was established in 2016–2018 and participants were recruited from 21 recruitment sites across the U.S. Further details about the ABCD study participants, recruitment, protocol, and measures, are reported elsewhere (Barch et al., 2018). The current analysis utilized pooled data from the ABCD study baseline, year 1, year 2, and year 3. Participants who met study criteria for BED at enrollment, or those with missing data for other variables, were excluded, resulting in a final sample of 9964 youth (aged 9–13 years at enrollment) for the current analysis. Institutional review board approval was received from the University of California, San Diego (160,091), and the respective IRBs of each study site. Written assent was obtained from participants, and written informed consent was obtained from their caregivers.

2.2. Measures

2.2.1. BMI

A trained research assistant measured each adolescent participant's weight (using the Healthometer 844 KL High-Capacity Digital Bathroom Scale; Health o Meter Professional Scales) and height (using a carpenter's square steel tape measure) three times, and an average was computed. Height and weight were converted to age- and sex-specific BMI percentiles according to the Centers for Disease Control and Prevention (CDC) guidelines (Kuczmarski et al., 2002). Secondary analyses also examined BMI as a dichotomous variable reflecting BMI percentile

<85th versus \geq 85th (Hampl et al., 2023).

2.2.2. Binge-eating behavior and BED

The Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS-5), an online tool that was developed to classify mental health concerns in children and adolescents consistent with DSM-5 criteria, was administered to parents/caregivers at baseline and years 1, 2, and 3 (Sarmiento & Lau, 2020). Parents/caregivers completed a subset of KSADS-5 modules on the frequency, duration, and characteristics of their child's binge-eating behaviors. Responses to the interview questions were scored based on the KSADS-5 scoring system to derive the corresponding diagnosis of DSM-5 BED. In the current study, binge-eating behavior was defined by the single KSADS-5 item. Parents were asked to report if their child had experienced episodes of uncontrollable overeating and consuming excessive amounts of food beyond their needs in the prior two weeks (Appendix 1) (Sarmiento & Lau, 2020).

2.2.3. Covariates

The following variables were included as covariates in the statistical models: age (years), sex (female, male), race/ethnicity (White, Latino/Hispanic, Black, Asian, Native American, and other), household income (U.S. dollars, six categories: less than \$25,000, \$25,000 through \$49,999, \$50,000 through \$74,999, \$75,000 through \$99,999, \$100,000 through \$199,999, and \$200,000 and greater), highest parent education (high school or less vs. college or more), and study site.

2.3. Follow-up

The current investigation utilized pooled data from assessments that participants and their parents/guardians completed at four timepoints: study enrollment, year 1, year 2, and year 3. Participants were classified into two groups based on the presence vs absence of binge-eating behavior at any of the first three assessment timepoints (enrollment, year 1, or year 2). The binge-eating behavior group (BE) included participants ($n = 975$) who met study criteria for binge-eating behavior at the enrollment, year 1, and/or year 2 assessments. The no binge-eating behavior group (No BE) included participants ($n = 8989$) who never met the study criteria for binge-eating behavior at any of the first three assessment timepoints.

Within the BE group, the 'baseline' date was defined as the first date when the presence of binge-eating behavior was endorsed on the KSADS-5 for each participant. For example, if an adolescent exhibited binge-eating behavior at study enrollment, they were followed until they developed BED, recovered (i.e., binge-eating behavior no longer endorsed), were lost to follow-up, or reached the year 3 assessment. Participants who first met study criteria for binge-eating behavior at a later assessment timepoint (i.e., year 1 or year 2) were assigned that date as their new 'baseline' date. From this point, they were followed until they developed BED, recovered, were lost to follow-up, or until the end of the three years of follow-up. Finally, within the No BE group, the 'baseline' date was study enrollment or a later assessment timepoint. For example, if the study enrollment assessment was missing, the subsequent assessment (either in year 1 or year 2) was designated as the baseline. Participants were then followed until they developed BED, were lost to follow-up, or reached the year 3 assessment.

2.4. Statistical analysis

Participants who met the study criteria for BED at any point in the study period were first compared to those who never met BED criteria using students' *t*-tests and chi-square tests. Among participants in the BE group, the Cox proportional hazard model was used to examine the prospective associations of 'baseline' BMI (i.e., BMI at the timepoint at which binge-eating behavior was first endorsed) with the subsequent onset of BED. Among participants in the No BE group, the Cox

proportional hazard model also was used to examine the prospective association of baseline BMI with the onset of BED. These two models were then repeated using the dichotomous BMI variable (i.e., <85th percentile versus \geq 85th percentile). Adjusted hazard ratios (adjusting for age, sex, race/ethnicity, household income, highest parent education, and study site) and associated 95% confidence intervals are reported. Data analyses were performed using Stata 18 (College Station, TX), and propensity weights based on the American Community Survey were applied (Heeringa et al., 2017). A threshold of $p < 0.05$ was considered significant.

