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The Impact of Gastric State on Perceptual and Attitudinal Body Image Dimensions and Their Moderation by Eating Pathology

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Abstract

Background: Body image encompasses cognitive-affective attitudes and explicit and implicit body size perceptions. Although interoception is implicated in eating pathology, evidence directly linking gastrointestinal states to body image remains limited by caloric confounds, a dearth of research using perceptual measures, and narrow assessments of interoceptive facets. Methods: To address these gaps, this study (*n*=68) manipulated gastric state using the Water Load Test-II to evaluate how gastrointestinal sensitivity, over/underconfidence in sensitivity, and appraisal are related to baseline body image and disordered eating, if gastric state can change body image, and if this is moderated by disordered eating. Results: At baseline, elevated hunger-fear and fullness-shame predicted heightened eating shame, dietary restriction/preoccupation, and reduced baseline body satisfaction, with fullness-

shame uniquely predicting greater weight/shape concerns and restraint. Heightened gastrointestinal sensitivity predicted less certainty in judging an aperture as passable relative to body size, whereas underconfidence in gastrointestinal sensitivity predicted smaller waist size estimations and greater certainty in judging an aperture as passable relative to body size. Controlling for baseline body image, fullness significantly decreased body satisfaction, increased the width required for an aperture to be judged as passable relative to body size, and increased waist size estimations according to disordered eating severity. Eating disorder severity predicted lower certainty for an aperture as passable relative to body size. Conclusions: During nutritional eating disorder recovery, where postprandial fullness is unavoidable, unaddressed negative appraisal, hypervigilance, and over/underconfidence in gastric sensitivity may perpetuate body image distortions and uncertainty of body size. Eating to satiation, rather than complete fullness, may offer a behavioral goal for ongoing treatment once weight is stabilised.

Key words: Eating disorders; Body Image; Interoception

Plain English Summary

Our stomach sends signals, such as hunger and fullness, that help us decide how much to eat. People differ in how sensitive or how well they notice these signals, how well they think they notice them, and how they feel about them (e.g., fearful or ashamed). These differences, and the signals themselves, may matter for eating disorders and body image, but few studies have tested this. We first measured people's eating disorder symptoms, feelings about hunger and fullness, body satisfaction, perceived body size, and how certain they were about their size. We then measured body image again when people were hungry, satisfied, and completely full. People who were afraid of hunger or ashamed of fullness reported more eating-related shame, dietary restriction, and lower body satisfaction. Being ashamed of fullness was also related to more body weight and shape concerns and desire to

restrict food intake. Feeling completely full lowered body satisfaction and made people think a doorway needed to be wider to fit through it. The more eating disorder symptoms people had, the larger they estimated their waist when full. People more sensitive to stomach signals were less sure they could fit through a doorway, while those who underrated their sensitivity judged their waist smaller. As fullness is unavoidable during eating disorder recovery, treatment might consider addressing the negative feelings and body image difficulties that may arise with it.

List of Abbreviations

ED(s)= Eating Disorder(s)

JND= Just Noticeable Difference

WLT-II= Water Loading Test-II

BISS= Body Image States Scale

EDEQ= Eating Disorder Examination Questionnaire

NAGS=Negative Appraisal of Gastric Sensations Scale

Introduction

Body image broadly refers to the mental representation of one's own physical body (1). Negative body image is central to the etiology and maintenance of eating disorders (EDs) characterised by food restriction or compensatory behaviours such as Anorexia Nervosa and Bulimia Nervosa (2–6). Anorexia Nervosa exhibits the highest mortality rate of any mental illness, second only to opioid addiction (7–10), with EDs frequently resulting in severe medical complications and psychological distress (11,12). Furthermore, negative body image often persists post-recovery (13) and serves as a significant predictor of relapse (14,15). Understanding the mechanisms underlying the persistence of body image disturbances is critical to mitigating these clinical risks, but this is complicated by its multidimensional nature.

The cognitive-affective dimension of body image captures attitudes toward the perceived body, whereas the perceptual dimension (16), which is further divided into explicit beliefs about body size and implicit felt representations (17,18), assess the size and/or shape we perceive our body to be. Cognitive-affective body image is routinely assessed via attitudinal questionnaires, such as the Body Shape Questionnaire (19), whereas explicit body size perception is evaluated using size estimation tasks, requiring participants to estimate the width or circumference of specific body parts (20). In contrast, implicit body size perception is typically assessed via motor-imagery paradigms, such as the aperture task, wherein a passability ratio measures how wide a gap must be relative to each participants' shoulder width before being judged passable (17,21,22). This task is commonly paired with a standard psychophysical metric, the just-noticeable-difference (JND), which quantifies the minimum detectable difference between an aperture width and felt body size (23). A smaller JND indicates heightened perceptual sensitivity to spatial differences relative to the body, reflecting greater certainty in implicit body size judgments (24). Consequently, an individual can simultaneously overestimate their body size while maintaining high perceptual certainty in that judgment. Disruptions across cognitive-affective and perceptual domains manifest as body dissatisfaction, size overestimation, and enlarged passability thresholds, hallmark features of Anorexia Nervosa (25,26) that are also documented in subclinical populations reporting comparable functional impairment and distress (27–29).

Body image is not the only facet of bodily experience disrupted in EDs. Interoception (the sensing, interpretation, integration, and regulation of internal bodily signals; (30,31) is widely recognized as dysfunctional in body image-related eating disorders, including Anorexia Nervosa and Bulimia Nervosa (32–38). However, empirical evidence directly linking interoception to body image outcomes remains inconsistent. For instance, while several studies report significant correlations between heightened heartbeat detection ability (accuracy) and greater body satisfaction (39,40), others fail to observe such associations (41–43). Similarly, Zamariola et al. (44) observed no significant differences in explicit body

size estimation between individuals with high versus low cardiac interoceptive accuracy. These mixed findings may stem from a pervasive over-reliance on cardiac tasks in the interoception literature, which lack physiological or pathology-specific salience regarding body size and weight regulation (45).

Gastrointestinal interoception is intuitively linked to body image. Visceral sensations of hunger and fullness directly regulate dietary intake, subsequently shaping physical appearance and bodily self-evaluation. The Water Load Test-II (WLT-II; (46) serves as a standardised gastric perturbation protocol designed to experimentally induce distinct states of satiation and maximum fullness. In this task, participants begin at a state of hunger, and then ingest water until reaching comfortable satiation and subsequently maximum fullness, enabling the calculation of satiation sensitivity (Sat%), an index representing the proportion of stomach capacity required for an individual to detect satiety. However, previous investigations using this paradigm have yielded mixed associations with body image dimensions. Van Dyck et al. (46) observed no significant correlation between satiation sensitivity and body dissatisfaction, Hill and Forney (47) found no relationship with feelings of fatness, and Ahlich et al. (48) similarly reported no association with weight and shape concerns. Unexpectedly, however, Ahlich et al. (48) demonstrated that heightened gastric sensitivity was linked to lower self-reported preoccupation with dietary rules and restriction. Nevertheless, despite these initial attitudinal findings, it remains unknown whether satiation sensitivity relates to the perceptual dimension of body size estimation.

The WLT-II protocol includes an accompanying post-ingestion questionnaire administered after participants reach comfortable satiation and maximum fullness. Participants rate to what extent they experience feelings of guilt, sluggishness, discomfort, alertness, and nausea, which are averaged to generate a composite negative affect score for each drinking condition. Using this metric, Van Dyck et al. (46) found no significant correlation between WLT-II negative affect and body dissatisfaction at either satiation or maximum fullness. This null result is surprising given that individuals with Anorexia Nervosa and Bulimia Nervosa

report significantly higher negative affect at both satiation and fullness compared to healthy controls on the same composite measure (34,38), a disparity expected to track with the elevated body dissatisfaction characteristic of these conditions (49).

A plausible explanation for this null finding lies in the item composition of the original WLT-II negative affect composite scale. Four of the five items assess somatic or physiological side effects of gastric distension, leaving guilt as the sole indicator evaluating cognitive-affective distress. As the overall composite is dominated by these somatic items, the findings of Van Dyck et al. (46) may reflect a lack of association between physical postprandial symptoms and body dissatisfaction, rather than an absence of relationship between affective appraisal of visceral states and body image. Supporting this distinction, Ahlich et al. (48) substituted the original WLT-II items with a measure of trust in hunger and satiety cues, demonstrating that greater interoceptive trust significantly predicted lower weight and shape concerns, reduced eating shame, and less dietary restriction. This finding underscores the importance of gastrointestinal interoceptive appraisal in body image when properly operationalised. Nevertheless, whether interoceptive appraisal relates to explicit or implicit perceptual dimensions of body size remains unknown, leaving a critical gap in our understanding of gastrointestinal interoception in body image processing.

Previous clinical research demonstrates that individuals with Anorexia Nervosa underestimate their perceptual accuracy despite displaying comparable or superior task performance (50,51). However, much of this research is in the cardiac domain, rather than in the gastric domain, in which accuracy is much less straightforward to assess; and recent research has highlighted that interoceptive accuracy is perhaps less central to mental health conditions than appraisal (52). Notably, the WLT-II does not allow indexing subjective belief against objective accuracy, but does have untapped potential to assess metacognitive insight regarding satiation sensitivity, specifically, the correspondence between an individual's observed satiation sensitivity (Sat%) and their self-reported sensitivity post drinking to satiation. This miscalibration(which we have termed satiation sensitivity bias) is

directional, with a predicted sensitivity higher than observed sensitivity indicating overconfidence bias, whereas a predicted sensitivity lower than observed sensitivity indicates underconfidence bias.

Perceptual body image and body dissatisfaction are inherently dynamic, exhibiting state-level instability in response to proximal factors (53–56). Heightened instability across these outcomes is strongly associated with greater eating disorder symptom severity (24,57), though this relationship has yet to be evaluated within implicit body size perception. As an unavoidable feature of physiological homeostasis, gastric state fluctuates from pre- to post-ingestion multiple times daily, positioning visceral distension as a key candidate for driving proximal shifts in body image. Supporting this view, Baumann et al. (58) observed higher passability ratios when participants were satiated compared to when hungry, although whether satiation was operationalised as comfortable fullness or maximum capacity remains unclear. Similarly, Vocks et al. (59) demonstrated that consuming a milkshake produced greater body dissatisfaction than consuming water. Lattimore et al. (60) likewise found that full participants experienced elevated body dissatisfaction and selected larger body silhouettes as representing their actual size compared to hungry participants.

Collectively, these findings suggest that acute changes in gastric state can influence explicit and implicit body size perception as well as cognitive-affective body image. Two critical questions, however, remain unresolved. First, it is unclear whether these perceptual and attitudinal shifts are driven by internal interoceptive state changes or by cognitive appraisal of the food itself, such as caloric content or perceived healthiness (61,62). Second, previous studies establishing instability-symptom relationships have relied on passive observation of naturally occurring daily fluctuations rather than experimental manipulation, leaving it untested whether symptom severity predicts the magnitude of body image instability induced by a standardized physiological task. The WLT-II paradigm directly addresses both limitations by manipulating gastric interoceptive states using water alone, eliminating the

confounding effects of caloric intake and food appraisal, while systematically evaluating state changes across discrete, standardized conditions.

Uncovering the specific role of gastrointestinal interoception in body image and eating disorders is of critical clinical importance. Poor body image, particularly body dissatisfaction, is one of the key predictors of eating disorder onset (5). As an unavoidable feature of physiological homeostasis, gastric state fluctuates from pre- to post-ingestion multiple times daily, positioning gastric state as a candidate for driving proximal shifts in body image and in turn potentially eating disorder development.

Furthermore, body image disturbances remain among the most treatment-resistant features of eating pathology, frequently persisting following weight restoration and serving as a key predictor of relapse (63–65). Standard recovery protocols require regular, structured eating (66). Consequently, individuals in treatment are repeatedly exposed to visceral sensations of satiation and fullness multiple times daily. These regular postprandial bodily cues may themselves directly exacerbate the very body image disruptions that clinical interventions seek to alleviate. Although novel interoceptive interventions for body image and disordered eating are already being piloted in clinical settings (67), these protocols currently lack empirical clarity regarding which specific interoceptive mechanisms, such as sensitivity, appraisal, or over/underconfidence bias, they should target.

