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Longitudinal Trends in Hedonic Hunger following Roux-en-Y Gastric Bypass in Adolescents

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Abstract

Background—Initial outcome studies have demonstrated that Roux-en-Y gastric bypass (RYGB) is safe and efficacious for adolescents with extreme obesity. While rapid weight loss is seen initially, data also show that modest weight regain typically occurs as early as the second post-operative year. The contribution of various psychological factors, including hedonic hunger to postoperative weight regain has not previously been studied in adolescents.

Objectives—To examine the variability in hedonic hunger and Body Mass Index (BMI) over the initial two-year period of weight loss and modest weight regain in adolescent RYGB recipients.

Setting—Academic Children's Hospital, United States

Methods—A total of 16 adolescents completed the Power of Food Scale prior to surgery, and at 3-, 6-, 12-, 18-, and 24-months postoperatively. Height and weight were measured at each time point, from which BMI was calculated.

Results—Nonlinear trends were observed for time on both overall hedonic hunger and hedonic hunger specifically related to food available in the adolescent's environment. The BMI reduction during the first 18-months postoperatively was paralleled by reduction in hedonic hunger; increases in hedonic hunger also paralleled the modest BMI increase at 24-months. In growth analysis, significant power gains are available to models using 4 or more points of data. However, only large effect sizes that are $> .85$ were detectable with a sample of 16 subjects.

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Conclusion—These data provide preliminary evidence that hedonic hunger is in need of further study in adolescent patients receiving RYGB both pre- and post-operatively.

Keywords

hedonic hunger; multi-level modeling; two-year weight trajectory

Extreme pediatric obesity (Body Mass Index [BMI] 99th percentile) affects between 3.8–6.4% of children in the United States, with the majority of cases occurring before age 8.^(1, 2) Extreme obesity is of particular concern in childhood and adolescence because of the increased risk for premature mortality and morbidity in adulthood.^(3, 4) Encouragingly, the initial outcome data support the safety and short-term efficacy of bariatric surgery for extreme obesity in adolescents.^(5–7) Interestingly, we provided preliminary support that, like adults⁽⁸⁾ changes in adolescent BMI are nonlinear, reflecting evidence of modest weight regain (3.23 BMI points or 13% over nadir on average) beginning as early as 24-months postoperatively.⁽⁹⁾ Arguably, this phenomenon may be biologically related to fine-tuning of the adiposity set point after surgery.⁽¹⁰⁾ Alternatively, an emerging adult literature suggests that psychological/behavioral factors such as preoperative food urges and subjective well-being are predictive of participants who gain weight (15% over nadir) at an average of 28 months.⁽¹¹⁾ Given our initial findings of nonlinear adolescent post-operative BMI trajectories,⁽⁹⁾ it is useful to examine modifiable variables that may help explain this period of weight adjustment, in an attempt to understand factors that may optimize treatment gains.

Hunger is one mechanism that may be useful for understanding thwarted attempts at maintaining weight loss. Hunger can be divided into two processes, homeostatic hunger and hedonic hunger. Homeostatic hunger arises from the subjective experience of an energy deficit, with the normal biologically adaptive response being to eat a sufficient number of calories to eliminate the deficiency. This form of need-based hunger is difficult to measure outside of laboratory-controlled settings, and may have less to do with actual consumption of highly palatable energy-dense foods than hedonic hunger or eating for reasons other than a calorie deficit.^(12, 13) Hedonic hunger is the appetitive drive experience of anticipated pleasure associated with eating in the absence of metabolic need combined with an imaginative desire for food when it is absent.⁽¹³⁾ In this case the person *wants* rather than *needs* food. The subjective experience of this *wanting* is what is captured by measures of hedonic hunger.

