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Validation of a Measure of Hypervigilance and Anxiety about Gastrointestinal Symptoms for Individuals with Elevated Eating Pathology

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Validation of a Measure of Hypervigilance and Anxiety about Gastrointestinal Symptoms for Individuals with Elevated Eating Pathology

Abstract

Gastrointestinal symptoms are common within eating disorders and gastrointestinal-specific anxiety is a posited maintenance factor. The current study sought to validate a modified version of an existing measure of gastrointestinal-specific anxiety and hypervigilance in a sample with elevated eating pathology. Esophageal-specific terms in the Esophageal Hypervigilance and Anxiety Scale were modified to measure any gastrointestinal symptoms as a general measure of gastrointestinal-specific anxiety and hypervigilance. 382 undergraduate students (83.5% female, 87.4% white) with elevated eating pathology completed a questionnaire battery that also measured gastrointestinal symptoms, general anxiety sensitivity, and lower gastrointestinal-specific anxiety on two occasions. Analyses were pre-registered at OSF. Confirmatory factor analysis indicated a two-factor solution (anxiety and hypervigilance) fit the data best. Internal consistency and two-week test-retest reliability were good for subscale scores. Subscale scores exhibited large associations with a measure of lower gastrointestinal-specific anxiety but did not exhibit the hypothesized relationships with general anxiety sensitivity. Subscale scores were at least moderately correlated with measures of gastrointestinal symptoms and somatic symptom severity, with some exceptions (Hypervigilance with nausea/vomiting, postprandial fullness/early satiety, bloating). Subscale scores exhibited negligible associations with discriminant validity measures. Results suggest that gastrointestinal-specific anxiety and hypervigilance are separable in samples with elevated eating pathology. The Anxiety and Hypervigilance subscale scores showed good reliability in a sample with elevated eating pathology. Correlations with measures of gastrointestinal symptoms and gastrointestinal specific-anxiety generally demonstrated good convergent and discriminant validity. We recommend researchers use subscale scores, rather than total score, in future research on gastrointestinal symptoms associated with eating pathology.

Keywords: feeding and eating disorders, anxiety, hypervigilance, gastrointestinal symptoms, avoidant/restrictive food intake disorder

Public Significance Statement: The current study supports the preliminary reliability and validity of a measure of gastrointestinal-specific anxiety and hypervigilance in individuals with elevated eating pathology. The two subscale scores (Anxiety and Hypervigilance) have sufficient stability over time and were related to conceptually similar measures and not related to dissimilar measures.

Validation of a Measure of Hypervigilance and Anxiety about Gastrointestinal Symptoms for Individuals with Elevated Eating Pathology

Individuals with eating disorders commonly report gastrointestinal (GI) symptoms (Gibson et al., 2021; Riedlinger et al., 2020) related to disorders of gut-brain interaction (previously known as functional GI disorders; Boyd et al., 2005, 2010; Burton Murray, Kuo, et al., 2021; Drossman et al., 2016; Hanel et al., 2021; Wang et al., 2014; Wiklund et al., 2021), chronic GI illness (e.g., inflammatory bowel disease, celiac disease; Hedman et al., 2019; Ilzarbe et al., 2017), problems with motility (e.g., slowed colonic transit; Benini et al., 2010; Kamal et al., 1991), and/or structural GI issues (e.g., liver dysfunction; Rosen et al., 2016). GI symptoms may develop in the context of an eating disorder, may increase risk for the development of an eating disorder, or a reciprocal relationship may exist (Atkins et al., 2023; Boyd et al., 2010; Hedman et al., 2019; Stein et al., 2021). Accordingly, there is increasing interest in the GI and eating disorder intersection (Burton Murray & Staller, 2022; Chey, 2019; G. K. W. Frank et al., 2021; Peters et al., 2022; Zucker & Bulik, 2020) to inform detection, prevention, and treatment. Regardless of etiology, GI-specific anxiety has been hypothesized to be a modifiable factor that contributes to a bi-directional relationship between GI disorders and eating disorders (Zucker & Bulik, 2020).

GI symptoms are present in both the “traditional” eating disorders, such as anorexia nervosa, bulimia nervosa, and binge-eating disorder (Gibson et al., 2021; Riedlinger et al., 2020), and in avoidant/restrictive food intake disorder (ARFID) (Gibson et al., 2021). While “traditional” eating disorders and ARFID differ in some aspects of clinical presentation, both groups of eating disorders are thought to share maintenance factors such as food avoidance and dysregulated appetite (Fairburn, 2008; Thomas et al., 2021). Indeed, these disorders share elevated fasting satiety hormones such as cholecystokinin (Burton Murray et al., 2022; Prince et al., 2009). Given these overlapping behavioral and physiological features, it may be that psychological features, such as GI-specific anxiety, overlap between the two conditions as well.

There are multiple pathways through which GI-specific anxiety may be relevant in etiology or maintenance of eating disorders. Based on the fear-avoidance model of pain (Vlaeyen et al., 2016), neurosensory changes in the gut-brain axis could lead to heightened sensitivity to visceral sensations (i.e., visceral sensitivity) and associated fear processes (e.g., hypervigilance, catastrophizing). Early life experiences with GI pain may sensitize some individuals to experience innocuous visceral sensations as painful and be at later risk for an eating disorder (Zucker & Bulik, 2020). Comorbidity between eating disorders and anxiety is high, with estimates of comorbidity with generalized anxiety disorder ranging from 7% to 55% in ARFID, anorexia nervosa, and bulimia nervosa (Kambanis et al., 2020; Swinbourne & Touyz, 2007). GI-specific anxiety may also be the result of or contribute to this comorbidity. For example, an individual with pre-existing fear and anxiety around GI sensations may be at risk for developing ARFID as an adult after linking a GI symptom event (e.g., vomiting) to a particular food/meal (Thomas et al., 2017). Alternatively, fear conditioning around GI symptoms in the context of the eating disorder could create neurosensory changes that predispose for development of or maintenance of GI issues. Anxiety and somatization are related to the presence of disorders of gut-brain interaction in female inpatients (Boyd et al., 2005) and greater GI-specific anxiety has been associated with both eating disorder symptom severity and lower GI symptom severity among patients with chronic constipation (Burton Murray et al., 2020).