The Current Study

In summary, gastrointestinal sensitivity and interoceptive appraisal have both been linked to weight and shape concerns, yet neither construct has been evaluated in relation to explicit or implicit body size perception. Furthermore, satiation sensitivity bias has not previously been examined within body image research. Evaluating sensitivity, appraisal, and metacognitive awareness simultaneously against baseline body image and eating disorder symptoms would establish their relative theoretical importance for the first time. Moreover, prior studies

examining the acute impact of gastric state on body image have been confounded by food calories and perceived healthiness, while earlier research linking body image instability to symptom severity has relied on passive, naturally occurring fluctuations rather than standardized experimental manipulation. The present study utilized the WLT-II to address these limitations. Specifically, the aims were to examine whether 1) gastrointestinal sensitivity, appraisal, and sensitivity awareness relate to baseline cognitive-affective, explicit, and implicit body image dimensions; 2) these same three interoceptive constructs predict eating disorder symptom severity; and 3) acute changes in gastric state induce state-level shifts across body image dimensions, and whether the magnitude of this shift is moderated by eating disorder symptom severity.

Hypothesis 1 (Baseline Body Image): Gastrointestinal satiation sensitivity will not significantly predict body satisfaction (46–48), whereas poorer interoceptive appraisal will predict lower body satisfaction (48). Given the absence of prior empirical research, no directional predictions are made regarding satiation sensitivity bias, explicit waist size overestimation, implicit passability ratios, or JND.

Hypothesis 2 (Eating Disorder Symptoms): Gastrointestinal appraisal will significantly predict eating disorder pathology, such that more negative appraisal will associate with elevated weight and shape concerns, eating shame, and dietary preoccupation, but not dietary restraint (48). Additionally, higher satiation sensitivity will significantly predict greater preoccupation with dietary rules and restriction (48).

Hypothesis 3 (Experimental State Manipulation and Moderation): Acute changes in gastric state will significantly alter perceptual and attitudinal body image metrics across drinking conditions. Specifically 1) satiation and maximum fullness will induce significant increases in passability ratios relative to baseline hunger (58); 2) maximum fullness will produce significant increases in waist size overestimation (60); and 3) maximum fullness will produce significant reductions in body satisfaction relative to baseline hunger (59,60). No

specific predictions are made regarding the effect of gastric state on just noticeable differences due to a lack of prior literature.

Finally, we predict that eating disorder symptom severity will significantly moderate the effect of gastric state on the magnitude of change in waist size overestimation and body satisfaction, with higher symptom severity predicting greater state-level instability (24,57). Moderation effects are not formally hypothesized for JND or passability ratios given the novelty of these metrics in gastric perturbation paradigms.

Methods

Participants

This study received ethical approval from the institutional review board (ref: 202458 & 202565). Participants aged 18 years or above were recruited from the university and local community via the university's research participant pool system, SONA, and local campus poster boards. Recruitment commenced in October 2025 and concluded in June 2026, yielding a total of 68 participants. Participants received either 2.5 course credits or a £12 Amazon e-voucher as compensation for their involvement. Exclusion criteria included: being pregnant; having a heart condition; Type 1 or Type 2 Diabetes; a history of fainting or seizures; a known food allergy; a gastric disorder; depression; anxiety; body dysmorphia; or Night Eating Syndrome. A detailed demographic breakdown of the sample is presented in Table 1, and the percentage of participants at high risk for an eating disorder according to EDEQ total scores (2.30 for females, 1.68 for males, and 1.68 for nonbinary (68,69)) was 42.65% (Female n=23, Male n=4, Non-binary n=2).

Table 1:
Participant Characteristics (N = 68)

Characteristic	n	%
Age (years)		

Mean=21.88, SD=6.83, range=18–63		
BMI (kg/m²)		
Mean=23.56, SD=4.04, range=17.44–34.20		
Gender		
Female	54	79.4
Male	12	17.6
Non-binary	2	2.9
Education		
A-levels or International Baccalaureate	38	55.9
University Undergraduate degree	20	29.4
University Postgraduate degree	7	10.3
Doctoral degree	2	2.9
Other	1	1.5
Ethnicity		
Any other Asian Background	3	4.4
Any Other Ethnic Group	1	1.5
Any other Mixed/Multiple Ethnicites	1	1.5
Any other White Background	6	8.8
Arab	1	1.5
Asian Chinese	6	8.8
Asian Indian	7	10.3
Black African	1	1.5
British Indian	1	1.5
White and Asian	2	2.9
White English/Welsh/Scottish/Northern Irish/British/European	38	55.9
White Gypsy or Irish Traveller	1	1.5

Measures

Water Load Test

Gastrointestinal state was manipulated via fasting, followed by The Water Load Test II (WLT-II) (46). Participants were required to complete a 12-hour overnight fast from all food and beverages except water, and a 2-hour fast from water specifically prior to the water loading session, for the (T1) hunger condition. During the WLT-II, opaque 2.2-L flasks, each containing 1.5 L of water, were kept out of the room until the relevant drinking period commenced. Participants were unaware of the amount of water in the flasks and did not know there would be two distinct drinking periods.

The WLT-II involved two main conditions: satiation (T2) and fullness (T3). For the satiation condition, the experimenter entered with the first flask and placed it on the desk, out of the participant's reach. Participants were instructed: *"During the following five minutes, we ask you to drink water until perceiving a sign of satiation. By satiation we mean the comfortable sensation you perceive when you have eaten a meal and you feel like you have eaten enough, but not too much. Please use the straw and do not lift the container up."* The researcher then started a timer, left the room, and returned after five minutes to stop the participant from drinking and to remove the flask. Participants then answered on a scale of 0-100 how good they thought they were at detecting satiation; we refer to this as retrospective performance.

For the subsequent fullness condition, the experimenter brought in the second opaque flask. Participants were instructed: *"We now want you to drink again in the next five minutes. Please continue drinking until your stomach is completely full, that is, entirely filled with water. Please use the straw and do not pick up the bottle."*

Following the satiation and fullness condition, participants completed the Negative Affect subscale of the WLT-II Questionnaire. In this subscale, they rated feelings of physical

discomfort, guilt, nausea, sluggishness, and alertness on a 7-point scale ranging from 1 (not at all) to 7 (extremely).

Analyses utilised two indices derived from the WLT-II: the Negative Affect score from the WLT-II Questionnaire, calculated as the average rating of 5 items, and satiation sensitivity (Sat%). The Sat% is calculated by dividing the millimeters consumed in the first period (Sat_ml) by the total millimetres consumed across both phases (Total_ml) and multiplying the result by 100. Lower scores on the Sat% calculation reflect a smaller gap between drinking to satiety and drinking to maximum fullness, which indicates lower sensitivity to gastric satiety distention cues. For example, if a participant consumed 800ml in the first phase (satiety) and only 900ml in total (across both phases), thus drinking only an additional 100ml between the point they reported being comfortably full and the point they reported being maximally full, their Sat% would be 88.9%. This would reflect a low sensitivity to satiety cues as it indicates their stomach would have to be 88.9% full for them to detect satiation. For the purpose of interpretation, Sat% scores were reverse-scored (100-Sat%) so that a higher resulting score actually indicated increased sensitivity to satiety. We calculated an additional construct termed satiation sensitivity bias (Sat% - retrospective self-reported performance). A positive value indicates underconfidence (i.e. believing oneself to be less sensitive to satiation than observed), whereas a negative value indicates overconfidence (i.e. believing oneself to be more sensitive to satiation than observed).

Waist estimation task

Perceptual body image was assessed via a size estimation task indexing the body perception index (70). This task required participants to estimate the length of string that corresponded to the circumference of their waist. They were explicitly instructed not to place the string against their body or hold it horizontally, but to estimate the circumference solely based on the perceived vertical length of the string. Using a pair of scissors, participants cut the string to the estimated length. This estimation task was performed under all four

experimental conditions: baseline, hunger, satiety, and fullness. Participants's actual waist circumference was measured by the experimenter in each of these conditions with string.

Body size perception was calculated by dividing the estimated circumference by actual circumference and multiplying it by 100. A score greater than 100 indicates an overestimation of waist circumference, while a score less than 100 indicates an underestimation.

Aperture task

Perceptual body image was measured using an aperture passability task, following the protocol established by (21). A projector was placed 350cm from a projection board, ensuring all projected doorways were 180cm in height. Participants were shown 51 doorways varying in widths from 30 (inclusive)- 80cm, going up in intervals of 1cm and presented in a random order. Each doorway width was presented 4 times, resulting in 204 observations for each condition (816 observations total). For each projected doorway, participants indicated whether they could fit through the opening without twisting their body using designated "yes" and "no" keys.

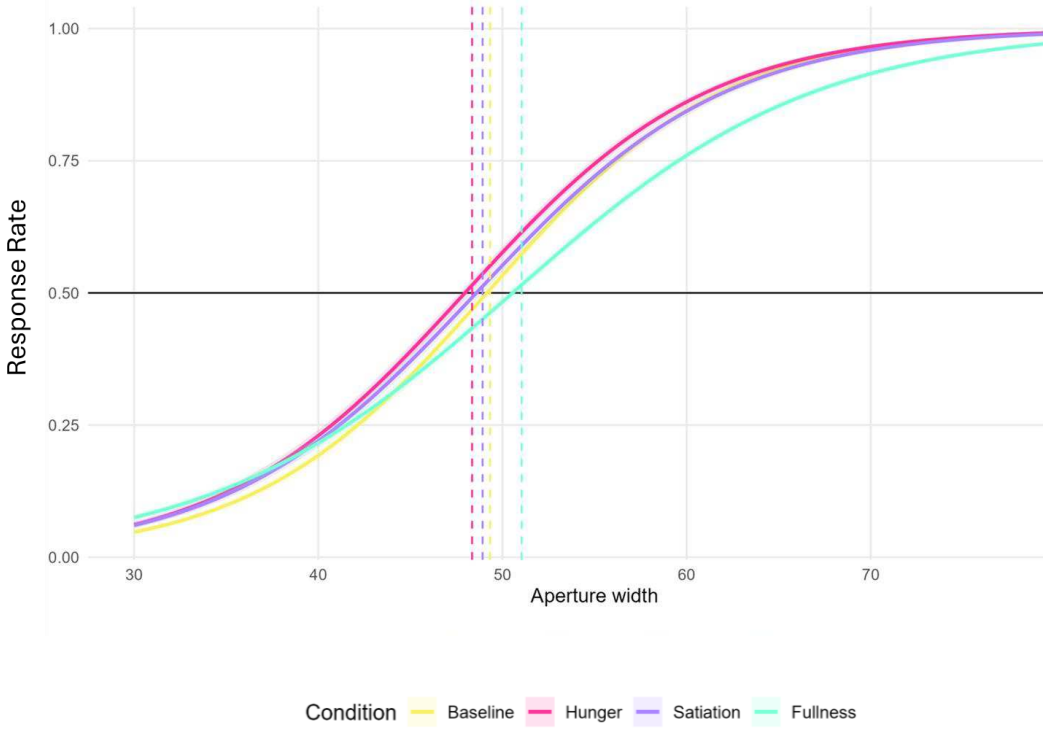
For each condition, the critical aperture (in cm) was calculated. This is defined as the aperture width that yields a 50% positive response rate ("Yes, I can walk through without turning sideways"). The perceived critical aperture was calculated using the psychometric function:

$$Perceived\ critical\ aperture\ =\ 1\ /\ (1\ +\ e\text{^}\{-k(c\ -\ a)\})$$

where c is the perceived critical aperture (in cm) corresponding to a 50% "yes" response rate, and k is the slope of the curve around point c (Figure 1). The perceived passability ratio was then determined by dividing the perceived critical aperture by the participant's actual shoulder width in cm. A passability ratio greater than 1 indicates an aperture must be wider than participants actual shoulder width, suggesting overestimation of body size.

JND was calculated as a standard psychophysical measure of the precision of the over/underestimation. The JND was calculated by subtracting the aperture value corresponding to a 25% "yes" response rate from the aperture value at the 75% "yes" response rate, and then dividing the result by two. This midpoint represents the smallest difference in aperture width a participant could reliably distinguish as passable from impassable relative to their shoulder width (23).

Figure 1:
Critical Aperture Per Condition



Note: Solid line= aggregate logistic fit. Dashed line= mean critical aperture (c). Black line= 50% positive ("yes") response rate.

Self report measures

Body Image States Scale

Current, state-level body image experiences were assessed using the Body Image State Scale (BISS) (71). This scale is a brief, 6-item measure designed to capture transient feelings about one's body at a specific point in time. Participants rated each item on a 9-point scale based on how they felt *"right now at this moment".* The six items focus on distinct

aspects of body image, evaluating: overall physical appearance (ranging from *Extremely dissatisfied* to *Extremely satisfied*), body size and shape (*Extremely dissatisfied to Extremely satisfied*), weight (*Extremely dissatisfied to Extremely satisfied*), physical attractiveness-unattractiveness (*Extremely unattractive to Extremely attractive*), current feelings regarding one's looks compared to how one typically feels (*A great deal worse to A great deal better*), and evaluation of one's appearance compared to the average person's appearance (*A great deal worse to A great deal better*). The total score for the BISS was calculated as the average of the six item ratings. Acceptable internal reliability was found for the current sample (Baseline α=.65, Hunger α=.61, Satiation α=.67, Fullness α=.64) in line with previous findings (71).