The experience of hedonic hunger is important for scientific study because its subjective nature may make it amenable to clinical intervention in obese individuals. One mechanism understudy is the way that the subjective experience of appetite appears to mediate the processing of food cues within the brain.⁽¹⁴⁾ For instance, after a fasting period, obese individuals with high hedonic hunger demonstrate lower confidence in their ability to self-regulate eating behavior, and a Functional Magnetic Resonance Imaging (fMRI) neural activation profile consistent with constant rumination about desirable foods. Conversely, those with low hedonic hunger do not exhibit these ruminative profiles.⁽¹⁵⁾

Roux-en-Y gastric bypass (RYGB) appears to normalize subjective feelings of hedonic hunger in obese adults, returning to levels similar to non-obese control participants,⁽¹⁶⁾ and

associated changes in dietary habits.⁽¹⁷⁾ While there is considerable work being done in the area of hedonic hunger following bariatric surgery in adults, there is a dearth of literature studying this phenomenon in adolescents. The understanding of hedonic hunger following RYGB is critical in adolescence because weight trajectories are best characterized by a period of steep initial weight loss followed by modest weight regain at 24-month follow-up.⁽⁹⁾ As noted above, this nadir and modest correction (weight regain) phenotype is quite consistent in human bariatric studies and may well be based on a combination of biological or psychosocial mediators. Nonetheless, understanding the psychological variables that are associated with this pattern may offer important information even if biological variables (e.g., the establishment of an adiposity set point) carry some of the variance. That is, biological and psychological explanations can co-occur and are not mutually exclusive. Changes in hedonic hunger may, indeed, provide clues as to the biopsychosocial processes that underlie this phenotype in RYGB patients.

The aim of the current study was to provide preliminary hypothesis generating data on the effect of RYGB on hedonic hunger in a sample of adolescents. We hypothesized that hedonic hunger will follow a similar nonlinear trend as BMI with initial reductions followed by an increasing slope over time.

METHODS

Data were collected as part of a prospective observational examination of psychosocial and weight loss outcomes for adolescents undergoing RYGB.^(9, 18) Data were collected pre-operatively (baseline) and at 3-month, 6-month, 12-month, 18-month, and 24-month post-operative intervals. The local institutional review board approved the protocol.

Participants

Published guidelines for selecting bariatric surgery candidates were used to screen participants for eligibility (e.g., BMI ≥ 40 kg/m²).⁽¹⁹⁾ In order to participate, subjects were required to obtain clinical and insurance approval for the surgical procedure, be between the ages of 14–17, and have no developmental disabilities due to the high reading demands of the research protocol. Using these criteria, the first 16 consecutive eligible patients agreed to participate. Study retention was high with data obtained at all 5 follow-up time points for 75% of the sample and at 4 time points for 94%. Data collection was completed for 88% of the sample ($n = 14$) at the 24-month interval. Participants were primarily girls (62.5%), non-Hispanic Caucasian (87.5%), and from a wide geographic area representing 7 states. The mean age for participants was 16.2 ± 1.4 years. The mean BMI for the sample was $M = 59.91 \pm 8.71$ at baseline (Table 1).

Data collection occurred using several different methods to reduce participant burden and maximize retention. Measures were administered at scheduled clinical visits when possible. However, in-home, telephone, and regular mail responses were also collected by trained study staff. These strategies were deployed at the 18-month (47% mail; 7% in-home) and 24-month (7% mail; 36% in-home) time-points. Participants were compensated for their involvement. When participants completed measures via the mail only, self-reported weight

and height were used (i.e., 8 of the 89 or 9% of weight and height measurements were self-reported).