To support further mechanistic and treatment research, reliable and valid measures of GI-specific anxiety in individuals with elevated eating pathology are needed. One prior study validated a measure of lower GI-specific anxiety, the Visceral Sensitivity Index, in a sample of adolescents and adults with eating disorders (Brown et al., 2021). The Visceral Sensitivity Index had adequate model fit and scores had good internal consistency and moderate associations with convergent measures. Supporting the relevance of lower GI-specific anxiety in eating disorders, Visceral Sensitivity Index scores were related to eating disorder symptom severity

(Brown et al., 2021). However, the Visceral Sensitivity Index is limited to lower GI symptoms and its single factor structure does not differentiate between the different aspects of GI-specific anxiety (e.g., catastrophizing, sensitivity, avoidance). GI-specific hypervigilance, or threat-induced attention to the body, is a cognitive-affective process related to but believed to be distinct from GI-specific anxiety (Taft et al., 2018; Van Oudenhove et al., 2016). GI-specific hypervigilance is independently associated with GI symptom severity in several upper GI disorders (Taft et al., 2021). GI-specific hypervigilance has yet to be independently evaluated in the context of elevated eating pathology. However, research on attentional bias shows that individuals with eating disorders have increased vigilance and bias to general threat (Stott et al., 2021). For those experiencing GI symptoms, heightened attention to the body may translate into GI-specific hypervigilance. Given the potential shared cognitive-affective processes and bidirectional relationship between GI symptoms and eating disorders, further exploration of the role of GI-hypervigilance in eating disorders is warranted. Thus, there is a need to measure broader aspects of GI-specific anxiety as well as hypervigilance in those with elevated eating pathology.

The Esophageal Hypervigilance and Anxiety Scale (EHAS; Taft et al., 2018) was developed to measure symptom-specific anxiety and hypervigilance in patients with esophageal symptoms (e.g., heartburn, dysphagia) regardless of underlying pathophysiology or diagnosis. Despite the disease-specific nature of the EHAS, the items measure the degree to which respondents experience anxiety and hypervigilance to esophageal symptoms broadly (e.g., “I often worry about problems in my throat/chest/esophagus”), as opposed to specific experiences that are unique to esophageal patients (e.g., anxiety/hypervigilance about food getting stuck in the throat). Therefore, the EHAS items can be easily adapted to capture anxiety and hypervigilance related to various GI symptoms across the GI tract, including the stomach and lower bowel. Such a measure would be useful in measuring GI-specific anxiety and hypervigilance in individuals with elevated eating pathology, where individuals may experience a

wide range of GI symptoms (Riedlinger et al., 2020). Identifying a measure of GI-specific anxiety and hypervigilance for use in this sample would provide a tool to better understand factors related to the gut-brain interaction and inform future mechanistic work within the field.

This study is the first to validate a modified version of the EHAS (replacing "throat/chest/esophagus" with "gut") to measure anxiety and hypervigilance towards GI symptoms in undergraduate students with elevated eating pathology. Such a measure will facilitate future mechanistic work. Undergraduate students are an appropriate population to study as late adolescence captures the peak onset for eating pathology (Smink et al., 2012) and approximately 12% of college students have elevated eating disorder risk, with 30 to 40% of college students reporting eating disorder behaviors (Lipson & Sonneville, 2017). To increase generalizability to those with eating disorders, we selected undergraduate students who had elevated scores on measures of eating pathology (see Participants and Procedures). Aim 1 sought to confirm the factor structure in a sample of undergraduate students with elevated eating pathology. We hypothesized that, similar to the original EHAS, a two-factor model would fit best. Aim 2 sought to evaluate internal consistency and test-retest reliability. We hypothesized that the modified EHAS scores would have good internal consistency, evidenced by a Cronbach's alpha above .70, and good test-retest reliability across two weeks, evidenced by an intraclass correlation coefficient (ICC) above .60. Aim 3 sought to evaluate convergent and discriminant validity using measures of general and lower GI-specific anxiety, GI symptom severity, and eating disorder symptoms. We hypothesized that the modified EHAS scores would have good convergent validity, evidenced by a positive correlation of at least .30 with measures of anxiety sensitivity, lower GI-specific anxiety, GI symptoms, and somatic symptoms. We also hypothesized that the modified EHAS scores would have good discriminant validity, as evidenced by a correlation lower than .30 with measures of unrelated constructs (weight bias, behaviors to increase muscularity). Exploratory aims include 1) comparing the measurement invariance between those with elevated shape/weight-oriented eating pathology and with

elevated ARFID-related pathology, 2) exploring the factor structure of a short-form, 7-item version (Taft et al., 2022), and 3) exploring study Aims 1-3 by diagnostic group and 4) with the short-form version.

Methods

Participants and Procedures

University students aged eighteen and older were recruited through the psychology department research participant pool to complete online surveys at public universities in Appalachia and the southern United States. All participants provided informed consent and study procedures were approved by the local institutional review boards. Participants received partial course credit. The data analytic plan was preregistered through Open Science Foundation (https://osf.io/tfu6p).

Recruitment procedures varied by site. Participants at the Appalachian university were invited to participate pending a positive screen for elevated eating pathology (see Measures – Eligibility Criteria). Eligibility was re-confirmed using Time 1 data. No screening procedures were used at the southern university; however, only the subset of individuals who met the same positive screening criteria for elevated eating pathology were included in analyses. Recruitment continued until at least 200 participants who passed sufficient effort responding criteria were enrolled at the Appalachian university in order to be powered for a CFA; recruitment then continued until the end of the academic semester. Data from the southern university were then added, resulting in the current sample size. Participant data at Time 1 was excluded if participants 1) took the survey rapidly (i.e., spent less than two seconds per item, on average) or 2) failed 50% or more of embedded insufficient effort responding items (Curran, 2016; Huang et al., 2015). Only participants who passed these checks were eligible to participate at Time 2. In total, 382 participants provided usable data at Time 1 and 238 provided data at Time 2 (62.3% retention). Participants participated at Time 2 on average 16.80(3.77) days after Time 1. In total, 310 individuals with elevated shape/weight-oriented eating pathology and 72 individuals

with elevated ARFID-related pathology participated. The discrepancy from the pre-registration (n=399 at Time 1) reflects a coding error in which 17 participants who endorsed eating disorder behaviors, elevated ARFID measures, and had EDE-Q8 scores < 2.3 were categorized as having both elevated shape/weight-oriented eating pathology and elevated ARFID-related pathology. These individuals were reclassified as elevated shape/weight-oriented eating pathology, only.

