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Effects of Liraglutide on Appetite, Food Preoccupation, and Food Liking: Results of a Randomized Controlled Trial

Jena Shaw Tronieri, Ph.D.[1], **Thomas A. Wadden, Ph.D.**[1], **Olivia Walsh, B.S.**[1], **Robert I. Berkowitz, M.D.**[1,2], **Naji Alamuddin, M.D.**[3], **Kathryn Gruber, C.R.N.P.**[1], **Sharon Leonard, R.D.**[1], **Zayna M. Bakizada, B.A.**[1], **Ariana M. Chao, Ph.D., C.R.N.P.**[1,4]

[1]Perelman School of Medicine at the University of Pennsylvania, Department of Psychiatry, Center for Weight and Eating Disorders, Philadelphia, PA

[2]The Children's Hospital of Philadelphia, Department of Child and Adolescent Psychiatry, Philadelphia, PA

[3]Perelman School of Medicine at the University of Pennsylvania, Department of Medicine, Philadelphia, PA

[4]University of Pennsylvania School of Nursing, Department of Biobehavioral Health Sciences, Philadelphia, PA

Abstract

Background: Some weight loss medications, including liraglutide 3.0 mg, are thought to facilitate weight loss by improving appetite control. However, no studies have evaluated their long-term appetitive effects.

Subjects/Methods: This study examined changes in appetite in a subsample of 113 adults with obesity (76.1% female, 55.8% white, BMI = 38.8±4.8 kg/m^2) who participated in a 52-week trial. Participants were randomized to intensive behavioral therapy alone (IBT-alone), IBT with liraglutide 3.0 mg/day (IBT-liraglutide), or IBT-liraglutide combined with a 12-week meal replacement diet (Multi-component). Participants rated their hunger, fullness after meals, liking of meals, and food preoccupation (all as experienced over the past week) using visual analogue scales (0-100 mm). Ratings were completed at baseline and 8 subsequent visits over the year.

Results: At week 52, participants treated by IBT-alone lost 6.2±1.6% of baseline weight, compared with 11.8±1.6% and 12.1±1.5% in the IBT-liraglutide and Multi-component groups, respectively. Compared to IBT-alone, IBT-liraglutide participants reported larger reductions at

All correspondence to: Jena Shaw Tronieri, Ph.D., University of Pennsylvania, 3535 Market Street, Suite 3025, Philadelphia, PA 19104. Tel.: 215-746-5045; Fax: 215-898-2878. jena.tronieri@pennmedicine.upenn.edu.

Competing Interests: Drs. Tronieri and Alamuddin serve as consultants to Novo Nordisk. Dr. Wadden reports serving on advisory boards for Novo Nordisk and Weight Watchers Inc. Dr. Berkowitz serves as a consultant to Eisai Pharmaceutical, and Dr. Chao has consulted with Shire Pharmaceutical. All other authors declare no potential competing interests.

Data deposition: A deidentified data set will be made available to external investigators (upon request to the first author), once the research team has completed its analysis and reporting of secondary findings from the study. This is expected to be approximately 2 years after the publication of this report.

Trial Registration: ClinicalTrials.gov number, NCT02911818

week 6 in hunger (−0.3±4.2 vs −16.8±4.0 mm, p=.005) and food preoccupation (+0.2±3.7 vs −16.3±3.6 mm, p=.002) and larger increases in fullness (−5.1±3.2 vs +9.8±3.0 mm, p=.001). These significant differences persisted at all assessments through week 24. There were no differences between IBT-alone and IBT-liraglutide in meal liking. IBT-alone and Multi-component participants differed in hunger at week 6, and in food preoccupation at all assessments through week 24. Multi-component participants reported reduced liking of meals relative to the IBT-alone and IBT-liraglutide groups through weeks 40 and 52, respectively. There were no other differences among any groups at week 52.

Conclusions: Consistent with short-term studies, IBT-liraglutide participants reported greater improvements in hunger, fullness, and food preoccupation than those assigned to IBT-alone. Differences in appetite persisted for 24 weeks but were not maintained at week 52, despite the relatively greater weight losses in the liraglutide-treated participants at the trial's end.

Keywords

weight management; appetite; lifestyle modification; anti-obesity agents

Introduction

Patients with obesity achieve larger mean weight losses when behavioral treatment and medication for chronic weight management are combined, relative to the weight loss achieved with either treatment alone (1,2). In a representative 1-year randomized trial (1), patients treated with sibutramine (15mg/d) alone lost 5.0±7.4 kg, those who received behavioral treatment alone lost 6.7±7.9 kg, and those who received the two interventions combined lost 12.1±9.8 kg. The additive benefits of behavioral and pharmacologic treatments for obesity have been attributed to their complementary mechanisms of action (3,4). Behavioral weight loss treatment helps patients modify or control the external food environment through techniques such as avoiding cues to eat, reducing portion sizes, and recording food and calorie intake. Centrally-acting pharmacologic agents for obesity, by contrast, are thought to modify patients' internal environment by decreasing hunger, increasing satiation and satiety, and improving other aspects of appetite. These internal changes likely facilitate adherence to dietary goals, including by reducing patients' responsiveness or vulnerability to the food environment (3,4).