Eating Disorder Examination Questionnaire- 6

Eating disorder psychopathology was assessed using the 28-item self-report Eating Disorder Examination Questionnaire- 6 (EDEQ) (72). For comparability with previous similar research (Ahlich et al.,(48), we used the four-factor structure proposed by Friborg et al., (73). This structure includes: Dietary Restraint (3 items,e.g., *"Have you been deliberately trying to limit the amount of food you eat to influence your shape or weight [whether or not you have succeeded]"*), Preoccupation with and reported Restriction (5 items; e.g., *"Have you gone for long periods of time (8 waking hours or more) without eating anything at all in order to influence your shape or weight?"*), Weight and Shape Concerns (11 items ,e.g., *"How dissatisfied have you been with your shape?"*), and Eating Shame (3 items; e.g., *"How concerned have you been about other people seeing you eat?"*). Responses on a 7-point scale are averaged, with higher scores reflecting greater eating disorder symptoms. EDEQ total is the average of the subscales. In the current sample, internal reliability was good/excellent for all subscales (Dietary Restraint α=.91, Preoccupation with/reported Restriction α=.82, Weight and Shape Concerns α=.95, Eating Shame α=.78, EDEQ Total α=.97), which is in line with previous research (48). Items 13-18 were not answered by

participants as they do not contribute to any subscale in the original subscale conceptualisation or Friborg's version.

Negative Appraisal of Gastric Sensations Scale

Negative appraisal of gastrointestinal sensations adjacent to eating-related states was assessed using the 21-item self-report Negative Appraisal of Gastric Sensations (NAGS) Scale (74). It is made up of two subscales, hunger-fear and fullness-shame. Hunger-fear measures the tendency to interpret somatic signals of hunger as threatening (10 items, e.g., *"When I get physical sensations of hunger in my stomach (e.g. rumbling, emptiness) I feel anxious")*, and fullness-shame assesses the tendency to respond to somatic signals of fullness with negative self-evaluation (11 items, e.g., *"When I get physical sensations of extreme fullness in my stomach (e.g. bloating, heaviness) I feel ashamed")* on a 5-point scale (*1=strongly disagree, 2=somewhat disagree, 3=neither agree nor disagree, 4=somewhat agree, 5=strongly agree*). Items are summed for a subscale score. Internal reliability of the subscales in the current study was excellent (Hunger-fear α=.92, Fullness-shame α=.93), which is inline with previous research (74).

Procedure

The experimental protocol was conducted across two distinct lab sessions, with session two taking place at least 48 hours after part one.

Part 1: Baseline

The first session was an in-person laboratory visit scheduled at least two hours after the participant's most recent meal. After reporting time since their last meal and drink, and rating how empty/full their stomach was (*How empty or full does your stomach feel right now? Extremely empty, somewhat empty, neither empty nor full, somewhat full, extremely full*), participants completed a baseline assessment battery. They first completed the BISS, EDEQ, and NAGS scale in a randomised order and then provided demographic details concerning their age, gender identity, highest educational level, and ethnicity. Then they

completed the Aperture Task and Size Estimation Task, always in that order. Self report measures were all completed via Qualtrics. Height and weight was recorded, and an experimenter measured shoulder width and waist circumference using string while the participant's eyes were closed to prevent visual feedback. Following this session, participants were instructed to fast before session two so they came in hungry.

Part 2: Experimental Manipulation

The second session took place at least 48 hours after the baseline visit. Upon arrival, participants confirmed their fast duration and rated how empty/full their stomach felt (using the same scale specified above). They then completed the Aperture Task and Size Estimation Task.

Following the fasted assessment, the WLT-II was administered in two stages (satiety and fullness). After drinking to satiation, participants were asked how well they think they did at detecting satiety (retrospective self-reported performance). They then rated how empty/full their stomach felt, and completed the BISS, Aperture Task, and Size Estimation Task. The negative affect composite of the WLT-II was measured at both satiety and fullness.

Analyses

Data Analytical Plan

The project was pre-registered at: https://osf.io/e2bh6. Data is available at: https://osf.io/crenv. Data analysis was performed using R version 4.4.0 (75) using the packages rstatix (76), lme4 (77), lmerTest (78), emmeans (79), robustbase (80), robustlmm (81), and boot (82). The validity of the WLT-II manipulation was examined by evaluating change in subjective stomach emptiness-fullness ratings across the four conditions (baseline, hunger, satiation, fullness) using a repeated-measures ANOVA (rstatix; Greenhouse-Geisser corrected where sphericity was violated) with Holm-corrected pairwise comparisons; a Friedman test with Holm-corrected Wilcoxon signed-rank tests (rstatix) was

additionally run where residuals were non-normally distributed. Internal consistency of all multi-item measures was assessed using Cronbach's alpha. The alternative EDEQ subscale structure (73) was used in place of the standard subscale structure for comparability with previous research. Preliminary associations among satiation sensitivity, satiation sensitivity bias, gastrointestinal interoceptive appraisal, baseline body image, and eating disorder symptomatology were examined using Spearman's correlations, with Holm-corrected p-values reported for all pairwise comparisons. These were computed on the same sample used in the regressions described below that excluded participants more than three standard deviations from the mean on the dependent variable of interest.

Associations between satiation sensitivity, satiation sensitivity bias, and appraisal and both baseline body image and eating disorder symptomatology were tested using hierarchical linear regressions, with age, BMI, and gender entered in Block 1 and the three predictors of interest entered together in Block 2. Block 2 coefficients and R^2 change were bootstrapped (boot; 1,000 replicates), and standardised coefficients were obtained by refitting each model on standardised variables. The effect of gastric state on body image, and its moderation by symptom severity, was tested using baseline-controlled linear mixed models (lme4, lmerTest; outcome regressed on EDEQ Total, State, their interaction, and their baseline as a covariate, with a random intercept for participant).

Normality and homoscedasticity were screened for each regression (Shapiro-Wilk, Breusch-Pagan) prior to reporting any results. Where both assumptions were met, the standard model was reported (Block 1, Block 2, standardised betas, and bootstrapped confidence intervals); where either assumption was violated, the standard model's results were not reported, and an MM-estimation robust regression was fit and reported in its place, with a robust Wald test providing the equivalent of the Block 2 R^2-change F-test. For the mixed models, assumptions were assessed visually via diagnostic plots, and a robust linear mixed model featuring State (hunger, satiation, and fullness), EDEQ Total, the corresponding baseline body image component (JND, passability ratio, body satisfaction, or waist

(over)estimation), and the State × EDEQ Total interaction was fit for every outcome. Emmeans does not support robust mixed-model objects, so corresponding Wald chi-square tests (including the State main effect, evaluated at the sample mean of EDEQ Total), simple-slope contrasts, and Tukey-corrected pairwise State comparisons for the robust models were derived directly from the fixed-effect estimates and covariance matrix rather than via emmeans. A three-standard-deviation exclusion rule (applied per dependent variable) was used for all regression and mixed-model analyses, with the number of people excluded per analysis found in the results. Outlier exclusion resulted in the removal of four unique participants across analyses (5.88% of the total sample). Two participants were excluded from all H1 and H2 regression analyses. One participant was additionally excluded from the waist size estimation linear mixed effects model, and one further participant from the JND linear mixed effects model, each on the basis of outlying scores on the relevant outcome variable. Tukey-corrected pairwise comparisons between States were conducted via the same delta-method approach for the robust models, and are displayed as significance brackets on the corresponding figures.

Results

Participants reported fasting for an average of 2.82 hours (SD=2.85) prior to Session 1, and 2.12 hours (SD)=2.49) since their last drink. At the start of Session 1, participants on average rated their stomach as feeling neither particularly empty nor full (M=2.91, SD=0.64, on a 1 (extremely empty) to 5 (extremely full) scale). Prior to Session 2, participants reported an average of 12.19 hours (SD=3.84) since last eating and 5.64 hours (SD=4.76) since last drinking, consistent with the Hunger condition being the intended starting state for this session. Accordingly, participants rated their stomach as feeling somewhat empty at the start of Session 2 (M=1.87, SD 0.62). The composite of negative affect from the WLT-II questionnaire violated the assumption of normality (W=0.958, p=0.026) and so a Wilcoxon signed ranks test was conducted and revealed a significant increase in negative affect from satiation (M=2.97, SD=0.92) to fullness (M=3.83, SD=1.11), W=1790.5, p<.001.

The assumption of normality of within-subject deviations was violated (W= 0.965, p<.001) and so a non-parametric Freidman test was conducted to examine if the WLT-II changed gastrointestinal state. Stomach emptiness to fullness ratings differed significantly across the four conditions $\chi^2(3, n=68)=158.25$, p< .001. Descriptively, ratings increased in the expected order across conditions, hunger (M=1.87, SD=0.62) was lowest, followed by baseline (M=2.91, SD=0.64), satiation (M=3.71, SD=0.71), and fullness (M=4.59, SD=0.81), which was highest.

All six pairwise comparisons (Wilcoxon signed-rank tests, Holm-corrected) were significant at p< .001. Hunger ratings were lower than baseline, Z=-1558, p<.001, and baseline ratings were in turn lower than both satiation, Z=-122.5, p<.001, and fullness, Z=-2.5, p<.001. Critically for the water-load manipulation itself, ratings increased significantly from hunger to satiation, Z=6.5, p<.001, and from satiation to fullness, Z=134, p<.001, confirming the intended hunger to satiation to fullness progression.

Descriptive statistics are presented in Table 1.

Table 1:
Descriptive Statistics for All Regression Variables (3SD-Outlier-Excluded)

Variable	N	Mean	Median	SD	Min	Max
Trait Measures						
EDEQ Eating Shame	68	1.397	1.000	1.267	0.000	5.000
EDEQ Dietary Restraint	68	2.353	2.167	2.021	0.000	6.000
EDEQ Preoccupation with/reported Restriction	68	1.338	1.000	1.308	0.000	4.600
EDEQ Weight and Shape Concerns	68	2.595	2.818	1.770	0.000	5.727
Satiation Sensitivity	68	49.614	48.390	12.699	22.880	79.460
Satiation sensitivity Bias	68	−20.372	−23.875	27.163	−66.950	60.300
Hunger-fear	68	24.603	24.000	10.042	10.000	49.000

Fullness-shame	68	34.809	37.000	12.275	12.000	55.000
Baseline Condition						
Body Satisfaction	68	31.059	31.000	6.906	16.000	49.000
Passability Ratio	68	1.199	1.185	0.226	0.732	1.768
JND	67	2.500	2.384	1.044	0.250	5.376
Waist (Over)estimation	67	115.755	114.286	24.329	68.675	176.471
Hunger Condition						
Body Satisfaction	68	30.706	31.000	6.876	15.000	46.000
Passability Ratio	68	1.177	1.136	0.243	0.784	1.779
JND	68	2.205	2.065	1.126	0.069	5.487
Waist (Over)estimation	67	117.077	116.216	26.581	66.667	206.349
Satiation Condition						
Body Satisfaction	68	30.691	31.000	6.721	16.000	44.000
Passability Ratio	68	1.191	1.157	0.251	0.769	1.729
JND	67	2.122	2.102	1.246	0.081	6.257
Waist (Over)estimation	67	119.073	114.286	28.078	69.444	191.892
Fullness Condition						
Body Satisfaction	67	28.403	29.000	6.937	15.000	44.000
Passability Ratio	68	1.243	1.194	0.308	0.775	2.162
JND	67	2.437	2.151	1.446	0.057	6.504
Waist (Over)estimation	67	122.218	120.000	29.702	69.091	207.812