Participants reported a M(SD) age of 19.96(3.99) years. Most participants identified as white (87.4%, n = 334), with others identifying Black/African American (4.2%; n = 16), Asian or Asian American (2.4%; n = 9), Native Hawaiian or Pacific Islander (0.5%, n = 2), American Indian or Native Alaskan (0.3%; n = 1), more than one race (2.4%; n = 9), preferred to self-describe (0.8%; n = 3), or missing data (2.1%; n = 8). A minority (2.6% n = 10) identified as Hispanic or Latino. Most participants identified as female (83.5%; n = 319), with 14.7% (n = 56) identifying as male and 1.8% (n = 7) identifying as transgender, gender queer, or self-describing. Most participants reported that they were heterosexual (78.5%, n = 300), with 14.7% (n = 56) identifying as bisexual, 2.9% (n = 11) identifying as gay or lesbian, and 3.9% (n = 15) self-describing their sexual orientation.

Measures

Eligibility Criteria

Eating Disorder Examination Questionnaire-8 (EDE-Q8; Kliem et al., 2016). The EDE-Q8 was used for screening at the Appalachian university and administered at Time 1 and Time 2 at both sites. Participants who scored $\geq$ 3.88 on the EDE-Q8 (Machado et al., 2020) were categorized as having elevated shape/weight-oriented eating pathology. This cut-off score had a good AUC (.83) in distinguishing between eating disorder patients and non-clinical controls.

Eating Disorder Examination Questionnaire (EDE-Q; Fairburn & Beglin, 1994). The behavioral items from the EDE-Q were administered at screening, Time 1, and Time 2.

Participants who endorsed engaging in eating disorder behaviors 4 or more times in the past month were categorized as having elevated shape/weight-oriented eating pathology. Behavioral items included objective binge-eating, self-induced vomiting, laxative misuse, and compulsive exercise. Agreement with the EDE interview is moderate for binge-eating and strong for purging behaviors (Berg et al., 2011). A minority of participants (10.6%; n = 33) endorsed symptoms consistent with binge-eating disorder (i.e., recurrent binge-eating in the absence of self-induced vomiting, laxative misuse, and compulsive exercise). These participants are included the elevated shape/weight-oriented eating pathology given the "traditional" eating disorder presentation. We chose to avoid referencing the group as "traditional" eating pathology to avoid stigmatizing language and to increase readability.

Nine Item Avoidant Restrictive Food Intake Screen (NIAS; Zickgraf & Ellis, 2018). The NIAS was administered at screening, Time 1, and Time 2. It comprises three subscales: Picky Eating/Sensory, Lack of Interest/Low Appetite, and Fear of Aversive Consequences. We utilized cut offs of ≥10 on the Picky Eating/Sensory subscale, ≥9 on the Lack of Interest/ Low Appetite subscale, and ≥10 on the Fear of Aversive Consequences subscale. Participants who met one of these criteria were categorized as elevated ARFID-related pathology if they also scored less than 2.3 on the EDE-Q8. This combined approach has AUC values between .59 and .84 in distinguishing ARFID from shape/weight-oriented eating disorders (Burton Murray, Dreier, et al., 2021).

Primary Measure

Esophageal Hypervigilance and Anxiety Scale (EHAS; Taft et al., 2018).[1] The EHAS is a 15-item questionnaire measuring esophageal hypervigilance and symptom specific anxiety. Items were modified by replacing "throat/chest/esophagus" with "gut" to make them more generalizable to symptoms affecting the entire digestive tract. The Total, Anxiety, and

[1] Researchers interested in using the modified EHAS in future should contact TNT.

Hypervigilance scores had good internal consistency and exhibited moderate associations with measures of esophageal symptoms in a sample of patients with esophageal disorders (Taft et al., 2018). In the present study, participants were instructed to rate their agreement with statements such as “I can’t seem to keep gut symptoms out of my mind” and “I anxiously want the gut symptoms to go away” over the past month. Response options were: 0=Strongly Disagree, 1 = Somewhat Disagree, 2 = Neither Agree nor Disagree, 3 = Somewhat Agree, and 4= Strongly Agree. Items were summed to make scale scores; higher scores indicate greater anxiety and hypervigilance surrounding gut symptoms. This measure was administered at both Time 1 and 2.

Convergent Validity Measures

Anxiety Sensitivity Index-3 (ASI-3; Taylor et al., 2007). This 18-item questionnaire measures anxiety sensitivity, the interpretation of anxiety-related bodily sensations and cognitions as dangerous. Supporting its construct validity, ASI-3 scores exhibit moderate to strong relationships with body vigilance and anxiety in psychiatric samples (Kemper et al., 2012). Cronbach’s alpha was .92 in the current sample.

Visceral Sensitivity Index (VSI; Labus et al., 2004). The 13-item scoring of this questionnaire that measures lower GI-specific anxiety was used (Brown et al., 2021). Both the 13 and 15-item version exhibit large associations with the ASI-3 (Brown et al., 2021; Labus et al., 2004), and the 15-item version exhibited a large association with irritable bowel symptom severity (Labus et al., 2004). Cronbach’s alpha was .92. The pattern of results was the same using the 15-item scoring.