Liraglutide, a glucagon-like peptide-1 (GLP-1) receptor agonist, is one of five medications currently approved by the Food and Drug Administration for chronic weight management. In a meta-analysis, liraglutide 3.0 mg produced an average placebo-subtracted weight loss of 5.3 kg at 1 year (5). Liraglutide appears to induce weight loss through its activation of GLP-1 receptors in brain areas associated with appetite and food reward (6,7). Several short-term laboratory studies have shown that, compared to placebo, liraglutide increased fullness (3 studies) and decreased hunger (2 of 3 studies) after an energy-fixed preload (8-10). These changes were associated with a 12 to 27% relative reduction in energy intake during a subsequent test meal, but not with differences in perceived palatability of the meal (8,10). In two short-term treatment studies (4 and 5 weeks), post-treatment hunger was lower with liraglutide than with placebo (7,11). One of these studies also found relative improvements in post-prandial fullness (i.e., "how full do you feel") and satiety (i.e., "how satisfied do you

feel") and lower energy intake during a test meal (11), but the other did not (7). An additional short-term study measured appetite sensations and ad libitum food intake during an inpatient stay following 12 weeks of treatment with a related GLP-1 agonist, semaglutide 1.0 mg, or with placebo. Participants reported improved hunger, fullness, and satiety and consumed 24% fewer calories over 12 hours with semaglutide, as compared to placebo (6). Palatability ratings did not differ during laboratory test meals, but past week ratings of liking of food were lower with semaglutide than placebo (6).

These laboratory-based and short-term treatment studies support the theory that adding liraglutide 3.0 mg to behavioral treatment would enhance weight loss by improving aspects of appetite control. However, little is known about whether these changes persist beyond the first few weeks or months. On average, patients treated with weight loss medications regain some of their lost weight after approximately 1 year, despite their remaining on medication and despite maintaining substantially larger weight losses than participants assigned to placebo (12,13). Studying the duration of the effects of obesity medications on appetite may improve our understanding of the long-term benefits of these drugs.

The present study evaluated the short- and long-term effects of liraglutide 3.0 mg on changes in hunger, fullness after meals, food preoccupation, the frequency of food cravings, and liking of meals during a 52-week, open-label, randomized controlled trial (RCT) that compared the efficacy of three treatment conditions: intensive behavioral therapy (IBT) as developed for delivery in primary care settings (IBT-alone); the same IBT program combined with liraglutide 3.0 mg/d (IBT-liraglutide); and IBT-liraglutide combined (for 12 weeks) with a portion-controlled diet that provided 1000-1200 kcal/d (Multi-component). We hypothesized that the IBT-liraglutide group would report greater improvements, beginning at week 6, in hunger, fullness after meals, food preoccupation, and craving frequency, than would the IBT-alone group, and that these differences would be maintained through weeks 24 and 52. We hypothesized that the two groups would not differ in liking of meals at any time point. We did not propose pre-specified hypotheses regarding the Multi-component group due to the unknown effect of the portion-controlled diet on liraglutide's appetite-control properties; comparisons with this group were considered exploratory.

Subjects and Methods

Participants

The study's methods and primary results have been reported previously (14). Briefly, participants were aged 21-70 years, had a body mass index (BMI) ≥ 30 and ≤ 55 kg/m², and had no serious medical or psychological conditions (e.g., diabetes mellitus, recent cardiovascular disease, current major depressive disorder) or contraindications to the use of liraglutide (e.g., personal or family history of medullary thyroid cancer or multiple endocrine neoplasia syndrome). All participants provided written informed consent, and study procedures were approved by the university's institutional review board. After completing an initial phone screen and a behavioral and medical assessment to determine eligibility, participants were assigned in equal numbers to the three intervention groups.

Collection of appetite measures was initiated after the first cohort of participants ($N = 37$) had been enrolled in the study. Thus, findings reported here are limited to a subsample of 113 of the total sample of 150 participants who enrolled in the 52-week RCT.

Interventions

During the 52-week treatment program, participants in all three groups received 21 brief (15 minute), individual sessions of IBT adapted from the Diabetes Prevention Program protocol (15,16). Participants were prescribed a calorie goal of 1200-1499 kcal/d for those <113.6 kg (250 lb) or 1500-1800 kcal/d for those ≥113.6 kg. They were instructed to gradually increase their physical activity to ≥225 minutes per week and were provided behavior change strategies to facilitate their adherence to these goals. Sessions followed the treatment schedule recommended by the Centers for Medicare and Medicaid Services (CMS) (i.e., weekly for 4 sessions, every-other-week for 10 sessions, every 4 weeks for 7 sessions) (17) and were delivered by a physician, nurse practitioner, or registered dietitian in an academic medical setting. Patients were offered all 21 sessions, regardless of whether they met the CMS eligibility criterion of losing ≥3 kg at month 6, needed to receive 6 additional monthly sessions. All participants also had seven brief medical visits to measure vital signs and review any health concerns.

IBT-alone.—Participants in this group received the intervention described above with no additional treatment.

IBT-liraglutide.—Participants in this group were provided the same IBT intervention combined with once daily subcutaneous injections of liraglutide 3.0 mg/day. The medication was initiated at 0.6 mg/day at week 1 and increased by 0.6 mg/day each week until 3.0 mg/day was achieved. Medication was dispensed every 4 weeks from week 1 to week 48, on a total of 13 occasions.

Multi-component.—These participants received the same treatment as the IBT-liraglutide group, combined with the prescription at week 4 of a 12-week, 1000-1200 kcal/day meal replacement diet. This diet included four servings of a liquid shake (Health Management Resources–HMR; 160 kcal/shake), a prepackaged entrée (250-300 kcal), 1-2 servings of fruit, and a salad.