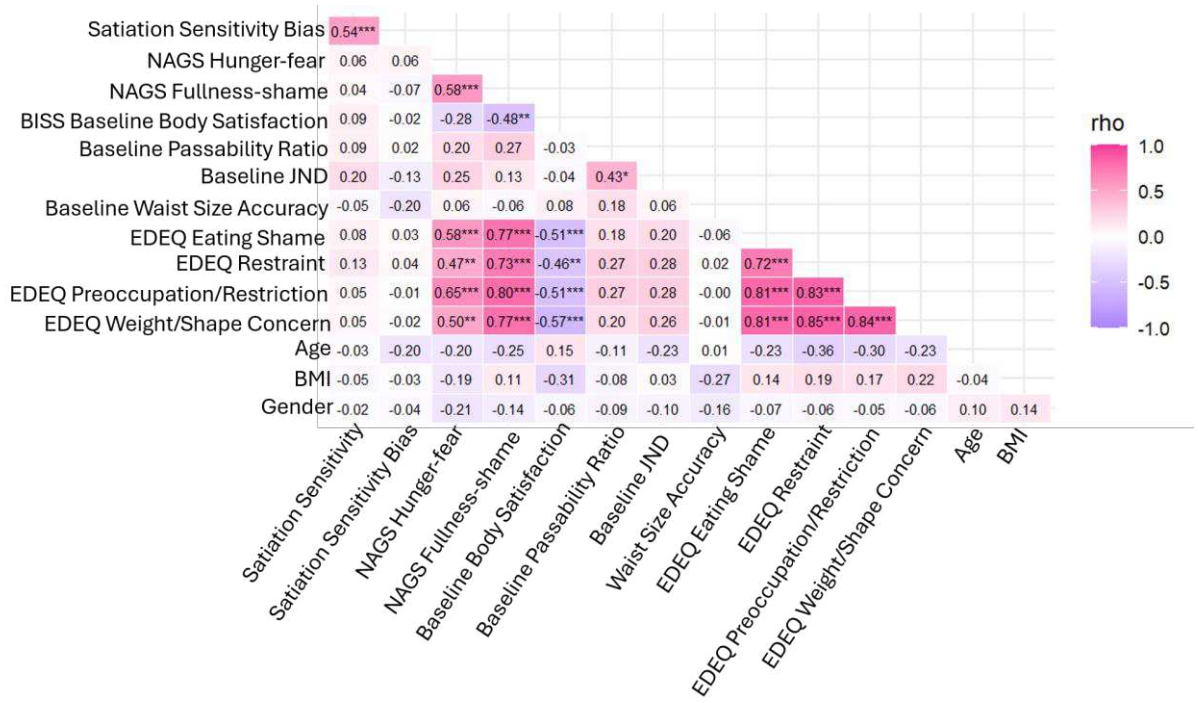
Note: Excludes values more than 3 SD from each variable's own mean, matching the sample used in the regression and mixed-model analyses. satiation sensitivity bias = Satiation Sensitivity (reversed) − Retrospective Self-reported Performance (signed; positive=underconfidence, negative=overconfidence).

H1 Results

Hierarchical multiple regressions were conducted to examine which facet of gastrointestinal interoception predicts baseline body satisfaction, passability ratio, JND, waist (over)estimation, dietary restraint, weight and shape concerns, preoccupation with/reported

restriction, and eating shame. Gender was dummy-coded (female=1; other identities=0), with females as the reference category. All VIFs <1.7. The correlation matrix is presented in Figure 2.

Figure 2:
Spearman's Correlation Matrix



*Note: Holm-corrected across 105 unique comparisons. Participants more than 3 standard deviations from mean excluded. *p < .05. **p < .01. ***p < .001. rho= Spearman's Rho*

Baseline body satisfaction: Two participants were excluded for being >3 standard deviations from the mean (n=66). Assumptions were met, with normally distributed residuals (W=.979, p=.314) and homoscedasticity satisfied (Breusch-Pagan BP=1.6277, df =7, p =0.978). Therefore, an ordinary least squares regression was carried out. Model 1 (BMI, gender, and age) was non-significant (F(3, 62)=2.062, p=.114), explaining 9.1% (R^2=.091, Adjusted R^2=.047) of the variance. No individual predictor reached significance. Model 2 (adding satiation sensitivity, satiation sensitivity bias, hunger-fear, and fullness-shame) was significant (F(7, 58)=3.35, p=.004), explaining 59.6% (R^2=.596, Adjusted R^2=.548) of the variance. The addition of satiation sensitivity, satiation sensitivity bias, hunger-fear, and fullness-shame explained a significant amount of additional variance (ΔF(4, 58)=4.02,

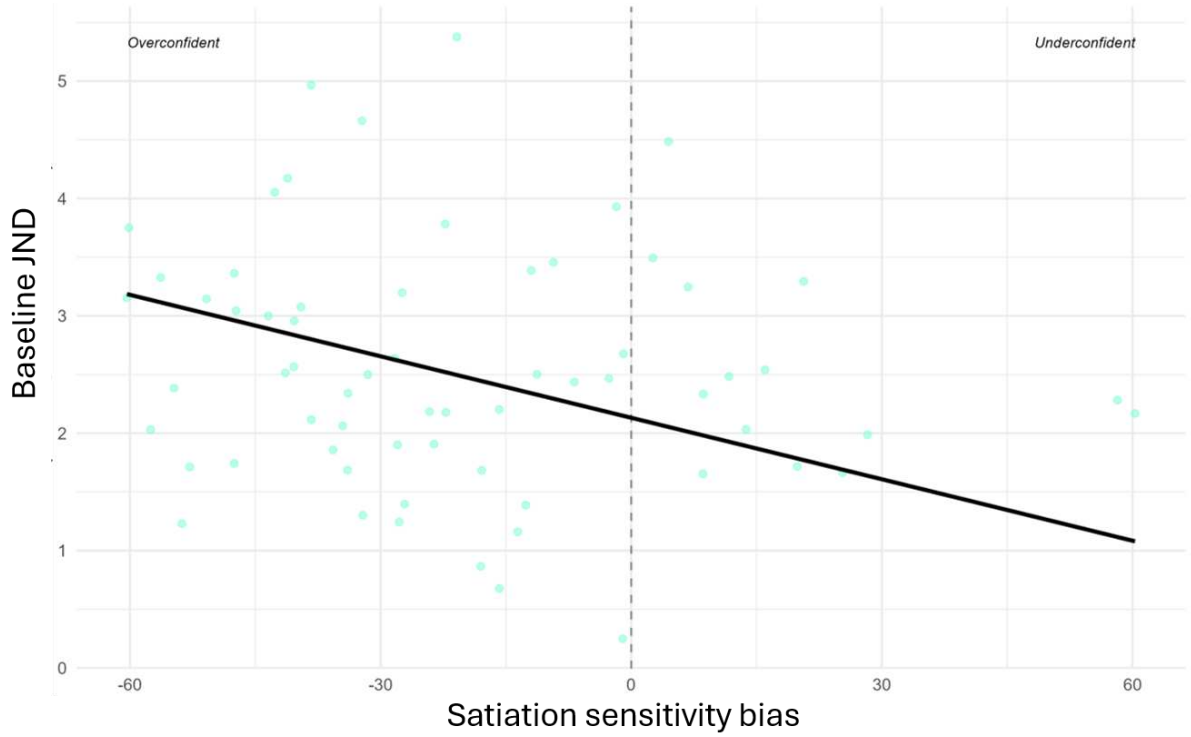
p=.006, ΔR^2 =.197). Increases in hunger-fear and fullness-shame predicted significant decreases in body satisfaction.

Passability ratio: Two participants were excluded for being >3 standard deviations from the mean (n=66). Assumptions were met, with normally distributed residuals (W=.981, p=.416) and homoscedasticity satisfied (Breusch-Pagan BP=7.7521, df=7, p=0.3550). Therefore, an ordinary least squares regression was carried out. Model 1 (BMI, gender, and age) was non-significant (F(3, 62)=1.053, p=.376), explaining 4.8% (R^2=.048, Adjusted R^2=.002) of the variance. No individual predictor reached significance. Model 2 (adding satiation sensitivity, satiation sensitivity bias, hunger-fear, and fullness-shame) was also non-significant (F(7, 58)=1.46, p=.200), explaining 15% (R^2=.149, Adjusted R^2=.047) of the variance. The addition of satiation sensitivity, satiation sensitivity bias, hunger-fear, and fullness-shame did not explain a significant amount of additional variance (ΔF(4, 58)=1.726, p=.167, ΔR^2 =.101). There were no significant individual predictors.

JND: Two participants were excluded for being >3 standard deviations from the mean (n=66). Checking assumptions, residuals showed a significant departure from normality (Shapiro-Wilk W=.908, p<.001), while the assumption of homoscedasticity was satisfied (Breusch-Pagan BP= 8.84, df=7, p=.265). Given this violation, results are reported from a MM-estimation robust regression. Model 1 (age, BMI, and gender) was non-significant overall, (robust Wald $\chi^2(3)$=6.09, p=.108), explaining 6.0% (R^2=.060, adjusted R^2=.014) of the variance. Older participants showed significantly smaller (more precise) discrimination thresholds. Model 2, adding satiation sensitivity, satiation sensitivity bias, hunger-fear, and fullness-shame, explained a significant amount of additional variance (ΔR^2 = .222, robust Wald $\chi^2(4)$=22.86, p< .001), with the full model explaining 28.2% (R^2=.282, adjusted R^2=.195) of the variance overall. Greater satiation sensitivity predicted larger (less precise) discrimination thresholds, but underestimating satiation sensitivity (underconfidence bias) (Figure 3) predicted smaller (more precise) discrimination thresholds.

Figure 3:

Satiation sensitivity bias predicting Baseline JND



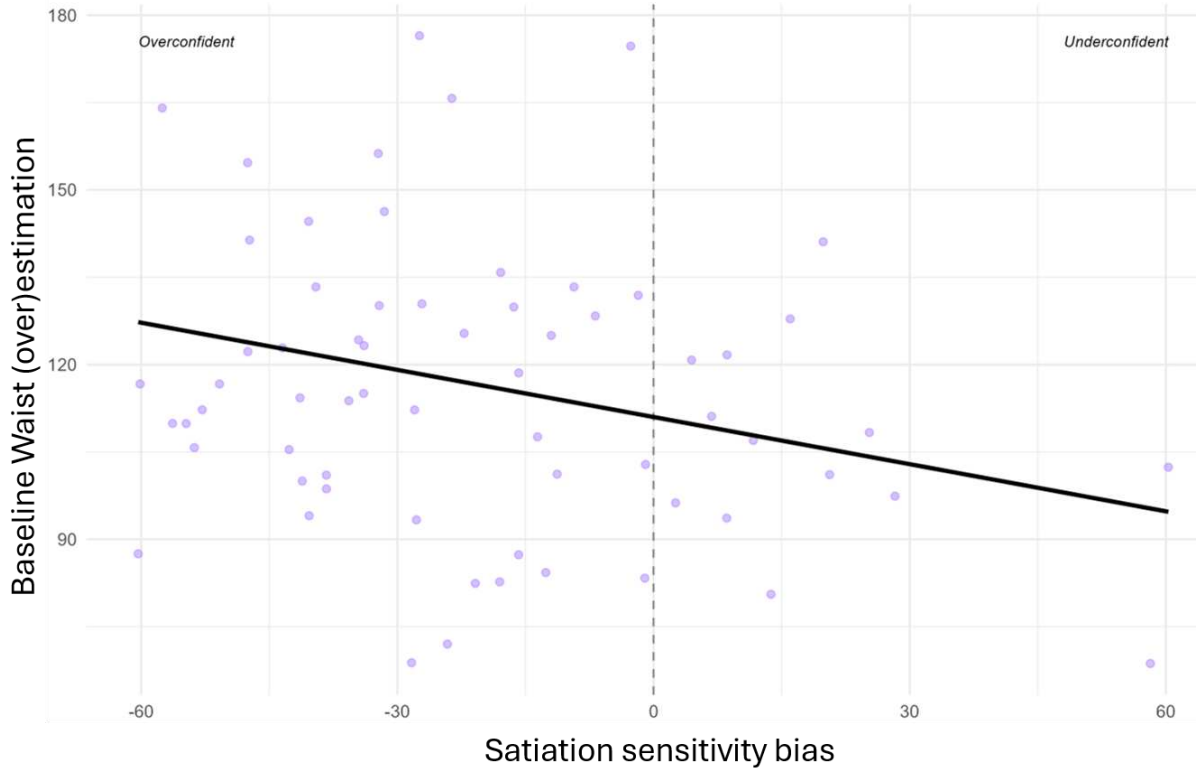
Note: Black line is the model predicted JND with all other predictors held at the mean. Smaller JND= more precise. Satiation sensitivity bias: negative= overconfident; positive= underconfident.