Patient Assessment of Gastrointestinal Symptom Severity Index (PAGI-SYM; Rentz et al., 2004). This 20-item questionnaire measured self-reported severity of upper GI symptoms. This measure yields six subscales including heartburn/regurgitation, early satiety/postprandial fullness, nausea/vomiting, bloating/distension, upper abdominal pain, and

lower abdominal pain. Scores exhibit moderate to large associations with symptom severity in GI outpatients (Rentz et al., 2004). Cronbach's alpha ranged from .73 to .94 across subscales.

Patient Assessment of Constipation Symptom Severity Index (PAC-SYM;L. Frank et al., 1999). This 12-item questionnaire measures symptoms that can be associated with constipation and was used in this study as a measure of lower GI symptom severity. There are three subscales: Abdominal, Rectal, and Stool symptoms. Scores are moderately to strongly correlated with patient and clinician measures of constipation severity (L. Frank et al., 1999). Cronbach's alpha ranged from .77 to .89 across subscales in the present sample.

Patient Health Questionnaire-15 (PHQ-15; Kroenke et al., 2002). The PHQ-15 is a measure of somatic symptom severity. Scores exhibit strong associations with self-reported pain and moderate associations with physical functioning (Kroenke et al., 2002). Cronbach's alpha was .79.

Discriminant Validity Measures

Eating Pathology Symptoms Inventory (EPSI; Forbush et al., 2013).[2] The Negative Attitudes Toward Obesity and Muscle Building subscales measured negative perceptions of overweight/obese individuals and engagement in extremely effortful or time-intensive exercise, respectively. The Negative Attitude Towards Obesity subscale has been conceptualized as measure of weight bias (Palermo et al., 2021) and scores exhibit small to moderate associations with eating pathology (Forbush et al., 2014). The Muscle Building Scale scores exhibit a moderate to strong association with muscularity concerns, but negligible associations with weight and shape concerns (Forbush et al., 2013). Internal consistency was adequate for

[2] The instructions of the Eating Pathology Symptoms Inventory were modified to administer online. From "Development and validation of the Eating Pathology Symptoms Inventory," by Forbush, K. T, et al. 2013, Psychological Assessment, 25, 859-878. Copyright © 2011 by Kelsie T. Forbush. Adapted in our research with permission, but not reproduced herein. No further reproduction, modification, or distribution of the Eating Pathology Symptoms Inventory, derivative versions, or translated versions is permitted without advance, written permission from the copyright holder (Dr. Kelsie Forbush).

Negative Attitudes Toward Obesity (alpha = .88) and Muscle Building (alpha = .73) scores in the present sample.

Data Quality Checks

Insufficient Effort Responding. Eight improbable items from the Infrequency Insufficient Effort Responding scale (Huang et al., 2015) were embedded within study questionnaires as attention checks at Time 1.

Ancillary Measures Not Analyzed

The following measures were included in data collection, but not utilized in analyses, at both universities at Time 1: The Eating Disorder Diagnostic Scale for DSM-5 (Stice, n.d.), a list of common gastrointestinal conditions, and the WHOQOL-BREF (The WHOQOL Group, 1998). At the southern university, the Multidimensional Assessment of Interoceptive Awareness 2 (Mehling et al., 2018) and the Body Vigilance Scale (Schmidt et al., 1997) were administered at Time 1 and the Eating Pathology Symptoms Inventory (Forbush et al., 2013) was administered at Time 2.

Data Analytic Plan

Confirmatory factor analysis (CFA) evaluated the factor structure of the modified EHAS. We estimated two models: 1) a one-factor model where all items load onto the same factor; 2) a two-factor model with an Anxiety factor (items 1-9) and a Hypervigilance factor (items 10-15) based on the original EHAS factor structure. The model fit was evaluated based on a combination of the standardized root mean square residual (SRMR) with either the root mean square error of approximation [RMSEA], or the comparative fit index [CFI]. The following thresholds were used to evaluate model fit: CFI ≥ .95 and SRMR ≤ .08 OR RMSEA ≤ .06 and SRMR ≤ .08 (Hu & Bentler, 1999). We then compared the two models to identify the model with the best fit. The CFA was estimated consistent with the procedures used in Brown et al. (2021). Items with factor loadings < .60 and inter-item correlations < .30 were removed. The best fitting model was used for subsequent analyses.

Reliability of the best-fitting modified EHAS model was examined by calculating Cronbach's alpha and the two-way random effects intra-class correlation coefficients (ICC) across two weeks. Zero-order correlations evaluated convergent and discriminant validity. Data and code for data analyses are available at https://osf.io/gh624/.

We pre-registered an exploratory aim to evaluate factor invariance between the two eating pathology subgroups; however, upon reflection, the elevated ARFID-related pathology sample size was too small to permit meaningful analyses. Consistent with the pre-registration, a supplemental analysis examined the factor structure of a 7-item short form version (Taft et al., 2022). Supplemental analyses also examined the reliability and validity within subgroups and a 7-item version of the scale (Taft et al., 2022). We post-hoc decided to examine the model fit within the elevated weight/shape-oriented eating pathology group, only.

Transparency and Openness

The study's analysis plan was preregistered and data and code are available at https://osf.io/gh624/. Materials are available by emailing the corresponding author. Data analyses were conducted using IBM SPSS Statistics version 29 (reliability and correlations) and lavaan 0.6.15 (Rosseel, 2012) in R.4.2.0 (confirmatory factor analysis; (R Core Team, 2022). We report how we determined sample size, data exclusions, all measures included in the study, and we follow JARS (Kazak, 2018).

Results

Model Fit

Item distributions were assessed to consider the estimation method for confirmatory factor analyses (CFA). Given that data were ordinal, diagonally weighted least squares (WLSMV) was used as an estimator, which has demonstrated less biased and more accurate fit compared to other estimation methods (e.g., robust maximum likelihood Li, 2016). There were no missing data for modified EHAS items. Multivariate normality for all EHAS items was

assessed through Mardia's test (skewness statistic = 22.51, $p < .001$; kurtosis statistic = 281.27, $p < .001$).