Appetite Measures

At nine of the treatment visits (i.e., weeks 1, 4, 6, 10, 16, 20, 24, 40, and 52), participants completed visual analogue scale (VAS) ratings of appetite in reference to how they had felt in the past week. The greater frequency of ratings during the first 24 weeks was intended to capture the timing of early changes in appetite. Hunger, fullness after meals, food preoccupation, craving frequency, and liking of meals were measured using 100-mm VAS line ratings (18,19), which were administered electronically via a tablet. Sample items included “how hungry did you feel over the past week?” and “how much did you think about wanting to eat over the past week?” VAS ratings of appetite have been shown to change in the expected directions following food consumption (6), to correlate with energy intake and weight change (20), and to have good convergent validity with full-scale measures of

appetite (18). A previous study instructed participants to complete daily VAS appetite ratings prospectively, at home, for several days (18). Then, at a clinic visit, they completed the same VAS items in reference to how their appetite had been in the past week. The retrospective past-week rating of each appetite construct correlated strongly with its average prospective daily rating during the same period (*r*s .63-.80), and the mean weekly and daily ratings were within 3.3 to 7.2 mm of each other. Further, the past-week VAS ratings were more strongly correlated with the mean of the daily ratings than they were with either the ratings from the most recent day or with the highest daily rating. This finding suggested that past-week appetite ratings most strongly reflect participants' appetite across the week as a whole, rather than their most recent or most salient appetite sensations. Short-term test-retest reliability for the weekly ratings was generally very high (18).

Body Weight

Body weight was measured using a digital scale (Tanita BWB-800) at all clinic visits and at three outcome assessments at weeks 1, 24, and 52.

Statistical Analyses

Linear mixed models with residual maximum likelihood were used to compare the three treatment groups on changes in VAS appetite ratings over time in the intention-to-treat (ITT) population. Unconditional models were used to determine the appropriate model shape (e.g., linear, quadratic, piecewise) and variance-covariance structure based on model fit criteria (21). Differences between groups in changes in appetite at each time point were then compared using least-squares means. The primary focus was on the comparisons at week 6 (i.e., early treatment) after most participants who received liraglutide had completed dose titration, as well as at the week 24 and week 52 assessments. Comparisons at additional time points were considered exploratory and were used to determine the duration of differences between treatment groups.

Results

Participant Characteristics and Weight Loss

The 113 participants included in the present study had a mean initial BMI of 38.8 kg/m2 (110.3 kg). Their mean age was 46.7 years; 76.1% were female, and 55.8% identified as white (42.5% as black) and 6.2% as Hispanic. Participants' additional demographic characteristics and mean appetite ratings at baseline are shown in Table 1. Baseline liking of meals was higher in the Multi-component group than in the IBT-liraglutide group. There were no other significant differences among the groups at baseline. The average participant completed appetite ratings on 7.6 (*SD* = 2.0) out of 9 occasions. At week 52, in this subsample of 113 participants, those who received IBT-alone lost a mean (± *SE*) of 6.2±1.6% of baseline weight, compared with a significantly greater 11.8±1.6% and 12.1+1.5% in the IBT-liraglutide and Multi-component groups, respectively (Figure 1).

Changes in Appetite

Hunger and fullness.—Table 2 shows estimated mean changes in appetite for each treatment group and comparisons among the groups at weeks 6, 24, and 52. The IBT-alone

group reported minimal changes in hunger of −0.3±4.2 mm at week 6, compared to the significantly larger −16.8±4.0 mm reduction in the IBT-liraglutide group (Figure 2a). These differences persisted at all time points through week 24 (+0.7±3.8 vs −11.9±3.7 mm, respectively) but not at weeks 40 or 52. The Multi-component group also reported larger reductions in hunger at week 6 (−11.7±3.8 mm) than the IBT-alone group. However, these two groups did not differ significantly after week 6. IBT-liraglutide participants did not differ from Multi-component participants in changes in hunger at any assessment.

The IBT-alone group reported a −5.1±3.2 mm mean reduction in fullness after meals at week 6, compared to the +9.8±3.0 mm increase reported by IBT-liraglutide participants (Figure 2b). Changes in postprandial fullness differed between these groups through week 24, at which time the IBT-alone participants reported a mean −4.3±3.1 mm reduction compared to a +6.7±2.9 mm increase in IBT-liraglutide. These groups did not differ significantly at weeks 40 or 52. Differences between the Multi-component group and the other two groups in fullness after meals were not statistically significant at any time.

Food preoccupation and craving frequency.—IBT-alone participants reported a small mean increase in food preoccupation of +0.2±3.7 mm at week 6, compared to a substantial −16.3±3.6 mm reduction in the IBT-liraglutide group at this time (Figure 3a). At week 24, IBT-alone participants reported a −2.4±3.5 mm mean decrease in food preoccupation, compared to the significantly larger −12.2±3.4 mm reduction reported by IBT-liraglutide participants. Multi-component participants also reported larger reductions than IBT-alone participants in food preoccupation at all time points through week 24, with reductions of −16.7±3.3 mm at week 6 and of −13.4±3.2 mm at week 24. There were no differences in food preoccupation between the IBT-liraglutide and Multi-component groups at any time and no differences among any of the groups at weeks 40 or 52. Although reductions in cravings did not differ significantly among any of the groups at most time points (Figure 3b), at week 52, IBT-alone participants reported larger mean reductions than the Multi-component group (−9.3±4.6 mm vs +3.5±4.2 mm).