Hedonic hunger—The Power of Food Scale (PFS) was initially developed for use in obese adults, and was subsequently validated in college-age students.⁽²⁰⁾ The 21-item measure assessed the feeling of being controlled by food even when food is not physically present. The measure is comprised of three subscales which all demonstrated acceptable internal consistency statistics in the current adolescent sample. Subscales assess feelings of wanting highly palatable foods when such foods are available but not physically present (Cronbach's alpha [α] = .88–.96; ranges represent 6 assessment periods), present but not tasted (α = .82–.94), food tasted (α = .68–.89), and a total score (α = .92–.97). The PFS measures the desire to eat highly palatable food in the absence of energy need and the rumination on highly palatable food as a psychological trait.⁽²¹⁾ In studies using the measure, participants who score high on the PFS and have had their energy needs met in the laboratory demonstrate differentiated fMRI profiles consistent with wanting a favorite food despite having no metabolic need.⁽¹⁵⁾ The PFS includes items such as: “I find myself thinking about food even when I'm not physically hungry” (available subscale); “When I'm in a situation where delicious foods are present but I have to wait to eat them, it is very difficult for me to wait” (present subscale); and “When I taste a favorite food, I feel intense pleasure” (taste subscale). Response choices are as follows: 1 = Don't agree at all, 2 = Agree a little, 3 = Agree somewhat, 4 = Agree, and 5 = Strongly agree. Therefore, higher scores indicate stronger power of food.

BMI—Height and weight measures were obtained by a trained research assistant using a calibrated stadiometer and digital scale with the participants in street clothing and no shoes. For those participants who completed the questionnaires by mail (47% at 18-months and 7% at 24-months), self-reported measurements were used. These data were used to calculate BMI using the standard formula kg/m^2 .

Statistical Approach

Hierarchical linear modeling analysis—Hierarchical linear modeling (HLM) using MplusVersion 6.12⁽²²⁾ was used to estimate the average growth trajectory of hedonic hunger over time.

Specifically, the level-1 and level-2 equations that define the analysis models are given by:

$$\text{Level-1: } Y_{ij} = \pi_{0j} + \pi_{1j}(LTime_{ij}) + \pi_{2j}(BMI_{ij}) + e_{ij}$$

$$\text{Level-2: } \pi_{0j} = \gamma_{00} + u_{0j}$$

$$\text{Level-2: } \pi_{1j} = \gamma_{01} + u_{1j}$$

$$\text{Level-2: } \pi_{2j} = \gamma_{02}$$

Where ‘Y’ refers generically to the following response variables (PFS total, available, present, and tasted scales), γ_{00} refers to the average response variable score across

participants at baseline, γ_{01} quantifies the average log-time response variable change, γ_{02} quantifies the average impact of BMI on log-time response variable change over time, u_{0j} quantifies the variation in the average response variable score at baseline across participants, and $(+u_{1j})$ refers to the fact that, for some response variables, log-time response variable change over time varied significantly across participants. Although, as noted above, complete data were available for 75% of the sample, Mplus allows for the use of full information maximum likelihood estimation (FIML), which accounts for missing data by estimating a complete covariance matrix and retaining all participants with multiple data points in the analysis. In growth analysis, significant power gains are available to models using 4 or more points of data. Even with these power gains, however, only large effect sizes that are $> .85$ will be detectable with a sample of 16 subjects.⁽²³⁾

As stated above, a nonlinear trend was hypothesized over time based on the established nonlinear trend of both anthropometric and psychosocial variables in bariatric populations.⁽⁹⁾ Given that the subsample for this analysis is relatively small, the traditional quadratic (time²) transformation included with linear time would have resulted in a model with too few degrees of freedom to test for an effect for BMI. In the alternative, we used a transformation of the time variable itself (Ltime = $\log[\text{month} + .5]$) as a single nonlinear function of time. A log transformation produces a curve similar to the quadratic polynomial for monotonic curves. That is, the curve is nonlinear but continually increasing or decreasing. Each response variable was analyzed using a three-step procedure: (1) a fixed-effect model, where changes in response variables changes over (L)time are not allowed to vary across participants; was estimated first, followed by (2) a random-effect model that tested for the presence of significant variation across participants in response variable changes over (L)time, and (3) a model with BMI added as a time-varying (Level-1) covariate. The final model was chosen based on all parameters being significant at probability of Type I error (p) $< .05$ with trends reported at $p < .10$ to maintain consistent with the hypothesis generating nature of these preliminary data with relatively low statistical power.