Table 1 provides the factor loadings for the 1-factor, 2-factor, and brief 1-factor model. Model fit indices for the 1-factor CFA model were Robust CFI = .83, Robust RMSEA (90% CI) = .16(.14-.17), SRMR = .08. All items loaded significantly on the single factor (see Table 1). Of note, item 7 had several inter-item correlations below the .30 threshold (with items 10, 11, & 15; see Supplemental Table 1), however, since this item met the ≥ .60 cutoff for factor loadings, we chose to retain item 7 within the model. Similarly, item 8 did not meet the ≥ .60 cutoff for factor loadings, but all inter-item correlations were ≥ .30; thus, we also chose to retain item 8. Notably, the 1-factor model did not meet the standards for acceptable model fit (CFI ≥ .95 and SRMR ≤ .08 or RMSEA ≤ .06 and SRMR ≤ .08).

Model fit indices for the 2-factor (Anxiety & Hypervigilance) CFA model had improved fit that did not meet the pre-registered threshold for acceptable fit (Robust CFI =.92, Robust RMSEA (90% CI) = .11(.10-.13), SRMR = .05). Similar to within the 1-factor model, item 8 did not meet the ≥ .60 cutoff for factor loadings, but all inter-item correlations were ≥ .30, and thus item 8 was retained. The 2-factor model has a preferable fit and was used for further analyses.

Reliability

Because the two-factor model was the best fit, we report analyses at the subscale level. Internal consistency of the Anxiety and Hypervigilance subscale scores was good at Time 1 (Cronbach's alpha = .92 and .87, respectively) and Time 2 (Cronbach's alpha = .92 and .84, respectively). Test-retest reliability was good across two weeks with an ICC of .77 (95% CI = .71-.82) for Anxiety scores and an ICC of .64 (95% CI = .56-.71) for Hypervigilance scores.

Convergent and Discriminant Validity

Table 2 displays correlations between the modified EHAS subscales and questionnaires. Anxiety subscale scores did not exhibit the expected association with general anxiety sensitivity; however, Anxiety was strongly correlated with lower GI-anxiety. As hypothesized, Anxiety

subscale scores were moderately to strongly positively correlated with measures of specific GI symptoms. Finally, Anxiety subscale scores had negligible associations with our discriminant validity measures, Negative Attitudes Toward Obesity and Muscle Building.

Similarly, Hypervigilance subscale scores did not exhibit the expected association with anxiety sensitivity. Associations with nausea/vomiting, postprandial fullness/early satiety, and bloating did not meet the *a priori* threshold for convergent validity. All other convergent validity hypotheses were supported. As hypothesized, Hypervigilance subscale scores had negligible associations with Negative Attitudes Toward Obesity and Muscle Building.

Supplemental Analyses

Short Form Modified EHAS Model Fit

We tested the model fit of the 7-item 1-factor CFA model, which also did not meet the *a priori* threshold for acceptable fit (Robust CFI = .90, Robust RMSEA (90% CI) =.17 (.14 - .20), SRMR =.07). As noted previously, item 7 had several inter-item correlations that were below the .30 threshold (with items 11 & 15); however, item 7 did meet the ≥. 60 cutoff for factor loadings. Notably, items 8, 11, and 15 also did not meet the ≥ .60 cutoff for factor loadings. For item 8, all inter-item correlations were ≥ .30. As noted above, items 11 and 15 had item-item correlations with item 7 that were under .30, suggesting potential problematic item fit.

Model Fit in Individuals with Elevated Shape/Weight-Oriented Eating Pathology

These post hoc analyses were not included in the pre-registration. Supplemental Table 2 provides the factor loadings for the 1-factor, 2-factor, and brief 1-factor model within the elevated shape/weight-oriented eating pathology subgroup. Overall, model fit is comparable to the full sample across all three models. Model fit indices for the 1-factor CFA model did not meet the *a priori* threshold (Robust CFI = .83, Robust RMSEA (90% CI) = .16(.14-.17), SRMR = .08). All items loaded significantly on the single factor (see Supplemental Table 2). As in the full sample, item 7 had several inter-item correlations below the .30 threshold (with items 10, 11, & 15); because item 7 met the ≥ .60 cutoff for factor loadings, it was retained. Items 8 and 15 did

not meet the ≥ .60 cutoff for factor loadings. Item 8 had inter-item correlations ≥ .30 and was retained. As noted above, item 15 had a low correlation with item 7, suggesting potential problematic item fit.

In contrast, model fit indices for the 2-factor (Anxiety & Hypervigilance) CFA model had improved fit that did not meet the pre-registered threshold for fit (Robust CFI =.91, Robust RMSEA (90% CI) = .12(.10-.13), SRMR = .06). Item 8 did not meet the ≥ .60 cutoff for factor loadings, but all inter-item correlations were ≥ .30, and thus item 8 was retained.

The 7-item 1-factor CFA model also did not reach the pre-registered threshold for fit in the subgroup with elevated weight/shape eating pathology (Robust CFI = .90, Robust RMSEA (90% CI) =.16 (.13 - .20), SRMR =.07). Item 7 had several inter-item correlations that were below the .30 threshold (with items 11 & 15); however, item 7 did meet the ≥. 60 cutoff for factor loadings. Similar to the full sample, items 8 and 15 did not meet the ≥ .60 cutoff for factor loadings. For item 8, all inter-item correlations were ≥ .30. As in the full sample, items 11 and 15 had item-item correlations with item 7 that were under .30, suggesting potential problematic item fit.

Subgroup Reliability and Validity Analyses

Elevated Shape/Weight-Oriented Eating Pathology. Cronbach's alpha was good for both the Anxiety and Hypervigilance subscale scores at Time 1 (.92 and .86, respectively) and Time 2 (.92 and .84, respectively). Two-week test-retest reliability was excellent for the Anxiety subscale score, ICC = .80 (95% CI = .74 - .84) and good for the Hypervigilance subscale score, ICC = .67 (95% CI = .58 - .74). The pattern of results largely mirrored those of the primary analyses (see Table 3), with the exception that anxiety sensitivity was positively correlated with Anxiety subscale scores at the *a priori* threshold and bloating was positively correlated with Hypervigilance subscale scores at the *a priori* threshold.