Liking of meals.—There were no significant differences at any time between IBT-alone and IBT-liraglutide participants in reported liking of their meals (Figure 4). Participants in both groups generally liked their meals, as indicated by mean ratings of 62.7 to 69.5 mm throughout the study. Multi-component participants reported a mean −13.7±3.1 mm reduction in liking of food at week 6, which differed significantly from the +3.4±3.5 mm and +3.5±3.3 mm increases in liking reported by the IBT-alone and IBT-liraglutide groups, respectively. The Multi-component group continued to report larger reductions in liking of meals than IBT-alone through week 40 (changes of −4.7±3.0 mm and +4.3±3.2 mm, respectively), and their ratings differed from those of IBT-liraglutide participants through week 52 (changes of −1.5±3.3 mm and +8.1±3.5 mm, respectively). Due to baseline differences among the groups in food liking, this analysis was repeated using change in liking as the outcome, controlling for baseline scores. In this analysis, changes in liking differed between the IBT-alone and the Multi-component groups at all times through week 24; the difference between the IBT-liraglutide and Multi-component groups was statistically significant from week 6 through week 24.

Changes in Appetite in Participants who Received Medication at Week 48

We conducted an additional exploratory analysis to examine whether the lack of statistical differences between groups in changes in appetite at week 52 could be attributed to some participants having discontinued the medication prior to that time. In the two medication conditions, liraglutide was dispensed to participants on an average of 11.6 of 13 occasions (SD = 3.2, median = 13.0); 79.2% of liraglutide-treated participants received medication at the last distribution at week 48. We examined group differences in appetite at the end of the trial when only participants who received liraglutide at week 48 were included for the medication conditions (n = 30 for IBT-liraglutide, n = 31 for Multi-component, and n = 36 for IBT-alone). In this subset of participants (N = 97), the overall patterns of change in the appetite measures in the medication groups were similar to the results described above. There were no significant differences between IBT-alone and either liraglutide-treated group in changes in appetite ratings at week 52.

Discussion

This study's principal finding was that the addition of liraglutide 3.0 mg to IBT produced larger initial improvements in hunger, fullness after meals, and food preoccupation than IBT alone. These findings are consistent with the results of previous short-term studies (7,11) and suggest that improved appetite control is one of the mechanisms by which liraglutide increases initial weight loss. Differences between IBT-liraglutide and IBT-alone on these three dimensions of appetite persisted through week 24. As expected, IBT-liraglutide and IBT-alone participants did not differ significantly in their reported liking of their meals, which increased slightly in both groups over the course of the 52-week trial. Previous studies have not found differences in palatability ratings of a laboratory test meal between participants who received liraglutide or placebo, despite lower intake in liraglutide-treated participants (8,10).

Changes in craving frequency did not differ between IBT-liraglutide and IBT-alone at any time. Previous studies of the effect of liraglutide on appetite did not measure craving frequency. However, one short-term study of semaglutide 1.0 mg did find a greater reduction in cravings relative to placebo after 12 weeks of treatment (6).

Across all appetite measures, the relative benefit of liraglutide declined over time, and changes in appetite with IBT-liraglutide were not statistically different from IBT-alone for any measure at week 40 or 52. This pattern does not appear to be attributable to liraglutide-treated participants discontinuing the medication, because excluding participants who did not receive medication at the end of the study did not alter the results. Hunger and desire to eat have been shown to increase following initial weight loss, possibly due to changes in circulating levels of hormones involved in appetite regulation (22,23,24).

Studies in rodents (e.g., 25) and two human trials (26, 27) have shown that the effects of long-acting GLP-1 agonists on gastric emptying, which influences perceived hunger and fullness, diminish over time. In a 16-week treatment study, Halawi and colleagues (26) found that there was a large delay in gastric emptying at week 5 with liraglutide 3.0 mg relative to placebo. At week 16, the rate of gastric emptying in liraglutide-treated

participants had increased significantly relative to week 5, although these participants still had a slower gastric emptying at week 16 than the placebo group. Tachyphylaxis of the gastric emptying response has been hypothesized to reflect the continual activation of GLP-1 receptors by these agonists, leading to tolerance (26). This same mechanism may reduce the effect of GLP-1 agonists, like liraglutide, on perceived hunger and satiation, such that participants no longer experience notable appetite control after approximately 24 weeks of treatment, the time at which weight loss also typically starts to slow or plateau. However, we are not able to determine from the present data whether potential decreases in the gastric effects of liraglutide contributed to the apparent erosion of appetite control over time. Other potential mechanisms, including changes in the medication's central effects or alterations in circulating levels of appetitive hormones with sustained weight loss also could have influenced perceived appetite.

We note, however, that IBT-liraglutide did significantly increase weight loss relative to IBT-alone at week 52 by 5.6 percentage points (losses of 11.8% and 6.2%, respectively). In addition, at week 52, participants in both liraglutide-treated groups continued to report small reductions in hunger and food preoccupation and small increases in fullness relative to their baseline ratings. Even though some participants may report after the first 6 months that the medication is "no longer working," based on perceptions of diminished appetite control, the rapid weight regain that occurs following termination of liraglutide (and other medications) provides eloquent testimony that the drug continues to have an effect on weight control (28). Long-term studies suggest that the majority of the initial weight lost with liraglutide is maintained for up to 3 years when patients remain on medication (12,29). The favorable effects of liraglutide on body weight thus are likely attributable to multiple mechanisms, in addition to its effects on gastric emptying and perceived appetite control.