Waist size estimation: Two participants were excluded for being >3 standard deviations from the mean (n=66). Assumptions were checked for the baseline waist size overestimation regression. Residuals showed a significant departure from normality (Shapiro-Wilk W=.880, p<.001), while the assumption of homoscedasticity was satisfied (Breusch-Pagan BP=6.01, df=7, p=.539). Given this violation, results are reported from an MM-estimation robust. Model 1 (age, BMI, and gender) was significant overall (robust Wald $\chi^2(3)=9.24$, p=.026, explaining 11.5% ($R^2=.115$, adjusted $R^2=.072$) of the variance. Higher BMI was associated with significantly less overestimation. Model 2, adding satiation sensitivity, satiation sensitivity bias, hunger-fear, and fullness-shame, did not explain a significant amount of additional variance ($\Delta R^2=.063$, robust Wald $\chi^2(4)=5.74$, p=.220, with the full model explaining 17.8% ($R^2 = .178$, adjusted $R^2 = .079$) of the variance overall. Despite the non-significant joint test,

underestimating gastrointestinal sensitivity was associated with lower waist size estimation (see Figure 4 and Table 3). BMI also remained a significant predictor in this model.

Figure 4:

Satiation Sensitivity Bias predicting Baseline Waist (Over)estimation



Note: Black line is the model predicted Waist (Over)estimation with all other predictors held at their mean. Baseline waist estimation: over 100 = overestimation; under 100= under estimation. Satiation sensitivity bias: negative= overconfident; positive= underconfident.

Table 3:

Standardised Block 2 Regression Results for Baseline Body Image Variables

Predictor	β	SE	t	p	95% CI
Baseline Body Satisfaction *(standard ordinary least squares regression)*					
Age	0.070	0.121	0.58	.565	[−0.172, 0.311]
BMI	**−0.259**	**0.117**	**−2.21***	**.031**	**[−0.493, −0.025]**
Gender (Other vs Female)	−0.400	0.283	−1.42	.162	[−0.966, 0.166]
Satiation Sensitivity	0.075	0.134	0.56	.580	[−0.194, 0.343]

Satiation Sensitivity Bias	−0.010	0.138	−0.07	.943	[−0.286, 0.267]
Hunger-fear	−0.100	0.144	−0.69	.491	[−0.388, 0.188]
Fullness-shame	**−0.387**	**0.139**	**−2.78****	**.007**	**[−0.665, −0.109]**
Baseline Passability Ratio *(standard ordinary least squares regression)*					
Age	−0.158	0.132	−1.20	.235	[−0.422, 0.106]
BMI	−0.057	0.128	−0.44	.659	[−0.313, 0.199]
Gender (Other vs Female)	−0.060	0.309	−0.20	.846	[−0.679, 0.558]
Satiation Sensitivity	0.154	0.147	1.05	.299	[−0.140, 0.447]
Satiation Sensitivity Bias	−0.121	0.151	−0.80	.426	[−0.423, 0.181]
Hunger-fear	0.072	0.157	0.46	.647	[−0.243, 0.388]
Fullness-shame	0.235	0.152	1.55	.127	[−0.069, 0.539]
Baseline JND *(MM-estimation robust regression)*					
Age	−0.234	0.127	−1.85	.070	[−0.487, 0.020]
BMI	0.056	0.131	0.43	.672	[−0.206, 0.317]
Gender (Other vs Female)	0.039	0.216	0.18	.859	[−0.393, 0.471]
Satiation Sensitivity	**0.415**	**0.121**	**3.43****	**.001**	**[0.172, 0.657]**
Satiation Sensitivity Bias	**−0.400**	**0.092**	**−4.33*****	**<.001**	**[−0.585, −0.215]**
Hunger-fear	0.198	0.113	1.76	.084	[−0.028, 0.424]
Fullness-shame	−0.147	0.131	−1.12	.269	[−0.410, 0.116]
Baseline Waist Size (Over)estimation *(MM-estimation robust regression)*					
Age	0.007	0.075	0.09	.925	[−0.143, 0.158]
BMI	**−0.206**	**0.081**	**−2.56***	**.013**	**[−0.368, −0.045]**
Gender (Other vs Female)	−0.316	0.281	−1.13	.265	[−0.879, 0.246]
Satiation Sensitivity	0.088	0.103	0.85	.397	[−0.118, 0.294]

Satiation Sensitivity Bias	**−0.238**	**0.101**	**−2.34***	**.023**	**[−0.441, −0.035]**
Hunger-fear	0.023	0.085	0.27	.788	[−0.147, 0.193]
Fullness-shame	−0.078	0.103	−0.76	.452	[−0.285, 0.129]

*Note. β = standardised coefficient. *p < .05. **p < .01. ***p < .001.*

H2 Results

Eating Shame: Two participants were excluded for being >3 standard deviations from the mean (n=66). Assumptions were checked for the EDEQ Eating Shame regression. Residuals were normally distributed (Shapiro-Wilk W=.985, p=.620), but the assumption of homoscedasticity was violated (Breusch-Pagan BP=15.92, df=7, p=.026). Given this violation, results are reported from an MM-estimation robust regression. Model 1 (age, BMI, and gender) was non-significant overall (robust Wald $\chi^2(3)=5.39$, p=.145), explaining 6.1% ($R^2=.061$, adjusted $R^2=.015$) of the variance. No individual predictor in Model 1 reached significance. Model 2, adding satiation sensitivity, satiation sensitivity bias, hunger-fear, and fullness-shame, explained a significant amount of additional variance ($\Delta R^2=.546$, robust Wald $\chi^2(4)=74.83$, p<.001), with the full model explaining 60.7% ($R^2=.607$, adjusted $R^2=.559$) of the variance overall. Greater shame of fullness and fear of fullness gastrointestinal sensations predicted significantly greater eating shame. Increases in BMI also predicted greater eating shame.

Dietary Restraint: Two participants were excluded for being >3 standard deviations from the mean (n=66). Assumptions were checked for the EDEQ Dietary Restraint regression. Residuals were normally distributed (Shapiro-Wilk W=.975, p=.210), but the assumption of homoscedasticity was violated (Breusch-Pagan BP=17.08, df=7, p=.017). Given this violation, results are reported from an MM-estimation robust regression. Model 1 (age, BMI, and gender) was non-significant overall (robust Wald $\chi^2(3)=2.43$, p=.488, explaining 13.4% ($R^2=.134$, adjusted $R^2=.092$) of the variance. No individual predictor in Model 1 reached significance. Model 2, adding satiation sensitivity, satiation sensitivity bias, hunger-fear, and

fullness-shame, explained a significant amount of additional variance (ΔR^2=.542, robust Wald $\chi^2(4)$=106.50, p<.001, with the full model explaining 67.6% (R^2=.676, adjusted R^2 = .637) of the variance overall. Greater shame and fear of fullness and hunger sensations was associated with greater dietary restraint. Also, older participants reported significantly less dietary restraint.

Weight and Shape Concerns: Two participants were excluded for being >3 standard deviations from the mean (n=66). Residuals were normally distributed (Shapiro-Wilk W=.983, p=.493), but the assumption of homoscedasticity was violated (Breusch-Pagan BP=20.58, df=7, p=.004). Given this violation, results are reported from an MM-estimation robust regression. Model 1 (age, BMI, and gender) was non-significant overall (robust Wald $\chi^2(3)$=2.20, p=.531, explaining 3.9% (R^2=.039, adjusted R^2=−.008) of the variance. No individual predictor in Model1 reached significance. Model 2, adding satiation sensitivity, satiation sensitivity bias, hunger-fear, and fullness-shame, explained a significant amount of additional variance (ΔR^2=.777, robust Wald $\chi^2(4)$=320.82, p<.001), with the full model explaining 81.5% (R^2=.815, adjusted R^2=.793) of the variance overall. Greater shame and fear of fullness and hunger significantly predicted greater weight and shape concerns. Increases in age and BMI also predicted significantly greater weight and shape concerns.

Preoccupation with/reported restriction: Two participants were excluded for being >3 standard deviations from the mean (n=66). Residuals were normally distributed (Shapiro Wilk W=0.979, p=0.336) and homoscedastic (Breusch-Pagan BP=10.01, df=7, p=0.188), so results are reported from an ordinary least squares regression. Model 1 (age, BMI, and gender) was non-significant overall (F(3, 62)=0.77, p=.514) explaining 3.6% (R^2=.036, adjusted R^2=−.011) of the variance. No individual predictor in Model 1 reached significance. Block 2, adding satiation sensitivity, satiation sensitivity bias, hunger-fear, and fullness-shame, explained a significant amount of additional variance (ΔR^2=.640, F(4, 58)=28.70, p<.001, with the full model explaining 67.6% (R^2=.676, adjusted R^2= .637) of the variance

overall (F(7, 58)=17.33, p<.001). Greater shame and fear of fullness and hunger sensations predicted significantly greater preoccupation with/reported restriction (see Table 4).

Table 4:

Standardised Block 2 Regression Results for EDEQ Subscales

Predictor	β	SE	t	p	95% CI
EDEQ Eating Shame *(MM-estimation robust regression)*					
Age	−0.044	0.080	−0.56	.580	[−0.204, 0.116]
BMI	**0.160**	**0.071**	**2.27***	**.027**	**[0.019, 0.302]**
Gender (Other vs Female)	0.076	0.206	0.37	.714	[−0.337, 0.489]
Satiation sensitivity	0.007	0.095	0.07	.945	[−0.183, 0.196]
Satiation Sensitivity Bias	0.039	0.151	0.26	.796	[−0.263, 0.341]
Hunger-fear	**0.319**	**0.109**	**2.92****	**.005**	**[0.101, 0.537]**
Fullness-shame	**0.481**	**0.110**	**4.37*****	**<.001**	**[0.261, 0.701]**
EDEQ Dietary Restraint *(MM-estimation robust regression)*					
Age	**−0.443**	**0.104**	**−4.24*****	**<.001**	**[−0.652, −0.234]**
BMI	0.106	0.077	1.37	.176	[−0.049, 0.261]
Gender (Other vs Female)	0.332	0.274	1.21	.230	[−0.216, 0.881]
Satiation Sensitivity	0.072	0.094	0.76	.448	[−0.117, 0.261]
satiation sensitivity bias	0.001	0.086	0.02	.986	[−0.171, 0.174]
Hunger-fear	0.174	0.113	1.54	.130	[−0.053, 0.401]
Fullness-shame	**0.597**	**0.106**	**5.63*****	**<.001**	**[0.385, 0.809]**
EDEQ Weight and Shape Concerns *(MM-estimation robust regression)*					
Age	0.133	0.061	2.16*	.035	[0.010, 0.255]
BMI	**0.145**	**0.064**	**2.26***	**.028**	**[0.016, 0.273]**

Gender (Other vs Female)	0.243	0.156	1.56	.124	[−0.068, 0.555]
Satiation Sensitivity	−0.096	0.076	−1.25	.216	[−0.248, 0.057]
Satiation Sensitivity Bias	0.097	0.083	1.17	.248	[−0.070, 0.264]
Hunger-fear	0.106	0.081	1.32	.193	[−0.055, 0.268]
Fullness-shame	**0.864**	**0.087**	**9.88*** **	**<.001**	**[0.689, 1.039]**
EDEQ Preoccupation with/reported Restriction *(standard Ordinary Least Squares regression)*					
Age	−0.084	0.081	−1.03	.306	[−0.247, 0.079]
BMI	0.103	0.079	1.31	.196	[−0.055, 0.261]
Gender (Other vs Female)	0.304	0.191	1.59	.116	[−0.078, 0.685]
Gastric sensitivity	−0.006	0.090	−0.06	.949	[−0.187, 0.175]
Satiation Sensitivity Bias	−0.032	0.093	−0.34	.735	[−0.218, 0.155]
Hunger-fear	**0.322**	**0.097**	**3.32****	**.002**	**[0.128, 0.516]**
Fullness-shame	**0.593**	**0.094**	**6.33*** **	**<.001**	**[0.405, 0.781]**