Elevated ARFID-Related Pathology. Cronbach's alpha was good for both the Anxiety and Hypervigilance subscale scores at Time 1 (.94 and .90, respectively) and Time 2 (.93 and

.83, respectively). Two-week test-retest reliability was good for Anxiety subscale scores, ICC = .68 (95% CI = .48 - .82) and fair for Hypervigilance subscale scores, ICC = .53 (95% CI = .28 - .72). The pattern of results largely mirrored those of the primary analyses, with the exception that Anxiety subscale scores were not associated with Nausea/Vomiting at the *a priori* threshold whereas bloating was positively correlated with Hypervigilance subscale scores at the *a priori* threshold.

Short Form Modified EHAS Reliability and Validity

Cronbach's alpha was good at Time 1 (.84) and Time 2 (.83). Two-week test-retest reliability was also good, ICC = .72 (95% CI = .65 - .78). The pattern of correlations with convergent and discriminant validity measures mirrored those of the Anxiety subscale (see Table 5).

Discussion

The present study sought to validate a modified version of the EHAS to measure anxiety and hypervigilance towards GI symptoms in individuals with elevated eating pathology. The 2-factor model (anxiety, hypervigilance) of the modified EHAS provided a better fit compared to a 1-factor model and a 7-item 1-factor model. None of the models met the pre-registered threshold for fit. Notably, the 7-item, 1-factor model exhibited several problematic loadings and inter-item correlations. This pattern was the same when restricted to the elevated shape/weight-related eating pathology subgroup. Both Anxiety and Hypervigilance subscale scores of the final 2-fatcor model displayed good internal consistency, good test-retest reliability, good discriminant validity, and convergent validity with measures of GI-specific anxiety and GI symptoms, with some exceptions.

CFA results supporting the superior fit of the 2-factor (Anxiety, Hypervigilance) version in individuals with elevated eating pathology are consistent with prior EHAS research in samples of individuals with esophageal symptoms (Taft et al., 2018). Notably, poor inter-item correlations were only present when requiring that all items load onto a single factor. Results are further

consistent with research supporting that GI-specific hypervigilance and GI-specific anxiety are distinct, but related, processes (Taft et al., 2018; Van Oudenhove et al., 2016). The 1-factor model did not provide a sufficient fit to the data in the sample with elevated eating pathology, suggesting that a total score for the modified EHAS may not be appropriate within an eating disorder sample. Exploratory analyses of the short form version of the modified EHAS (Taft et al., 2022) revealed that several items had poor inter-item correlations or factor loadings within the single-factor structure. This further suggests that conflating GI-specific anxiety and hypervigilance in samples with elevated eating pathology may be problematic. As such, we recommend that future research using the modified EHAS use the 2-factor version.

Anxiety and Hypervigilance subscale scores showed good internal consistency in the full sample and two subgroups. While Anxiety subscale scores showed good test-retest reliability in the full sample and both subgroups, Hypervigilance subscale scores only showed good test-retest reliability in the full sample and elevated shape/weight-oriented eating pathology subgroup. This may reflect the smaller sample of individuals with elevated ARFID-related pathology. Interestingly, across the full sample and subgroups, Hypervigilance subscale scores tended to have lower test-retest reliability than the Anxiety subscale scores. Future research may wish to compare the temporal stability of hypervigilance around GI symptoms in eating disorder samples in order to inform etiological and maintenance models.

Overall, analyses support the convergent and discriminant validity of the Anxiety and Hypervigilance subscale scores of the modified EHAS in populations with elevated eating pathology. In the full sample and the two subgroups, subscale scores exhibited high correlations with the VSI, a unidimensional measure of lower GI-specific anxiety (Labus et al., 2004). Given that the original EHAS measure adapted several items from the Visceral Sensitivity Index (another measure of GI-specific anxiety), the correlations between these measures are likely inflated. However, correlations between the modified EHAS and the Visceral Sensitivity Index, particularly the Hypervigilance subscale, are not so high as to confer that they are not distinct.

Surprisingly, the modified EHAS subscale scores had weaker associations with general anxiety sensitivity, which did not reach our *a priori* threshold for evidence of convergent validity. This is particularly surprising given large associations between the Visceral Sensitivity Index and general anxiety sensitivity in an eating disorder sample (Brown et al., 2021). This difference might reflect Brown and colleague's use of Spearman's Rho, rather than a Pearson correlation. To test this post-hoc explanation, we re-ran analyses using Spearman's Rho and found the same effect sizes (Anxiety Rho = .27, Hypervigilance Rho = .24.). As the relative difference in effect sizes persisted, this suggests that the Anxiety and Hypervigilance subscales are tapping into slightly different, and perhaps more expanded, constructs related to anxiety and hypervigilance than the Visceral Sensitivity Index. More research is needed to better understand to what extent the constructs measured by the Visceral Sensitivity Index and EHAS overlap or are distinct.

The Anxiety subscale scores exhibited moderate to large associations with GI symptoms across the GI tract as well as a measure of somatic symptoms in the full sample. These findings were largely replicated in the subgroup analyses, with the Anxiety subscale scores failing to reach the *a priori* threshold with nausea/vomiting in the elevated ARFID-related pathology subgroup. These findings confirm the relevance of GI-specific anxiety to GI symptoms within populations with elevated eating pathology. In contrast, the Hypervigilance subscale scores did not reach the *a priori* threshold for associations with nausea/vomiting, postprandial fullness/early satiety, and bloating in the full sample and both subgroups. While these associations are not meaningfully different from the *a priori* threshold, Hypervigilance subscale scores exhibited significantly smaller associations with the VSI, GI symptoms, and somatic symptoms than Anxiety subscale scores in post hoc tests comparing correlation coefficients in the full sample (Z's $\geq$ 2.30, one-tailed p's $\leq$ .01). Pending replication, this may indicate that anxiety and hypervigilance play different roles in the etiology or maintenance of GI symptoms and eating

pathology. Given the range of effect sizes observed (.27 - .67), the relevance of anxiety and hypervigilance may also differ based on specific symptom.