In the Multi-component group, improvements relative to IBT-alone in hunger and fullness after meals were more modest in size than with IBT-liraglutide. Multi-component participants only differed from IBT-alone in changes in hunger at weeks 4 and 6. The smaller relative improvements in hunger and fullness in the Multicomponent participants may be attributable to the lower calorie prescription in this group during the 12-week meal replacement diet. Multi-component participants were prescribed 1000 to 1200 kcal/d, compared with 1200 to 1800 kcal/d (based on body weight) in the other two treatment groups.

Similar to IBT-liraglutide, however, the Multi-component group differed from IBT-alone in food preoccupation through week 24. Lower food preoccupation could be attributed to the effect of the medication in both groups. However, meal replacement diets also have been shown to reduce food preoccupation, likely by providing a structure that lessens participants' need to make eating-related decisions (19,30).

The most notable difference between the Multi-component group and the other groups was in liking of meals. There was a clear drop in liking during the meal replacement diet that was not reported by the treatment groups that were instructed to consume a low-calorie diet of conventional foods of their choosing.

This study had several strengths, including the measurement of multiple aspects of appetite at regular intervals over the 52-week study. No previous studies, to our knowledge, have reported the effects of liraglutide on appetite beyond the initial weeks of treatment. A major limitation, however, of our study concerns the absence of a placebo-control (i.e., IBT combined with placebo or liraglutide in a double-blind fashion). Although our results are consistent with short-term placebo-controlled studies, we cannot rule out the possibility that participants' attributions about the study medication contributed to their reports of perceived changes in appetite. (We note, however, that improvements were not reported for all appetite variables, i.e., cravings, and the improvements were not sustained at 1 year.)

Recall bias also could have influenced the accuracy of participants' appetite ratings in the present study. The study could be repeated using prospective appetite ratings, as well as ecological momentary assessment to capture participants' appetite in real time. The study findings also would be strengthened by the inclusion of physiological and behavioral measures of appetite, in addition to the subjective ratings used, and by including measures of other potential mechanisms of action such as the rewarding value of food. The inclusion of measures of gastric emptying or circulating neuropeptides could help to elucidate the mechanisms by which the subjective appetitive benefits of liraglutide decline after 24 weeks.

In conclusion, the addition of liraglutide to IBT improved hunger, fullness after meals, and food preoccupation for approximately 24 weeks, but did not affect perceived liking of meals relative to participants treated with IBT alone. Further research is needed to better understand the mechanisms by which liraglutide helps participants maintain lost weight at 52 weeks and beyond, despite the apparent attenuation of its subjective effect on appetite.

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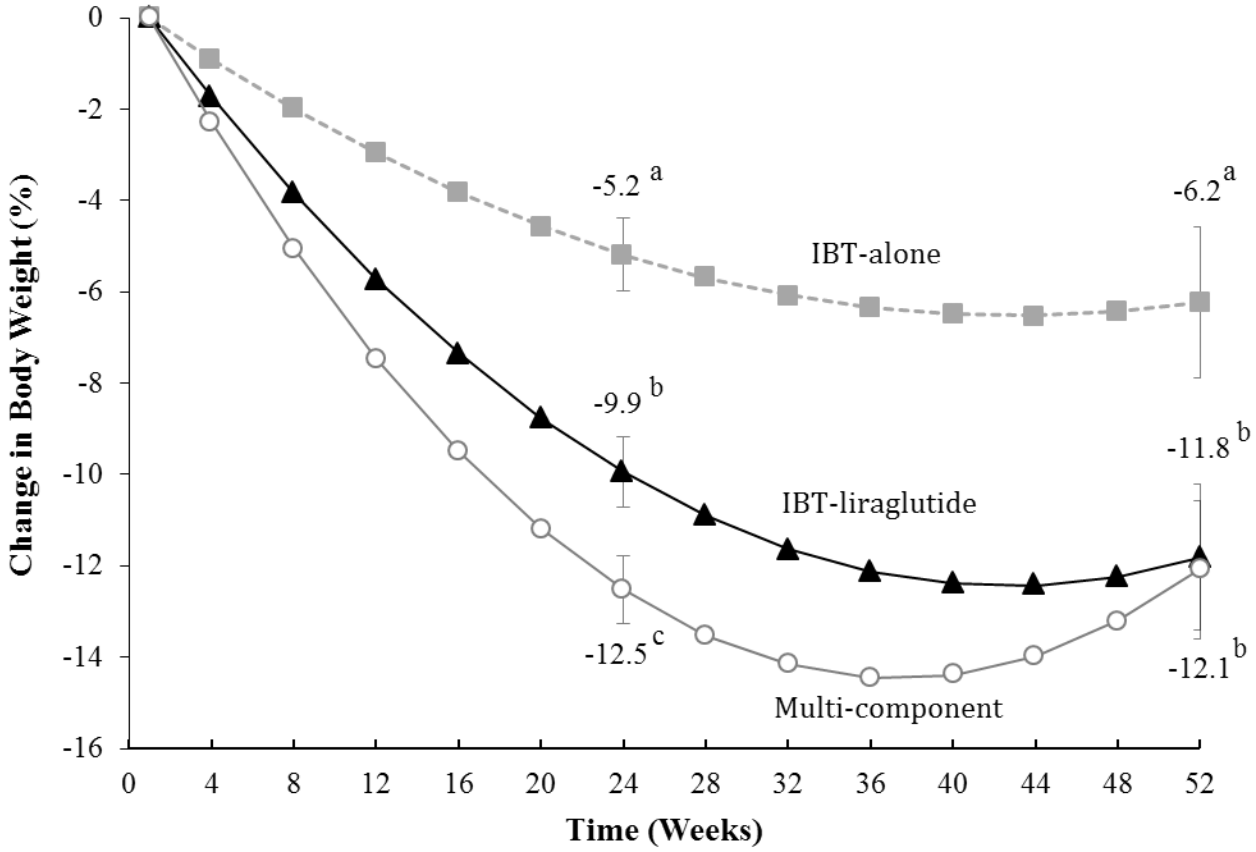

Figure 1.