RESULTS

Preliminary analyses

The results of the preliminary analysis revealed no differences based on male/female groupings. Therefore, males and females were collapsed and analyzed in aggregate in subsequent analyses.

Hedonic hunger 2-year multilevel models

There was a negative nonlinear effect of Ltime on the present, available, and total score scales. The total score and available scale models also demonstrated significant slope variance at Level 2. See Figures 1 and 2 for graphical representations of the Level 1 and Level 2 regression lines. The trend for the taste scale over Ltime was not significant. Results of the models attempting to explain the trends in 2-year hedonic hunger slopes revealed significant nonlinear effects of a Ltime with a main effect of BMI on the available scale ($\beta = .24$; $p = .01$; Figure 1) and a trend for the total score ($\beta = .43$; $p = .07$; Figure 1) and

meaning that as BMI decreased over the initial 18-month period so did the desire for highly palatable foods that were available in the environment; when BMI began to increase so did the drive to eat highly palatable foods in the absence of metabolic need as measured by the PFS.

DISCUSSION

There are three important conclusions to take away from the current preliminary study. First, hedonic hunger follows a nonlinear function in obese adolescents after RYGB. This function is similar to the nonlinear trend observed in BMI over the same period for this sample of RYGB recipients⁽⁹⁾ and raises research questions about how hedonic hunger measured in this interesting period of early weight adjustment (2-years) after RYGB may be related to longer term (e.g., 5-year) weight regain as evidenced by the significant main effect of BMI on hedonic hunger observed in the postoperative period. Second, it is interesting that the effect of hedonic hunger is due to the available and not the present or tasted scales of the PFS. This finding is consistent with the idea that the major impact of hedonic hunger comes from the rumination on highly desired foods rather than compulsive eating of food that is immediately present or tasted.¹⁵ Finally, existing prospective studies of hunger (specifically food cravings) in adults following bariatric surgery are limited to a six-month follow-up window.⁽²⁴⁾ Our data indicate that a 6-month window may be insufficient to capture the nonlinear nature of hedonic hunger and weight regain.⁽⁹⁾

Our data indicate that hedonic hunger levels at baseline decline through 18-months and increase at 24-months (a trajectory also observed in BMI for this sample). This process appears to be primarily driven by the positive association with food even when not immediately present in the environment. It is important to note that when accounting for the effect of BMI the levels of hedonic hunger related to available foods are higher in the current sample than in adult samples and never decline to levels consistent with reports of obese adults (e.g., 3.6-2.7 in the current sample vs. approximately 2.6 in adults) suggesting an important relationship between BMI and hedonic hunger.^(16, 21) While it is not yet clear what normative mean level values should be expected in adolescents, the absolute differences between our sample and adults lead us to tentatively suggest that the process of developing hedonic hunger in adolescents maybe developmental as well as biopsychosocial. Future studies should attempt to determine if adolescents demonstrate greater than expected hedonic hunger when accounting for BMI. We believe that the developmental trajectory of such problems could be a particularly important area for investigation.

There are a number of notable limitations in the current study with consequent directions for future research. First, while the sample was large enough to detect important statistical trends within this specific cohort of adolescent RYGB patients, the sample size is not large enough to draw definitive inferences about the total population of adolescents who undergo bariatric surgery. Further, these bariatric outcome data are limited to a 24-month follow-up window. Only prospective and larger sample studies that are longer-term (e.g., beyond 24-months) will provide sufficient evidence of the durability of adolescent surgical weight loss over time and a context to evaluate potentially modifiable predictive factors of less optimal outcomes. To maximize participation rates at later time-points, the current study utilized

self-reported height and weight data in 9% of cases. Given noted trends that adolescents, when asked, may underestimate weight and overestimate height, the present data may therefore reflect an underestimation of true BMI at 18 and 24-months. That is, adolescents generally underreport their measured weight by ~3.5 pounds and overestimate their height,⁽²⁵⁾ which may have biased the data downward, but not in the observed direction of increasing BMI and hedonic hunger at 24-months. Finally, while hedonic hunger has been reliably and validly measured in college-aged students⁽²⁰⁾ the measure has not been validated in a purely adolescent (i.e., 13–18 years old) sample. Moreover, normative data are not available for adolescents making it difficult to ascribe meaning to the absolute levels of hedonic hunger observed in the current sample. Nonetheless, the trend over time can be taken as a valid finding as the shape of the slopes would be unaffected by the presence of normative data.