Finally, we *a priori* selected two measures that should not have theoretical relevance to GI symptoms to evaluate discriminant validity: Negative Attitudes Towards Obesity and Muscle Building. Supporting discriminant validity, these two measures exhibited negligible associations with the modified EHAS subscale scores. This increases confidence that the subscales have specificity to GI-specific anxiety and hypervigilance.

Strengths and Constraints on Generality

This study had a number of strengths including selecting a sample with elevated eating pathology, pre-registering hypotheses and analyses, use of measures with well-established psychometric properties, and use of attention checks for data quality purposes. We used a robust estimator and fit statistics. Model fit did not reach the pre-registered threshold, suggesting that adding or revising items may be helpful in better quantifying these constructs in future versions of the scale. While our sample was diverse in sexual orientation, we had limited variability in gender and racial/ethnic background, and all participants had the financial means to be enrolled in college in the United States. This limits the generalizability of findings to all individuals with elevated eating pathology, particularly those who do not identify as female, are not white, are of lower socioeconomic status, and those in different cultural contexts. Due to a small sample of individuals with elevated ARFID-related pathology, we were unable to evaluate measurement invariance across different symptom presentations. Future research should investigate if GI-specific anxiety and hypervigilance functions similarly, or differently, between ARFID and other DSM-5 eating disorders. Finally, these results are preliminary given the absence of interview-confirmed eating disorder diagnoses. Future research should evaluate how the modified EHAS performs in different eating disorder populations, including those with interview-confirmed eating disorder diagnoses.

Conclusion

Taken together, the present study provides preliminary support for the psychometric properties of the modified EHAS Anxiety and Hypervigilance subscales in samples of individuals with elevated eating pathology. The current measure has the benefit of measuring all types of GI symptoms, which may reduce participant burden relative to measures of specific GI symptoms. The modified EHAS provides additional nuance in differentiating between two aspects of this construct, anxiety and hypervigilance, that are conflated within existing measures (e.g., VSI; Brown et al., 2021; Labus et al., 2004). The validation of the modified EHAS will allow for future research to examine whether GI-specific anxiety, hypervigilance, or both are associated with eating pathology cross-sectionally and longitudinally. Indeed, the overall pattern of results support distinguishing between anxiety and hypervigilance and suggest future research should consider these domains separately.

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Table 1

Factor Loadings and Item-Total correlations of a modified Esophageal Hypervigilance and Anxiety Scale (EHAS) in a sample of undergraduate students with elevated eating pathology

	1-factor Solution			2-factor Solution			1-Factor Short Form		
Items	Std Load	SE	Item-Total rho	Std Load	SE	Item-Total rho	Std Load	SE	Item-Total rho
ANXIETY									
1. Can't keep gut symptoms out of mind	.863	.000	.81	.879	.000	.83	-	-	-
2. Difficult time enjoying myself	.878	.023	.80	.890	.023	.82	-	-	-
3. Symptoms are awful, overwhelming	.903	.022	.83	.914	.022	.85	.892	.000	.82
4. Worry during the day	.848	.024	.79	.861	.024	.83	.836	.028	.80
5. Worry about problems in my gut	.856	.024	.81	.869	.024	.84	-	-	-
6. Symptoms are terrible, never going to get better	.866	.025	.80	.879	.024	.84	.917	.024	.82
7. Nothing I can do	.650	.036	.61	.667	.036	.70	.724	.033	.68
8. Discomfort in my gut frightens me	.565	.042	.56	.583	.043	.59	.555	.047	.62
9. Want symptoms to go away	.811	.025	.80	.836	.026	.81	-	-	-
HYPERVIGILANCE							-	-	-
10. Notice changes in gut symptoms	.778	.030	.70	.835	.000	.79	-	-	-
11. Aware of sudden changes	.759	.033	.64	.803	.038	.76	.596	.047	.62
12. Notice symptoms even if I am busy	.767	.030	.71	.823	.034	.79	-	-	-
13. Focus on sensations	.744	.031	.73	.811	.038	.79	-	-	-
14. Sensitive to sensations	.784	.027	.74	.853	.035	.80	-	-	-
15. Keep track of symptoms	.601	.041	.61	.653	.048	.70	.578	.046	.65

Note. Items were modified from the original EHAS by replacing "throat/chest/esophagus" with "gut" to make them more generalizable to symptoms affecting the entire digestive tract.

Table 2

Convergent and Discriminant Validity of a Modified Esophageal Hypervigilance and Anxiety Scale (EHAS) Anxiety and Hypervigilance Subscales in a Sample of Undergraduate Students with Elevated Eating Pathology

Measure Name	*r* Anxiety	*r* Hypervigilance	Mean	SD	Observed Range	N
Modified EHAS – Anxiety Subscale	--	--	12.80	9.45	0-36	382
Modified EHAS – Hypervigilance Subscale	.72***	--	11.96	6.15	0-24	382
Anxiety Sensitivity Index -3	.27***	.24***	28.53	15.26	2-71	381
Visceral Sensitivity Index (13 item)	**.81*** **	**.64*** **	24.88	14.68	0-62	381
Nausea/Vomiting	**.37*** **	.27***	.83	.88	0-4.67	382
Postprandial Fullness/Early Satiety	**.40*** **	.29***	2.09	1.08	0-5	382
Bloating	**.43*** **	.29***	2.46	1.45	0-5	382
Upper abdominal pain	**.54*** **	**.40*** **	1.10	1.26	0-5	382
Lower abdominal pain	**.59*** **	**.46*** **	1.54	1.38	0-5	382
Heartburn/Regurgitation	**.44*** **	**.36*** **	.87	.93	0-4.71	382
Abdominal Symptoms	**.67*** **	**.53*** **	1.32	.87	0-4	382
Rectal Symptoms	**.46*** **	**.35*** **	.68	.79	0-3.67	382
Stool Symptoms	**.53*** **	**.43*** **	1.15	.95	0-4	382
Patient Health Questionnaire-15	**.53*** **	**.40*** **	12.27	5.08	0-28	380
Negative Attitudes Toward Obesity	**-.01**	**-.01**	5.30	4.42	0-20	380
Muscle Building	**-.001**	**.02**	3.39	3.39	0-20	380

Note: Bold correlation coefficients indicate hypotheses were supported.