Estimated mean percentage reduction in baseline weight over 52 weeks in the intention-to-treat-population for the subsample of participants included in the present study ($N = 113$). Values with different superscripts (a vs b) differ significantly from each other at $p < 0.05$, and values that share a superscript do not differ significantly. At week 52, IBT-alone participants had lost less weight than IBT-liraglutide participants ($p = .017$) and Multi-component participants ($p = .010$). The IBT-liraglutide group did not differ significantly from the Multi-component group at week 52 ($p = .899$).

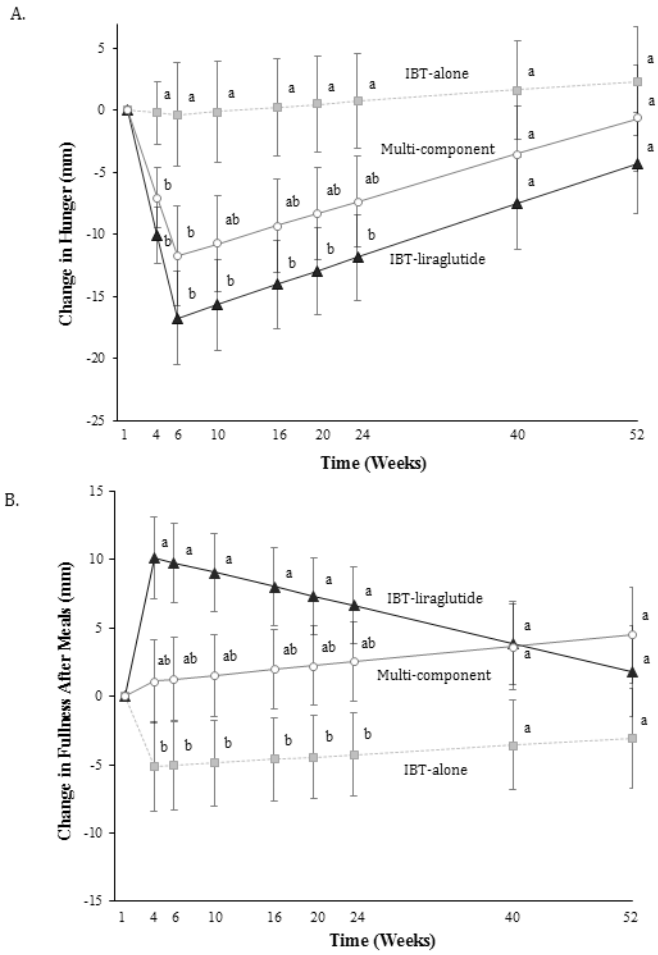

Figure 2.

Panel A shows change in VAS ratings of hunger, and panel B shows change in fullness after meals. Values are estimated modeled mean changes relative to baseline (± SE) in the intention-to-treat population ($N = 113$). Values with different superscripts (a vs b) differ significantly from each other at $p < 0.05$. In panel A, the IBT-alone group differs from the IBT-liraglutide group in change in hunger at weeks 4, 6, 10, 16, 20, and 24, and IBT-alone differs from the Multi-component group at weeks 4 and 6. In panel B, the IBT-alone group differs from the IBT-liraglutide group in change in fullness after meals at weeks 4, 6, 10, 16, 20, and 24. Values that share a superscript do not differ significantly.

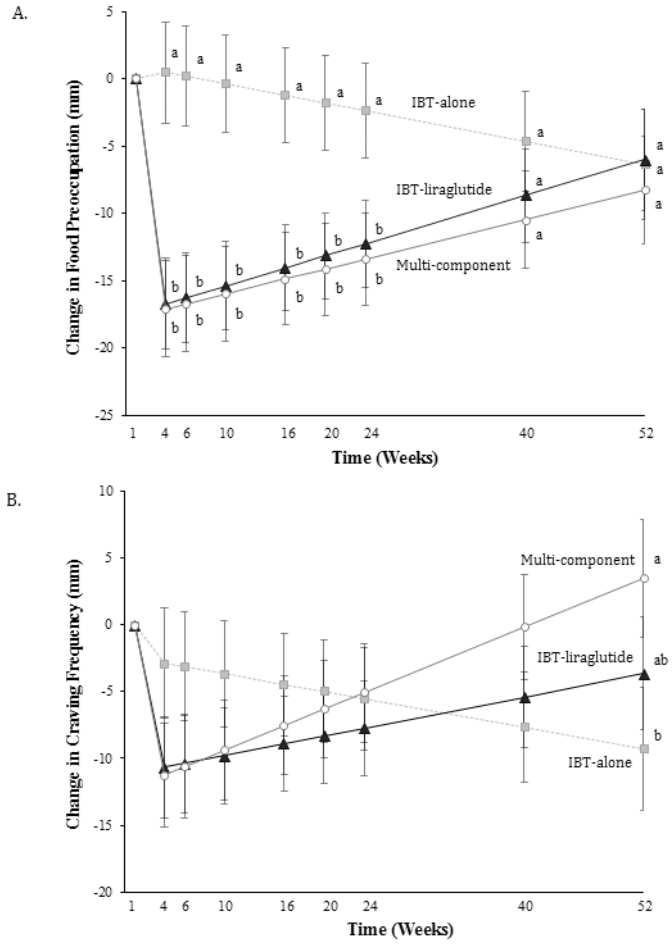

Figure 3.