3. Results

3.1. Participant characteristics

Among the total sample of 9964 adolescents, 48.6% were female, 44.1% were non-white, and 54.6% came from a household with income <75 K (see Table 1 for complete sociodemographic characteristics). The mean BMI percentile at study enrollment was 61.4 (30.7).

Among the 975 adolescents in the BE group, 89 (9.1%) experienced subsequent onset of BED during the follow-up (median: 12.5 months). Participants in the BE group who progressed into BED were 51.1% female, 73.5% came from a household with income <75 K, and had a mean BMI percentile of 92.8 (12.8). (Table 1). Among the 8989 adolescents in the No BE group, 82 (0.9%) experienced subsequent onset of BED during follow-up (median: 35.1 months). Participants in the No BE group who developed BED were 58.7% male, 67.4% came from a household with income <75 K, and had a mean BMI percentile of 85.4 (25.2).

3.2. Prospective association of continuous BMI percentile with BED onset

Among participants in the BE group, results of weighted Cox regression analysis showed that BMI percentile at participant baseline was significantly associated with risk of subsequent BED onset (adjusted HR = 1.03, 95% CI 1.00–1.06; see Table 2). Similarly, among participants in the No BE group, results revealed that BMI percentile at participant baseline was significantly associated with the risk of subsequent BED onset (adjusted HR = 1.05, 95% CI 1.03–1.07; see Table 2).

3.3. Prospective association of dichotomous BMI percentile with BED onset

Among participants in the BE group, having a BMI \geq 85th percentile at participant baseline was significantly associated with risk of subsequent BED onset (adjusted HR = 2.60, 95% CI 1.00–6.68; see Table 2). Similarly, among participants in the No BE group, having a BMI \geq 85th percentile at participant baseline was significantly associated with risk of subsequent BED onset (adjusted HR = 6.01, 95% CI 3.90–11.10; see Table 2.)

4. Discussion

In this prospective cohort study that used parent reports of adolescents' binge-eating behavior and BED, we found that higher BMI at participant baseline was significantly associated with a greater risk of BED onset in participants either with or without binge-eating behavior. These findings aligned with our study hypothesis and confirmed results from prior research that reported cross-sectional and prospective associations of BMI with binge-eating symptoms and BED in adolescents (Derks et al., 2022; Elliott et al., 2013; Olsen et al., 2021; Stice et al., 2002). This study adds new findings to the literature and highlights BMI as an apparent risk factor for the development of BED, including among adolescents who are already engaging in binge-eating behavior. Moreover, the significant association between BMI and risk for BED onset among adolescents without binge-eating behavior at baseline is

Table 1
Sociodemographic characteristics of participants at study enrollment, ABCD study.

N	No BE	No BE to BED	P	BE	BE to BED	P	Total
	8907	82		886	89		
Age (Mean and SD)	9.9 (0.7)	9.8 (0.7)	0.012	10.8 (1.0)	10.5 (0.6)	<0.001	10.1 (0.8)
Sex (%)							
Female	48.9%	41.3%	0.159	46.4%	51.1%	0.539	48.6%
Male	51.1%	58.7%		53.6%	48.9%		51.4%
Race/ethnicity (%)							
White	57.3%	53.4%	0.543	44.3%	48.7%	0.133	55.9%
Latino	17.5%	24.4%		27.5%	21.9%		18.5%
Black	15.3%	16.2%		16.4%	21.1%		15.5%
Asian	5.4%	3.6%		4.9%	0.6%		5.3%
Native American	2.8%	2.4%		4.2%	7.6%		3.0%
Other	1.7%	–		2.7%	–		1.7%
Parent education (%)							
≥ College	83.8%	81.5%	0.679	64.5%	51.7%	0.010	79.0%
≤ High school	16.2%	18.5%		35.5%	48.3%		21.0%
Household income (%)							
<25 K	16.6%	27.8%	0.079	21.6%	27.9%	0.105	17.3%
25-<50 K	19.0%	16.6%		24.7%	33.1%		19.6%
50-<75 K	17.8%	23.0%		15.5%	12.5%		17.7%
75-<100 K	14.3%	13.0%		13.6%	14.3%		14.2%
100-<200 K	24.3%	19.6%		18.4%	11.7%		23.6%
≥200 K	8.1%	–		6.2%	5.3%		7.8%
BMI percentile (continuous, Mean and SD)	58.4 (30.5)	85.4 (25.2)	<0.001	82.9 (22.4)	92.8 (12.8)	<0.001	61.4 (30.7)
BMI percentile (binary, %)							
BMI percentile <85th	72.7%	67.1%	<0.001	32.0%	9.4%	0.001	67.7%
BMI percentile ≥85th	27.3%	32.9%		68.0%	90.6%		32.3%