*** $p < .001$

Table 3

Convergent and Discriminant Validity of a Modified Esophageal Hypervigilance and Anxiety Scale (EHAS) Anxiety and Hypervigilance Subscales in a Sample of Undergraduate Students with Elevated Shape/Weight-Oriented Eating Pathology

Measure Name	*r* Anxiety	*r* Hypervigilance	Mean	SD	Observed Range	N
Modified EHAS- Anxiety Subscale	--	--	12.76	9.23	0-36	310
Modified EHAS- Hypervigilance Subscale	.71***	--	11.88	5.98	0-24	310
Anxiety Sensitivity Index -3	**.31*** **	.28***	28.77	15.27	2-71	310
Visceral Sensitivity Index (13 item)	**.79*** **	**.64*** **	25.03	14.30	0-62	310
Nausea/Vomiting	**.39*** **	.28***	.82	.89	0 – 4.67	310
Postprandial Fullness/Early Satiety	**.38*** **	.28***	2.06	1.05	0-5	310
Bloating	**.45*** **	**.31*** **	2.63	1.43	0-5	310
Upper abdominal pain	**.53*** **	**.39*** **	1.08	1.23	0-5	310
Lower abdominal pain	**.57*** **	**.45*** **	1.54	1.36	0-5	310
Heartburn/Regurgitation	**.42*** **	**.35*** **	.87	.92	0-4.43	310
Abdominal Symptoms	**.67*** **	**.53*** **	1.35	.86	0 – 4	310
Rectal Symptoms	**.42*** **	**.34*** **	.71	.78	0-3.67	310
Stool Symptoms	**.54*** **	**.46*** **	1.20	.93	0-4	310
Patient Health Questionnaire-15	**.56*** **	**.42*** **	12.36	14.30	0-28	309
Negative Attitudes Toward Obesity	**.02**	**.04**	5.60	4.33	0-20	309
Muscle Building	**-.01**	**.004**	3.54	3.42	0-20	309

Note. Bold correlation coefficients indicate hypotheses were supported.

*** $p < .001$

Table 4

Convergent and Discriminant Validity of a Modified Esophageal Hypervigilance and Anxiety Scale (EHAS) Anxiety and Hypervigilance Subscales in a Sample of Undergraduate Students with Elevated Avoidant/Restrictive Food Intake Disorder-Related Pathology

Measure Name	*r* Anxiety	*r* Hypervigilance	Mean	SD	Observed Range	N
Modified EHAS– Anxiety	--	--	12.96	10.44	0-35	72
Modified EHAS– Hypervigilance	.74***	--	12.28	6.88	0-24	72
Anxiety Sensitivity Index -3	.14	.11	27.49	15.25	3-67	71
Visceral Sensitivity Index (13 item)	**.87*** **	**.63*** **	24.20	16.33	0-60	71
Nausea/Vomiting	.26*	.26*	.89	.88	0 – 4	72
Postprandial Fullness/Early Satiety	**.46*** **	.29*	2.19	1.19	0-4.75	72
Bloating	**.46*** **	**.31** **	1.76	1.36	0-5	72
Upper abdominal pain	**.60*** **	**.42*** **	1.18	1.40	0-5	72
Lower abdominal pain	**.66*** **	**.47*** **	1.53	1.46	0-5	72
Heartburn/Regurgitation	**.52*** **	**.39*** **	.91	1.02	0-4.71	72
Abdominal Symptoms	**.70*** **	**.54*** **	1.16	.89	0-4	72
Rectal Symptoms	**.58*** **	**.39*** **	.59	.83	0-3.67	72
Stool Symptoms	**.52*** **	**.35** **	.94	.98	0-4	72
Patient Health Questionnaire-15	**.46*** **	**.34** **	11.84	5.07	2-21	71
Negative Attitudes Toward Obesity	**-.11**	**-.15**	4.03	4.60	0-18	71
Muscle Building	**.04**	**.08**	2.76	3.17	0-14	71

Note. Bold correlation coefficients indicate hypotheses were supported.

*p < .05; **p < .01; *** p < .001

Table 5

Convergent and Discriminant Validity of the Short Form Version of a Modified Esophageal Hypervigilance and Anxiety Scale (EHAS) in a Sample of Undergraduate Students with Elevated Eating Pathology

Measure Name	*r* Short Form	Mean	SD	Observed Range	N
Short-Form Modified EHAS	--	10.18	6.47	0-27	382
Anxiety Sensitivity Index -3	.26***	28.53	15.26	2-71	381
Visceral Sensitivity Index (13 item)	**.78*** **	24.88	14.68	0-62	381
Nausea/Vomiting	**.34*** **	.83	.88	0-4.67	382
Postprandial Fullness/Early Satiety	**.37*** **	2.09	1.08	0-5	382
Bloating	**.38*** **	2.46	1.45	0-5	382
Upper abdominal pain	**.50*** **	1.10	1.26	0-5	382
Lower abdominal pain	**.54*** **	1.54	1.38	0-5	382
Heartburn/Regurgitation	**.43*** **	.87	.93	0-4.71	382
Abdominal Symptoms	**.62*** **	1.32	.87	0-4	382
Rectal Symptoms	**.46*** **	.68	.79	0-3.67	382
Stool Symptoms	**.53*** **	1.15	.95	0-4	382
Patient Health Questionnaire-15	**.50*** **	12.27	5.08	0-28	380
Negative Attitudes Toward Obesity	**- .004**	5.30	4.42	0-20	380
Muscle Building	**.03**	3.39	3.39	0-20	380

Note. All correlations are with the short form modified Esophageal Hypervigilance and Anxiety Scale. Bold correlation coefficients indicate hypotheses were supported.

*** $p < .001$