Panel A shows change in VAS ratings of food preoccupation, and panel B shows change in craving frequency. Values are estimated modeled mean changes relative to baseline (± SE) in the intention-to-treat population ($N = 113$). Values with different superscripts (a vs b) differ significantly from each other at $p < 0.05$. In panel A, the IBT-alone group differs from both the IBT-liraglutide and the Multi-component group at weeks 4, 6, 10, 16, 20, and 24. In panel B, the IBT-alone group differs from the Multi-component group at week 52. Values that share a superscript do not differ significantly. In panel B, no other pairwise comparisons were statistically significant.

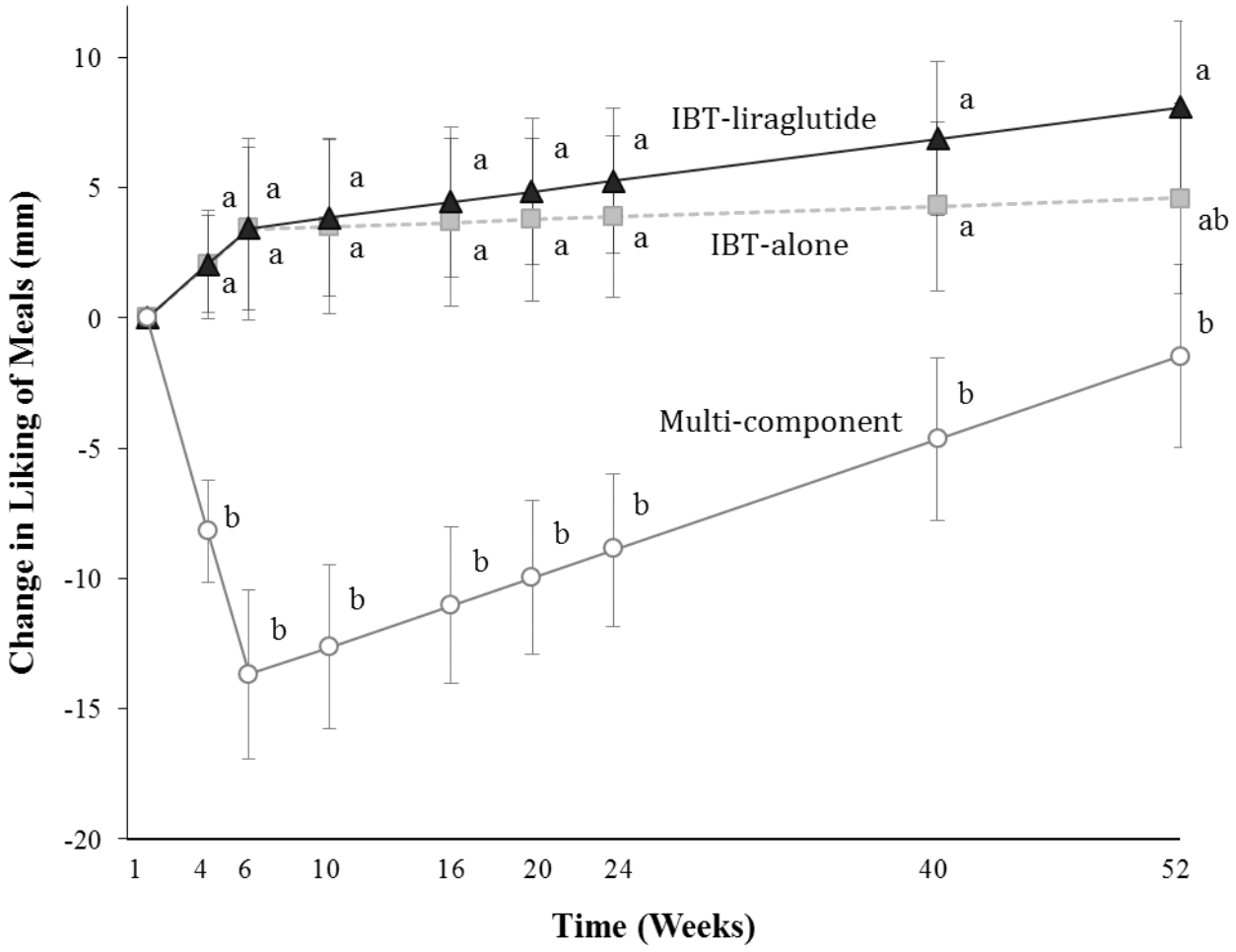

Figure 4.