*Note. β = standardised coefficient. *p < .05. **p < .01. ***p < .001.*

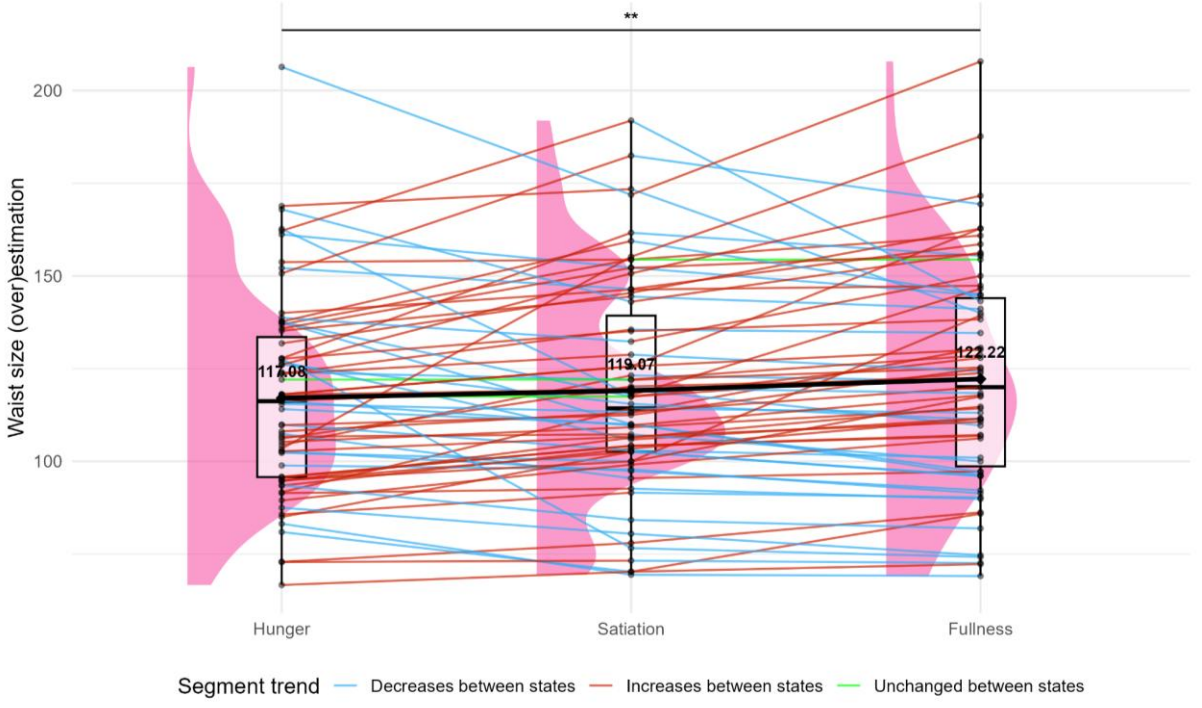
H3 Results

Full results for H3 can be found in Table 5.

Waist size (over)estimation: One participant was removed for benign more than 3 standard deviations from the mean (*n*=67). Residuals were non-normally distributed according to a Q-Q plot, so a robust linear mixed model was used. There was a significant main effect of State ($\chi^2(2)=10.90$, p=.004), whereby waist overestimation differed across states. This was driven specifically by significantly greater overestimation at fullness relative to hunger (z=3.29, p=.003) (Figure 5). There was also a significant EDEQ Total × State interaction ($\chi^2(2)=10.27$, p=.006). To characterise the interaction further, simple slopes of EDEQ Total were estimated within each state. None of the three slopes was individually significant (Table 6). However, Tukey-adjusted pairwise comparisons between these slopes showed the fullness slope was

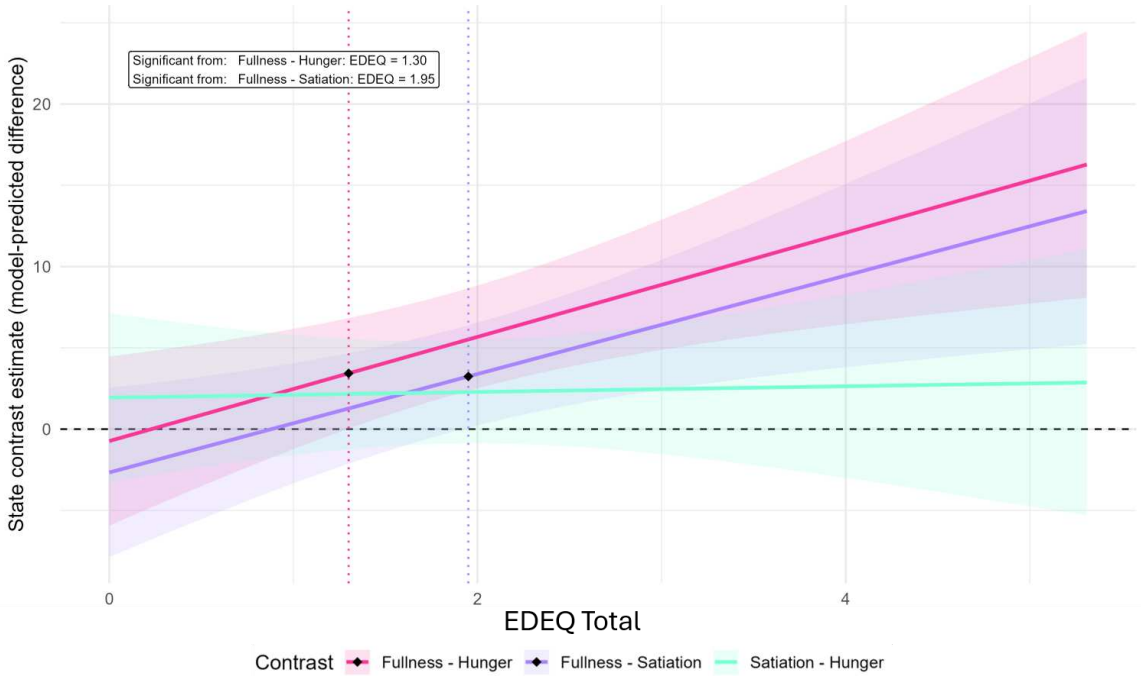
significantly steeper than both hunger's and satiation's (Table 6 and Figure 6). The fullness−hunger contrast became significant at EDEQ Total=1.30 (estimate=3.43, 95% CI [0.03, 6.83]) and remained significant for the rest of the observed range, and the fullness-satiation contrast became significant slightly later, at EDEQ Total=1.95 (estimate=3.24, 95% CI [0.09, 6.39]). This indicates that the relationship between EDEQ Total and waist overestimation is significantly stronger at fullness relative to hunger and satiation, rather than reflecting a significant relationship between EDEQ Total and Waist size overestimation at fullness in isolation.

Figure 5:
Waist (Over)estimation by State



Note: Black Line and diamond = overall mean trajectory across states. Blue/red/green segments= individual state-to-state transitions. Significance brackets represent Tukey-adjusted pairwise comparisons. *$p < .05$. **$p < .01$. ***$p < .001$.

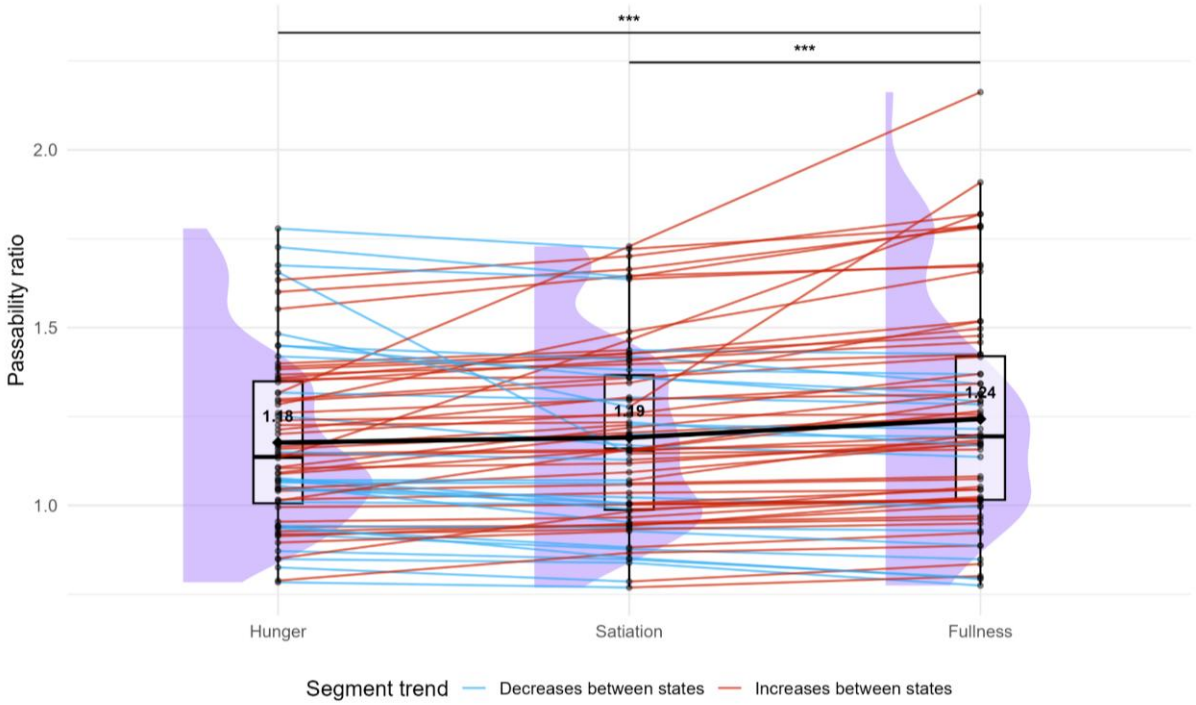
Figure 6:
Waist (over)estimation state contrast estimate interaction with EDEQ Total.



Note: Dashed grey line = no difference between states. Dotted vertical lines mark where each contrasts 95% confidence intervals first excludes zero and stays excluding it for the rest of the EDEQ range. Black diamond on dotted vertical line= where contrast becomes significant according to EDEQ score.

Passability Ratio: Residuals were non-normally distributed according to a Q-Q plot. There was a significant main effect of State ($\chi^2(2)=31.73$, $p<.001$). Tukey-adjusted pairwise comparisons indicated passability was significantly higher at fullness than at both hunger ($z=5.38$, $p<.001$) and satiation ($z=4.14$, $p<.001$) (Figure 7).

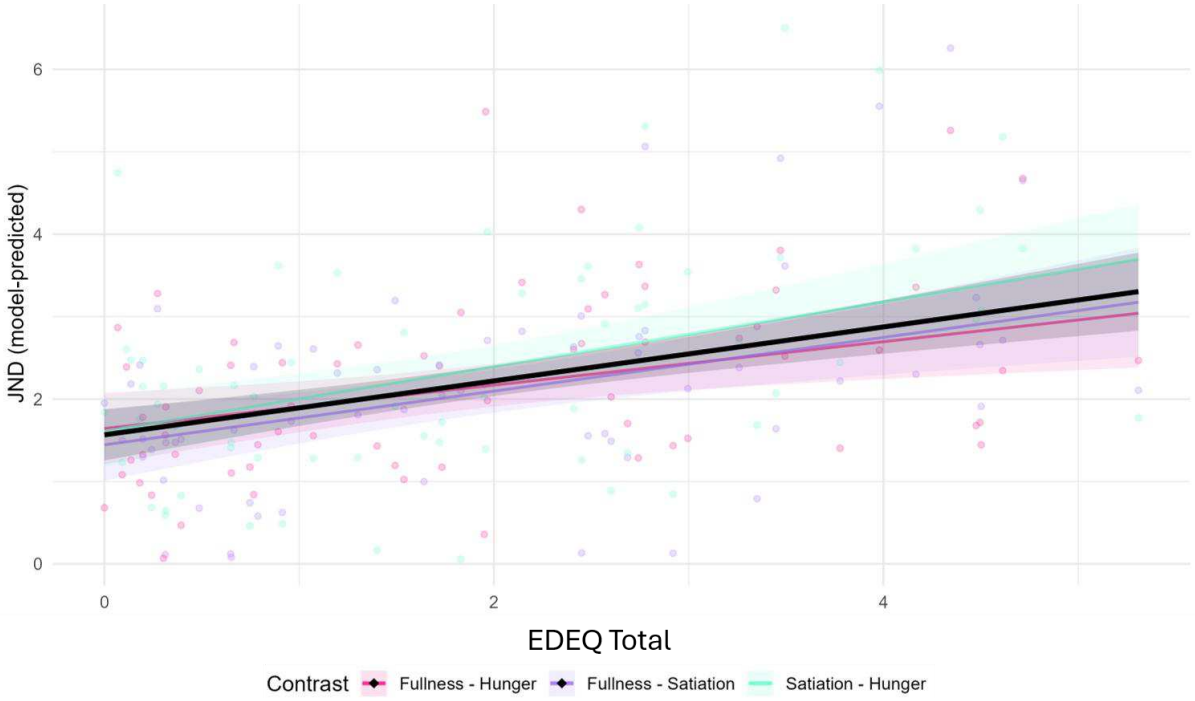
Figure 7:
Passability Ratio by State



Note: Black Line and diamond = overall mean trajectory across states. Blue/red segments= individual state-to-state transitions (no green lines due to no evidence of unchanged trajectory). Significance brackets represent Tukey-adjusted pairwise comparisons. **p < .05. **p < .01. ***p < .001.*

JND: One participant was removed for benign more than 3 standard deviations from the mean (*n*=67). Residuals were non-normally distributed according to a Q-Q plot. A robust linear mixed model showed a significant main effect of EDEQ Total ($\chi^2(1)=8.25$, p=.004), indicating higher eating pathology severity was associated with poorer discrimination precision (Figure 8).