Directions for Future Research

Hedonic hunger appears to be affected by RYGB in adolescents with extreme obesity. However, the process is nonlinear and is associated with BMI such that modest weight regain is related to concurrent increases in hedonic hunger. This raises empirical questions regarding the developmental and biopsychosocial context that surrounds issues of weight management following RYGB. In particular, future work is needed to understand what biological factors (i.e., anorexic peptides, D2 regulation) mediate this psychological process, and what effect developmental age has on these processes. That is, does the fact that most cases of extreme obesity emerge in a critical neurodevelopmental period (i.e., < 8-years of age)⁽²⁾ influence the intensity and developmental course of hedonic hunger? One concerning yet relevant fact is that in rodents the neurobiological processes that govern food reward (striatal D2 receptors) become dysregulated simply by allowing free access to a cafeteria style Western diet. In this setting, weight gain as a natural consequence of overfeeding results in exacerbations in the process of downregulation of striatal D2 receptors.⁽²⁶⁾ These (admittedly nonhuman) data provide physiologic evidence that the neurobiological processes that govern hedonic hunger are dynamic. We believe that answers to empirical questions regarding the neurobiological mechanisms governing hunger combined with clinical interventions aimed at helping patients cope with increases in hedonic hunger may help prevent or arrest weight regain beyond what would be expected as a function of establishing an adiposity set-point following RYGB.

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Figure 1.

Level 1 & 2 slopes for the PFS Total Score with BMI as a Covariate Over 24-Months Post-RYGB

Level 1 & 2 Slopes for the PFS Available Scale with BMI as a Covariate Over 24-Months Post-RYGB

BMI: Body Mass Index; PFS: Power of Food Scale; RYGB: Roux-en-Y Gastric Bypass

Table 1

Adolescent BMI and PFS Model Means and Standard Deviations

Variable	Baseline (n = 16)	3-mo FU (n = 16)	6-mo FU (n = 14)	12-mo FU (n = 14)	18-mo FU (n = 15)	24-mo FU (n = 14)
BMI (M $\pm$ SD) (kg/m ²)	59.91 $\pm$ 8.71	48.96 $\pm$ 9.07	42.21 $\pm$ 7.80	36.94 $\pm$ 4.94	35.17 $\pm$ 5.14	38.40 $\pm$ 7.53
PFS Total X BMI (M $\pm$ SD)	2.79 $\pm$.18	2.34 $\pm$.18	2.39 $\pm$.17	2.26 $\pm$.17	2.22 $\pm$.18	2.28 $\pm$.16
PFS Available X BMI (M $\pm$ SD)	3.61 $\pm$.30	3.23 $\pm$.31	2.99 $\pm$.28	2.80 $\pm$.28	2.74 $\pm$.30	2.85 $\pm$.26
PFS Present (M $\pm$ SD)	2.54 $\pm$ 1.23	1.87 $\pm$.71	1.80 $\pm$.83	1.59 $\pm$.51	1.71 $\pm$.88	1.79 $\pm$.82
PFS Tasted (M $\pm$ SD)	2.26 $\pm$.98	1.91 $\pm$.65	1.86 $\pm$.72	1.64 $\pm$.54	1.76 $\pm$.84	1.56 $\pm$.56

BMI: Body Mass Index; PFS: Power of Food Scale; FU: Follow Up; M: Mean; SD: Standard Deviation