Change in VAS ratings of liking of meals. Values are estimated modeled mean changes relative to baseline (± SE) in the intention-to-treat population ($N = 113$). Values with different superscripts (a vs b) differ significantly from each other at $p < 0.05$. The IBT-alone group differs from the Multi-component group at weeks 4, 6, 10, 16, 20, 24, and 40. The IBT-liraglutide group differs from the Multi-component group at weeks 4, 6, 10, 16, 20, 24, 40, and 52. Values that share a superscript do not differ significantly.

Table 1.

Participants' characteristics and appetite ratings at baseline.

Characteristic	IBT-alone (*n* = 36)	IBT-liraglutide (*n* = 37)	Multi-component (*n* = 40)	Total (*n* = 113)*
Sex (female), N (%)	27 (75.0%)	31 (83.8%)	28 (70.0%)	86 (76.1%)
Race, N (%)				
White	20 (55.6%)	19 (51.4%)	24 (60.0%)	63 (55.8%)
Black	15 (41.7%)	18 (48.6%)	15 (37.5%)	48 (42.5%)
Multiracial or other	1 (2.8%)	0	1 (2.5%)	2 (1.8%)
Ethnicity (Hispanic), N (%)	2 (5.6%)	2 (5.4%)	3 (7.5%)	7 (6.2%)
Age	47.4 ± 11.8	44.3 ± 11.7	48.4 ± 12.9	46.7 ± 12.2
BMI (kg/m^2)	37.6 ± 4.1	39.2 ± 5.0	39.3 ± 5.3	38.8 ± 4.8
Hunger (mm)	51.4 ± 20.2	51.5 ± 19.3	53.1 ± 23.5	52.0 ± 21.0
Fullness after meals (mm)	69.2 ± 18.1	61.5 ± 18.4	65.2 ± 21.8	65.2 ± 19.6
Food preoccupation (mm)	57.8 ± 15.7	51.6 ± 20.4	59.4 ± 19.6	56.4 ± 18.8
Craving frequency (mm)	59.9 ± 24.3	49.5 ± 24.0	56.6 ± 23.1	55.4 ± 24.0
Liking of meals (mm)	64.6 ± 20.8^{ab}	58.8 ± 22.1^{a}	71.0 ± 17.2^{b}	65.0 ± 20.5

Values shown are N (%) or means ± standard deviations. Note: BMI = body mass index.

*Missing values at baseline were due to skipped items: $N = 112$ completed baseline ratings of fullness after meals and liking of meals; $N = 111$ rated food preoccupation; and $N = 104$ rated hunger. $P > 0.05$ for all comparisons between treatment groups, except as noted by superscript. For liking of meals, values with different superscripts (a vs b) differ significantly from each other at $p < 0.05$. (Values that share a superscript do not differ significantly.)

Table 2.

Estimated mean changes in VAS appetite ratings at weeks 6, 24, and 52 in the intention-to-treat population.

VAS rating (mm)	IBT-alone (*N* = 36)	IBT-liraglutide (*N* = 37)	Multi-component (*N* = 40)	P value		
				IBT-liraglutide vs. IBT-alone	Multi-component vs. IBT-alone	Multi-component vs. IBT-liraglutide
Change in hunger						
Week 6	−0.3 ± 4.2	−16.8 ± 4.0	−11.7 ± 3.8	0.005	0.045	0.360
Week 24	+0.7 ± 3.8	−11.9 ± 3.7	−7.4 ± 3.5	0.018	0.118	0.376
Week 52	+2.4 ± 4.4	−4.2 ± 4.3	−0.6 ± 4.1	0.283	0.619	0.540
Change in fullness after meals						
Week 6	−5.1 ± 3.2	+9.8 ± 3.0	+1.2 ± 2.9	0.001	0.151	0.045
Week 24	−4.3 ± 3.1	+6.7 ± 2.9	+2.5 ± 2.8	0.010	0.104	0.307
Week 52	−3.1 ± 3.7	+1.8 ± 3.5	+4.5 ± 3.4	0.335	0.130	0.585
Change in food preoccupation						
Week 6	+0.2 ± 3.7	−16.3 ± 3.6	−16.7 ± 3.3	0.002	0.001	0.928
Week 24	−2.4 ± 3.5	−12.2 ± 3.4	−13.4 ± 3.2	0.045	0.022	0.808
Week 52	−6.3 ± 4.1	−6.0 ± 4.0	−8.3 ± 3.8	0.955	0.733	0.686
Change in craving frequency						
Week 6	−3.1 ± 4.1	−10.4 ± 3.8	−10.6 ± 3.7	0.196	0.175	0.967
Week 24	−5.5 ± 3.8	−7.8 ± 3.7	−5.1 ± 3.5	0.676	0.932	0.602
Week 52	−9.3 ± 4.6	−3.7 ± 4.4	+3.5 ± 4.2	0.379	0.041	0.242
Change in liking of meals *						
Week 6	+3.4 ± 3.5	+3.5 ± 3.3	−13.7 ± 3.1	0.994	<0.001	<0.001
Week 24	+3.9 ± 3.1	+5.3 ± 2.9	−8.9 ± 2.8	0.745	0.002	0.001
Week 52	+4.6 ± 3.6	+8.1 ± 3.5	−1.5 ± 3.3	0.490	0.218	0.049

Values shown are estimated marginal means (± *SEM*) of VAS ratings (mm) for the intention-to-treat population (*N* = 113).

* Due to baseline differences among the groups, we repeated this analysis including baseline as a covariate and change score as the outcome. There were no changes to the pattern of differences among the groups except for that the comparison between IBT-liraglutide and Multi-component at week 52 was no longer statistically significant (p=0.512).