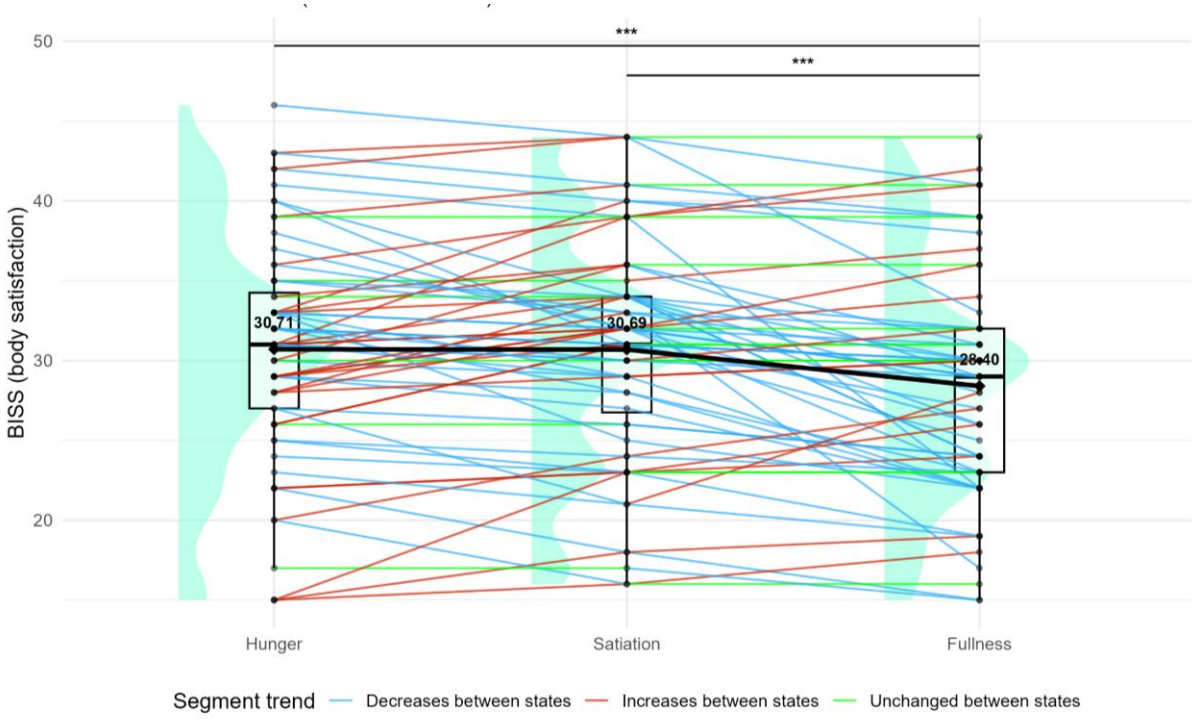
Figure 8:
Main effect of EDEQ Total on JND



Note: Black Line = overall mean trajectory across EDEQ Total.

Body Satisfaction: Residuals were non-normally distributed according to a Q-Q plot. A robust linear mixed model found a significant main effect of State ($\chi^2(2)=23.89$, $p<.001$). Tukey-adjusted pairwise comparisons indicated body satisfaction was significantly lower at fullness than at both hunger ($z=4.22$, $p<.001$) and satiation ($z=4.25$, $p<.001$) (Figure 9).

Figure 9:
Body Satisfaction by State



Note: Black Line and diamond = overall mean trajectory across states. Blue/red/green segments= individual state-to-state transitions. Significance brackets represent Tukey-adjusted pairwise comparisons. **p < .05. **p < .01. ***p < .001.*

Table 5:

Robust Linear Mixed Effects Model Results (MM-estimation, DAStau) for Body Image Outcomes

Predictor	b	SE	df	t	χ^2 (df)	p
Waist size (over)estimation						
EDEQ Total	0.570	2.093	60.11	0.27	0.07 (1)	.786
State – Satiation	1.934	2.655	43.73	0.73		.470
State – Fullness	**−0.736**	**2.655**	**43.73**	**−0.28**	**10.90 (2)****	**.004**
Baseline covariate	**0.659**	**0.118**	**54.99**	**5.60*****	**31.35 (1)*****	**<.001**
EDEQ Total × Satiation	0.175	1.125	43.73	0.16		.877
EDEQ Total × Fullness	**3.205**	**1.125**	**43.73**	**2.85****	**10.27 (2)****	**.007**
Participant intercept variance	487.14 (SD=22.07)					
Residual variance	82.23 (SD=9.07)					

Passability Ratio						
EDEQ Total	0.009	0.011	41.79	0.83	0.68 (1)	.408
State – Satiation	0.018	0.015	47.34	1.23		.225
State – Fullness	**0.033**	**0.015**	**47.34**	**2.25***	**31.73 (2)*****	**<.001**
Baseline covariate	**0.976**	**0.069**	**35.91**	**14.09*****	**198.41 (1)*****	**<.001**
EDEQ Total × Satiation	−0.004	0.006	47.34	−0.60		.552
EDEQ Total × Fullness	0.008	0.006	47.34	1.26	3.59 (2)	.215
Participant intercept variance	0.0138 (SD=0.117)					
Residual variance	0.0026 (SD = 0.051)					
JND						
EDEQ Total	**0.263**	**0.092**	**88.49**	**2.87****	**8.25 (1)****	**.005**
State – Satiation	−0.198	0.270	128.09	−0.73		.465
State – Fullness	−0.033	0.270	128.18	−0.12	3.44 (2)	.179
Baseline covariate	**0.294**	**0.093**	**28.02**	**3.15****	**9.89 (1)****	**.004**
EDEQ Total × Satiation	0.062	0.111	127.93	0.56		.575
EDEQ Total × Fullness	0.129	0.112	129.25	1.15	1.32 (2)	.252
Participant intercept variance	0.278 (SD=0.527)					
Residual variance	0.841 (SD=0.917)					
Body Satisfaction						
EDEQ Total	0.324	0.326	57.18	0.99	0.99 (1)	.325
State – Satiation	0.326	0.743	36.88	0.44		.663
State – Fullness	**−1.991**	**0.743**	**36.88**	**−2.68***	**23.89 (2)*****	**<.001**
Baseline covariate	**0.843**	**0.058**	**29.05**	**14.51*****	**210.56 (1)*****	**<.001**

EDEQ Total × Satiation	−0.163	0.308	36.88	−0.53		.599
EDEQ Total × Fullness	0.044	0.309	36.97	0.14	0.50 (2)	.889
Participant intercept variance	5.969 (SD=2.443)					
Residual variance	6.524 (SD=2.554)					

*Note. Reference category for State is Hunger. χ² columns report the Wald chi-square omnibus test for terms with more than one coefficient (State; EDEQ Total × State); single-coefficient terms show the individual t-test only. Baseline covariate refers to each model's own baseline value of the dependent variable. *p < .05. **p < .01. ***p < .001.*

Table 6:

Robust Simple Slopes of EDEQ Total on Waist Size (Over)estimation, by State

Simple Slopes				
State	***b***	***SE***	***z***	***p***
Hunger	0.570	2.093	0.27	.786
Satiation	0.745	2.093	0.36	.722
Fullness	3.775	2.093	1.80	.071
Pairwise Slope Comparisons (Tukey-adjusted)				
Contrast	***Estimate***	***SE***	***z***	***p***
Hunger − Satiation	−0.175	1.125	−0.16	.987
Hunger − Fullness	**−3.205**	**1.125**	**−2.85**	**.012***
Satiation − Fullness	**−3.030**	**1.125**	**−2.69**	**.019***

*Note. *p < .05.*

Sensitivity Analyses

To check that the linear mixed models were adequately powered to detect the H3 EDEQ × State interaction, a simulation-based sensitivity analysis was conducted for each outcome (simr) (83) (α = .05). Data were simulated from the baseline-controlled linear mixed model using standardised predictors and the between-participant and

residual variances estimated for each outcome in the present data. Across varying interaction sizes (500 simulations each), the study had 80% power to detect even small interactions for all outcomes, with $f^2 \approx .011$ for passability ratio, .012 for waist size estimation, .032 for JND and .034 for body satisfaction (See Supplementary Materials, Table S2).

Discussion

The aim of this study was to examine the relationships between gastrointestinal interoception and both cognitive-affective and perceptual body image, as well as the effects of gastrointestinal state on these body image components using the WLT-II protocol. Emptiness-fullness ratings increased progressively from hunger to baseline, satiation, and maximum fullness, while negative affect scores increased from satiation to fullness (38,46–48). These results support that the WLT-II manipulated gastrointestinal state.

Eating disorder symptoms assessed via the EDEQ (specifically eating shame, dietary restraint, preoccupation with or reported restriction, and weight and shape concerns) were significantly positively associated with NAGS hunger-fear and fullness-shame. In contrast, satiation sensitivity and satiation sensitivity bias showed no significant associations with these clinical features. This pattern reinforces growing evidence that appraisal-based gastric interoception is more critical for disordered eating (84) and broader mental health outcomes (85) than interoceptive detection or insight alone. While no association between satiation sensitivity and weight and shape concerns aligns with results from Hill and Forney (47), this diverges from Ahlich et al. (48). Ahlich et al., (48) unexpectedly reported that higher satiation sensitivity was linked to significantly lower restriction, observing a non-linear cubic relationship where higher sensitivity related to increased restriction, leveling off at moderate sensitivity, and reaching its lowest point at the lowest sensitivity levels. In contrast, the present data revealed no significant linear association between satiation sensitivity and restriction, and direct non-linear testing yielded no evidence of the cubic relationship

reported by Ahlich et al. (48) (Supplementary Materials Table S1). Furthermore, the trajectory of the fitted curve in our sample followed a U-shaped pattern, with higher restriction present at both low and high sensitivity levels and lowest restriction at intermediate sensitivity, rather than the monotonic decrease reported in prior work (Supplementary Materials Figure S1). This divergence may be due to differences in sample characteristics, such as the range and distribution of eating disorder symptom severity, that could alter the shape of non-linear interoceptive relationships.

Fullness-shame predicted eating shame, dietary restraint, weight and shape concerns, and preoccupation with or reported restriction. In contrast, hunger-fear did not predict dietary restraint or weight and shape concerns. These results mirror findings by Stafford et al., (74) (supplementary materials), who observed that fullness-shame, but not hunger-fear, was associated with body dissatisfaction. Together, these patterns clarify the distinct constructs tapped by each subscale. One interpretation is that fullness-shame reflects concerns with somatic fatness, whereby physical fullness exacerbates weight and shape concerns by mimicking the bodily sensation of fatness (74). This conceptualisation explains why fullness-shame exclusively predicted weight and shape concerns.

Notably, hunger-fear significantly predicted preoccupation with or reported restriction, suggesting it may relate specifically to behavioral dietary control rather than broader body dissatisfaction. Although the finding that fullness-shame also predicted dietary restraint might initially appear to challenge this distinction, the items across these subscales target fundamentally different constructs. The EDEQ ‘dietary restraint’ subscale captures intentional attempts to reduce intake to alter weight and shape, whereas the ‘preoccupation with or reported restriction’ subscale assesses the frequency of restrictive behaviors (e.g., fasting for 8+ hours) and food-related thoughts without probing underlying motives. Future research should utilise measures that differentiate motives for restriction, such as shape and weight control (as measured by the EDEQ) versus adherence to rigid food rules (as measured by the Inflexible Eating Questionnaire; (86)). Examining how these distinct

motivations relate to fullness-shame, hunger-fear, satiation sensitivity, and satiation sensitivity bias would clarify how gastrointestinal interoception maps onto specific eating pathology motives rather than general symptom presence.

Increased satiation sensitivity (i.e. observed sensitivity) predicted a significantly larger, and thus less precise, JND. This pattern is clarified by distinguishing satiation sensitivity from interoceptive accuracy. Interoceptive accuracy reflects an individual's ability to objectively detect a physiological signal, such as tracking heartbeat timing via electrocardiography (87). Given that the WLT-II paradigm lacks an objective biological landmark for satiety equivalent to an ECG signal, interoceptive accuracy cannot be evaluated within this framework. Instead, satiation sensitivity measures the degree of stomach fullness required for an individual to report satiation. With the reverse scoring applied in the present study, higher satiation sensitivity indicates that less stomach fullness is needed to detect satiation, reflecting a lower subjective threshold. Rather than representing heightened accuracy, this lower threshold may reflect interoceptive hypervigilance toward subtle gastric distension. This interpretation aligns with Pennebaker's Competition of Cues Hypothesis (88–90), which posits that elevated attentional focus on internal somatic states reduces attentional capacity available for exteroceptive processing. Consequently, hypervigilance toward internal gastric cues may explain why greater satiation sensitivity was associated with poorer precision on the exteroceptive body size discrimination task.