BED = Binge-Eating Disorder, BE = Binge-Eating Behavior.

Table 2
Adjusted hazard ratios and 95% confidence intervals for the association between body mass index and risk of binge-eating disorder, ABCD study.

	No BE to BED	BE to BED
	Adjusted HR (95% CI)	Adjusted HR (95% CI)
BMI percentile (continuous)	1.05 (1.03, 1.07)	1.03 (1.00, 1.06)
BMI percentile (binary)		
BMI percentile <85th	Ref	Ref
BMI percentile ≥85th	6.01 (3.90, 11.10)	2.60 (1.00, 6.68)

Note. BMI= Body Mass Index, BE= Binge-Eating Behavior, BED= Binge-Eating Disorder. All models adjusted for age, sex, race/ethnicity, household income, highest parent education, and study site.

consistent with results from previous studies among adolescents (Da Luz et al., 2017; Jebeile et al., 2021) that found adolescents with a higher BMI are susceptible to the onset of eating disorders. Notably, secondary findings that examined BMI dichotomously showed that having an elevated BMI (i.e., ≥85th percentile) was particularly strongly associated with risk for BED onset.

There are numerous theoretical models of binge eating that may inform the potential mechanisms underlying the prospective association between BMI and BED risk observed in this study, largely related to dietary restriction/restraint. For example, restraint theory posits that chronic efforts to restrict food intake led to reduced awareness of internal hunger cues and increased salience of external food cues. Both the physiological effects of reduced food intake and the greater influence of external stimuli (e.g., sights and smells of palatable foods) led to an increased risk for binge eating. Further, according to the dual-pathway model, internalization of the thin body ideal and pressures to be thin can lead to body dissatisfaction, which is particularly relevant for those with a higher body weight that is more discrepant from the 'ideal'. In turn, body dissatisfaction can promote dieting and/or negative affect, both of which increase the risk for binge-eating behavior (Rohde et al., 2015). Similarly, the transdiagnostic cognitive-behavioral theory suggests weight-control behaviors and strict dieting arise from an overvaluation of eating/shape/weight, which leads to an increased risk of binge eating (Williamson et al., 2004). Notably, evidence also suggests

that experiences of weight stigma and weight bias internalization (i.e., internalization of negative weight-related stereotypes and associated self-disparagement), which are particularly prominent among those with a higher BMI, are also associated with greater binge eating and other adverse mental health outcomes (Durso & Latner, 2008; Puhl et al., 2007; Vartanian & Porter, 2016). Weight-based teasing, which can originate from parents, siblings, and/or peers, may also increase the risk for binge-eating behavior and other forms of disinhibited eating among youth, likely mediated at least in part by negative affect (Haines et al., 2006; Neumark-Sztainer et al., 2002; Rubin et al., 2021). Moreover, behavioral susceptibility theory suggests that some youth are more genetically susceptible to excess weight gain, with inherited appetitive patterns posited to underlie the apparent link of interacting genetic and environmental factors with risk for overeating and weight gain (Llewellyn et al., 2023). Consistent with this theory, findings indicate that higher responsiveness to external food cues during early childhood is prospectively associated with greater risk for binge-eating symptoms (and other disinhibited and disordered eating behaviors) in adolescence (Derks et al., 2024). Therefore, a complex interplay of genetic and environmental influences along with dispositional variations in appetite regulation and other salient processes, may impact both eating behavior and body weight among adolescents, including developing binge-eating behavior and BED.

Other theories of potential relevance to the current findings relate to the possible biological and neurobiological effects of higher BMI that may promote binge eating. For example, previous studies suggest that higher BMI is associated with alterations in brain regions responsible for executive functions and impulse control, which may underlie an increased risk for BED (Kittel et al., 2017; Saruco & Pleger, 2021). In particular, alterations in brain function during adolescence, particularly in areas related to inhibitory control and reward processing, may contribute to difficulties in controlling eating behavior, consequently promoting binge eating in adolescents (Kittel et al., 2017; Saruco & Pleger, 2021). Furthermore, consumption of ultra-processed foods by adolescents may alter the gut microbiota, which in turn can affect the production of neurotransmitters and other signaling molecules (Song et al., 2023). These changes may impact brain function related to appetite control, reward, and mood regulation, potentially increasing

the risk for binge-eating behavior due to disrupted satiety signals and heightened food cravings (Song et al., 2023).