In contrast, underestimating sensitivity (i.e. satiation sensitivity miscalibration underconfidence bias) predicted a significantly smaller, and thus more precise, JND alongside significantly smaller waist size perception. Specifically, underconfident participants (those who believed they were less sensitive to gastric cues than their objective threshold indicated) demonstrated the most precise discrimination and least waist overestimation, whereas overconfident participants exhibited the opposite pattern across both measures. This trend may reflect how individuals calibrate their trust in interoceptive signals (50), with

heightened trust (overconfidence) coinciding with poorer perceptual performance, and lower trust (underconfidence) aligning with superior accuracy.

Although this pattern may appear counterintuitive given that interoceptive trust typically relates to positive body image (91), prior research has assessed trust exclusively via self-report questionnaires measuring either generalised bodily trust (92,93) or trust in hunger and satiety cues (94), and primarily in relation to cognitive-affective body image outcomes (Ahlich et al., 2023). We propose instead that the specific physiological signal being trusted plays a critical role in perceptual body image processing. Satiation is an inherently ambiguous interoceptive signal (95) without a precise bodily sensation, unlike direct visual or proprioceptive inputs regarding body size. Placing strong subjective trust in an ambiguous visceral cue may leave overconfident individuals uniquely vulnerable to imprecise or biased exteroceptive body judgments. Given that the present study is the first to operationalise satiation sensitivity bias in relation to perceptual body image, additional research is required to validate these underlying mechanisms.

Notably, no facets of interoception predicted the baseline passability ratio. This finding contributes to ongoing discussions surrounding the distinction between resting (trait) interoception and interoception experienced during heightened or aversive states (37,96). In the present study, hunger-fear and fullness-shame were assessed at baseline without experimental manipulation. Similarly, satiation sensitivity and satiation sensitivity bias were measured during standard satiation, a state characterised by subtle, ambiguous bodily signals rather than salient physiological markers (95). Given that the passability ratio only increased during fullness, with no significant effect of satiation on body image compared to hunger, it is possible that an association would emerge if fullness sensitivity or fullness-sensitivity bias were directly captured. Future research could adapt the WLT-II to address this by having participants drink to complete fullness across two separate trials. A smaller difference in volume between trials could reflect higher fullness sensitivity, whereas a larger difference would indicate lower sensitivity. Furthermore, akin to the satiation sensitivity bias

index developed here, participants could self-report their perceived fullness sensitivity post-task. Validating these novel behavioral and subjective measures could be an important direction for future study.

Passability ratio increased and body satisfaction decreased at fullness compared to both hunger and satiation, and waist size overestimation increased specifically at fullness relative to hunger. These results align with previous literature that used food intake to manipulate gastrointestinal state (58–60). The elevation in passability ratio may be explained by O'Shaughnessy's (97) Long-Term Body Image Hypothesis. This model distinguishes between a long-term body image, which is an explicit representation of size and shape accumulated through visual input (such as waist size), and a short-term body image, which is an implicit representation (such as felt body size) driven by transient somatosensory signals. As bodily sensations do not inherently convey metric spatial information, the long-term body image (i.e. an explicit size belief) is thought to supply the spatial framework necessary for the short-term image (i.e. implicit felt body size) to translate transient sensations into a perceived body size (98). Applied to the present findings, the somatosensory experience of fullness may have updated felt body size through its integration with long-term body image (i.e. explicit body size beliefs), which was also enlarged with fullness.

Eating disorder symptoms significantly interacted with gastrointestinal state for waist size estimation, such that fullness-related overestimation was amplified by higher symptom severity. This outcome extends O'Shaughnessy's (97) Long-Term Body Image Hypothesis. Although that model posits that the long-term body image provides the spatial framework necessary to interpret somatosensory input as perceived body size (98), it does not specify whether visceral sensations can reciprocally update the long-term (i.e. explicit representation of body size) image. The present findings suggest that such updating does occur, and that this effect becomes stronger as symptom severity increases. Furthermore, these results extend the Allocentric Lock Hypothesis (99), which proposes that individuals with anorexia

nervosa are unable to update an oversized allocentric body representation due to sensory deficits. Rather than demonstrating a global impairment in updating body representation, the present data indicate that this updating resistance may be selective for corrective, size-reducing sensory information.

There was no main effect of state on JND. Instead, uncertainty in felt body size varied as a function of eating disorder symptoms, such that higher symptom severity predicted significantly greater uncertainty. This finding diverges from Mussap et al. (24), who reported no relationship between eating disorder pathology and body size uncertainty. This discrepancy may stem from methodological differences. Whereas the present study used doorways of varying widths, Mussap et al. (24) assessed certainty using digitally distorted photographs of participants' bodies. Consequently, their paradigm required explicit visual comparisons against body size photos, likely engaging explicit perceptual body image rather than the implicit representation tapped by motor-imagery affordance tasks. Supporting this distinction, the main effect of eating disorder symptoms on our own explicit perceptual measure, waist circumference estimation, was likewise non-significant.

Given the centrality of regular eating to clinical recovery, these findings carry important therapeutic implications. The physiological state most necessary for recovery, fullness, is also the state most consistently associated here with transient body image distress. Consequently, each meal may temporarily counter the body image improvements that recovery seeks to foster. This mechanism offers one potential explanation for why body image disturbances often persist even after body weight and nutrition have been stabilised (100). At later stages of recovery, clinical interventions may benefit from incorporating principles of intuitive eating, which emphasise eating until satiation rather than complete fullness (101). As satiation did not worsen body image in the present study, targeting satiation rather than fullness offers a specific, evidence-based behavioral goal for ongoing treatment.

This study possesses several methodological strengths. First, using a standardised paradigm (the WLT-II) rather than food intake isolated the interoceptive state from confounding factors such as caloric content and perceived healthiness, which are known to influence body image (61,62). This addresses a key limitation of prior literature in this domain (58–60). Second, the sample was relatively diverse, with 44% of participants identifying as ethnically distinct from White British or European backgrounds, providing a necessary counterweight to a literature historically dominated by homogenous White samples. Third, adopting the Friborg et al. (73) subscale scoring for the EDEQ ensured direct comparability with recent work (48). Finally, this study extended the assessment of interoceptive states beyond cognitive-affective body image outcomes and introduced a novel interoceptive construct, the satiation sensitivity over/underconfidence bias index, to complement the WLT-II paradigm.

However, these strengths must be considered alongside several limitations. First, sample diversity was limited with respect to gender, as 74.9% of participants identified as female. Although gastric interoception does not appear to differ significantly by gender (102), body ideals vary substantially across gender identities and could influence how gastrointestinal changes affect body image. For instance, while fullness may diminish body satisfaction among individuals who internalise a thin ideal, it may not elicit the same response in those who pursue a muscular ideal such as cis heterosexual men (103). Second, using water rather than food to manipulate stomach distension introduces potential cognitive framing effects. Water is frequently associated with positive appearance-related outcomes, such as skin health (104), and is sometimes utilised for appetite suppression (105). Consequently, some participants may have viewed water ingestion as beneficial to their appearance, possibly explaining why some individual's body satisfaction scores stayed stable or increased at fullness at the individual level (Figure 9).

Another concern regarding the WLT-II is the satiation sensitivity measure. When participants drink to complete fullness, we are assuming that this is their ultimate stomach capacity, and

this is used to index how full their stomach must be to detect satiation (46,48). However, there is no guarantee that their perception of complete fullness can be equated with stomach capacity (106), leaving questions about what satiation sensitivity may actually represent (48). It is also notable that satiation sensitivity is measured using just one trial, in comparison to a measure such as the Heart Rate Detection Task, which samples sensitivity across multiple heartbeats within a single session (96). This brings into question the reliability of our satiation sensitivity and bias measures, although the state-based nature of satiation makes it difficult to measure at multiple timepoints in the way a continuous signal like heartbeat can be, since satiation cannot be repeatedly induced within the same session. One way around this could be to introduce graded subjective checkpoints during water intake, asking participants to indicate as they drink when their stomach feels a given percentage full (e.g., 5%, then continuing to indicate further percentages up to complete fullness), alongside retrospective ratings of their performance at each checkpoint for a measure of sensitivity bias. Once complete fullness is reached, the volume consumed at each checkpoint could be divided by the total volume consumed to reach complete fullness and multiplied by 100, in the same way satiation sensitivity is currently calculated, giving a graded, multi-point index of how full the stomach has to be for each successive level of subjective fullness to be detected, analogous to the trial-by-trial structure used in cardiac interoception tasks. Nevertheless, this approach does not resolve one of the original concerns, as it would still rely on self-reported complete fullness as its reference point, with no guarantee that this corresponds to actual stomach capacity.

Finally, it remains debatable whether the aperture passability and size estimation tasks actually measure perceptual body image. Previous literature suggests size estimation tasks may rely heavily on memory representations of the body rather than real-time perception given that during the task, participants lack a third-person visual perspective (107). Indeed, providing mirror feedback reduces passability ratios and brings size estimates closer to actual body dimensions (108). This raises an important theoretical distinction regarding

whether gastrointestinal states alter real-time perceptual processing or instead modify stored memory representations of felt and believed body size.

Overall, the WLT-II successfully manipulated gastric interoceptive states across experimental conditions. Regression analyses revealed that higher hunger-fear and fullness-shame, subscales from the novel NAGS scale, both predicted increased eating shame and elevated preoccupation with or reported restriction, whereas fullness-shame exclusively predicted greater weight and shape concerns and dietary restraint. Furthermore, elevated levels of both fullness-shame and hunger-fear predicted lower baseline body satisfaction. Regarding perceptual metrics, increased satiation sensitivity predicted a larger, and thus less precise, JND. Conversely, underestimating sensitivity compared to observed sensitivity predicted a smaller, more precise JND alongside reduced explicit waist size estimations. Experimental manipulation of gastric state significantly impacted both attitudinal and perceptual body image outcomes. Specifically, maximum fullness significantly reduced body satisfaction relative to baseline hunger and comfortable satiation, while also increasing the size an aperture must be relative to body size for it to be judged as passable. Fullness similarly increased explicit waist size overestimation compared to baseline hunger, an effect that was significantly amplified among individuals reporting higher eating disorder symptom severity. Additionally, overall eating disorder symptom severity predicted larger, less precise JNDs across conditions. Taken together, these findings demonstrate associations between distinct facets of gastrointestinal interoception and cognitive-affective, and explicit and implicit perceptual dimensions of body image. Moreover, acute manipulation of gastric state directly drives state-level shifts across these domains, with the magnitude of explicit perceptual distortion magnified by eating disorder pathology. Although future research is needed to further clarify the psychological constructs underlying satiation sensitivity bias (e.g., interoceptive trust), these results carry crucial clinical implications for eating disorder treatments where postprandial fullness is an unavoidable feature of nutritional recovery, and unaddressed hypervigilance, negative appraisal, and overconfidence in gastric cues may

systematically trigger and sustain the body image distortions that perpetuate eating pathology. As satiation did not worsen body image relative to hunger, eating to satiation rather than fullness may offer a behavioral goal for ongoing treatment once weight is stabilised.

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Declarations

Ethics approval and consent to participate

This research was carried out in agreement with the Declaration of Helsinki, and it was approved by the Institutional Review Board of the University of York, UK (Approval Numbers: 202458 & 202565). All participants gave their informed consent by signing a consent form before joining the study. They were fully briefed on the research details after participation ended.

Consent for publication

This manuscript does not contain any individual person’s data in any form (including individual details, images, or videos).

Availability of data and materials

Data and Materials are available at: https://osf.io/crenv.

Competing interests

The authors declare no competing interests.

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Authors' contributions

CRediT: Conceptualization, LS; Methodology, L.S; Data curation, L.S; Formal analysis, L.S; Funding acquisition, L.S; Investigation, L.S, A.C.P, C.E.J.P; Project administration, L.S; Resources, L.S, C.E.J.P; Software, L.S; Supervision, A.C.P, C.E.J.P; Visualization, L.S; Writing—original draft, L.S; Writing—review and editing, L.S, A.C.P, C.E.J.P

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