4.1. Strength and limitations

This study had several strengths. First, the sample of youth was large and diverse, and recruited nationwide within the U.S., enhancing the generalizability of the findings. Second, the longitudinal design of the study allowed for the examination of prospective associations, offering insights into higher BMI as a potential risk factor for the new onset of BED. However, the study also had limitations. First, a parent-reported computerized assessment was used to establish adolescents' binge-eating behaviors and the other criteria for BED. Evidence suggests that there can be low concordance between parent and child reports of binge eating (Bartholdy et al., 2017; Tanofsky-Kraff et al., 2005), and parents of children with higher BMIs in particular may endorse greater binge-eating symptoms for their children than the children do themselves (Zenlea et al., 2015). However, parents can also be important reporters of eating disorders in younger children and early adolescents given that they may have less insight regarding their eating behaviors (Barch et al., 2018; Braet et al., 2007). Second, there are limitations in the use of BMI, such as the inability to distinguish between fat and muscle mass, and potential inadequacy in accurately reflecting overall health status or accounting for racial/ethnic-specific variations. Third, we were not able to follow the fluctuation in the diagnoses of BED and BED behaviors across each year between assessments. Fourth, although we adjusted for numerous theoretically relevant covariates, there may be other salient covariates that were not assessed in this study. Fifth, due to the observational nature of the study, causality cannot be inferred. Sixth, the DSM-5 definition of binge-eating behavior (i.e., objective binge eating, requiring consumption of an unusually large amount of food) and the criteria for BED might not fully capture the nuances of clinically relevant disinhibited eating in adolescents, given that their eating patterns and nutritional needs naturally fluctuate across development (Tanofsky-Kraff et al., 2008). Future studies that evaluate the broader construct of LOC eating (i.e., subjective binge eating, with loss of control regardless of the amount of food consumed) in examining the associations investigated here are recommended. Finally, the number of participants who developed BED across the three years of follow-up was modest, precluding the ability to examine moderation based on potentially relevant sociodemographic characteristics (e.g., sex, race/ethnicity).

4.2. Conclusion

In this national longitudinal study of U.S. adolescents, we found that higher BMI was associated with a greater likelihood of BED onset both in participants with and without binge-eating behavior. The findings of this study have multiple potential clinical implications for adolescents. For example, results support the importance of screening adolescents who have a higher BMI for binge-eating behavior to enhance early detection and timely intervention for patterns of disordered eating. Additionally, these findings also point towards the importance of family and community education about the inter-relation of higher BMI and eating disorder risk, particularly given the common regard that eating disorders are associated predominantly with low body weight. Finally, healthcare providers working with youth who have a higher BMI are encouraged to address any weight-related issues sensitively and inclusively, particularly given evidence supporting links of weight-based stigma and teasing with binge-eating and eating disorder risk. Future research evaluating potential behavioral, psychosocial, biological, and neurobiological mechanisms underlying the prospective associations observed in the current study is needed. Additionally, further studies are needed to investigate the impacts, either positive or negative, of weight management interventions on the prospective association of BMI with binge-eating behavior and BED in youth.

Ethical statement

Institutional review board approval was received from the University of California, San Diego (160,091), and the respective IRBs of each study site. Written assent was obtained from participants, and written informed consent was obtained from their caregivers.

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Role of the funder/sponsor

The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Additional information

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Data code and availability statement

Data used in the preparation of this article were obtained from the ABCD Study (<https://abcdstudy.org>), held in the NIMH Data Archive (NDA).

CRediT authorship contribution statement

Abubakr A.A. Al-shoaibi: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Jason M. Lavender:** Writing – review & editing. **Sean J. Kim:** Writing – review & editing. **Iris Yuefan Shao:** Writing – review & editing. **Kyle T. Ganson:** Writing – review & editing. **Alexander Testa:** Writing – review & editing. **Jinbo He:** Writing – review & editing. **David V. Glidden:** Writing – review & editing. **Fiona C. Baker:** Writing – review & editing, Formal analysis, Data curation. **Jason M. Nagata:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.appet.2024.107419>.

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