Original Research

Short-Term Effect of Eggs on Satiety in Overweight and Obese Subjects

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Key words: obesity, eggs, satiety, weight loss, hunger, breakfast

Objective: To test the hypotheses that among overweight and obese participants, a breakfast consisting of eggs, in comparison to an isocaloric equal-weight bagel-based breakfast, would induce greater satiety, reduce perceived cravings, and reduce subsequent short-term energy intake.

Subjects: Thirty women with BMI's of at least 25 kg/M^2 between the ages of 25 to 60 y were recruited to participate in a randomized crossover design study in an outpatient clinic setting.

Design: Following an overnight fast, subjects consumed either an egg or bagel-based breakfast followed by lunch 3.5 h later, in random order two weeks apart. Food intake was weighed at breakfast and lunch and recorded via dietary recall up to 36 h post breakfast. Satiety was assessed using the Fullness Questionnaire and the State-Trait Food Cravings Questionnaire, state version.

Results: During the pre-lunch period, participants had greater feelings of satiety after the egg breakfast, and consumed significantly less energy (kJ; 2405.6 $\pm$ 550.0 vs 3091.3 $\pm$ 445.5, Egg vs Bagel breakfasts, $p < 0.0001$), grams of protein (16.8 $\pm$ 4.2 vs 22.3 $\pm$ 3.4, Egg vs Bagel breakfasts, $p < 0.0001$), carbohydrate 83.1 $\pm$ 20.2 vs 110.9 $\pm$ 18.7, Egg vs Bagel breakfasts, $p < 0.0001$), and fat 19.4 $\pm$ 5.1 vs 22.8 $\pm$ 3.2, Egg vs Bagel breakfasts, $p < 0.0001$) for lunch. Energy intake following the egg breakfast remained lower for the entire day ($p < 0.05$) as well as for the next 36 hours ($p < 0.001$).

Conclusions: Compared to an isocaloric, equal weight bagel-based breakfast, the egg-breakfast induced greater satiety and significantly reduced short-term food intake. The potential role of a routine egg breakfast in producing a sustained caloric deficit and consequent weight loss, should be determined.

INTRODUCTION

The World Health Organization has declared that obesity has reached epidemic proportions [1] and its prevalence is rapidly rising in the United States [2]. Regardless of the various etiological factors proposed to explain the high prevalence and incidence of obesity, a diet that induces a negative energy balance continues to be an important part of obesity management. Various anorectic drugs as well as macronutrient combinations have been tested to aid in the difficult task of eating less than desired, by reducing hunger and/or increasing satiety. Foods with higher satiety values would be useful in reducing subsequent energy intake in comparison with isocaloric foods with lower satiety values.

Holt et al showed that as the satiety values of isocaloric breakfasts increased (Satiety Index, SI), energy intake at a test meal 2 h later decreased [3]. In a study to determine satiety after four different types of isocaloric breakfasts [4], satiety was the greatest with the breakfast consisting of All-bran cereal, a banana, and milk. These satiety ratings were followed in decreasing order by breakfasts consisting of corn flakes, eggs-and-bacon or croissants. However, the results were confounded by the varying

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weights of the breakfasts, which were 425 g, 360 g, 213 g and 135 g, respectively, indicating that heavier breakfasts were more satiating. Interestingly, both the eggs-and-bacon and all-bran breakfasts had roughly equal percentages of protein, 18.6 versus 18.0, respectively.

To date, five breakfast studies using randomized cross-over designs have examined the impact of different macronutrients on subsequent food intake; four of these five examined the impact on satiety [5–10]. All five studies included average-weight subjects among whom the influence of satiety and macronutrient content on subsequent food intake may differ from that of overweight and obese subjects. Obese subjects have greater fasting volume of the stomach in the antral [11] and distal area [12]. When offered a high-fat pre-load meal, obese subjects consumed about 66% more energy compared to non-obese controls [13]. These differences in energy consumption were also supported by a demonstration of different patterns in regional cerebral blood flow in obese compared to non-obese subjects [14]. Therefore, it is important to study overweight and obese subjects instead of extrapolating the effects from the non-obese counterparts.

Eggs are a convenient, affordable and nutritious source of key macro and micronutrients. They are an integral and established part of breakfast in numerous cultures and may be eaten safely on a regular basis. Discretionary use of eggs has been traditionally advised due to their cholesterol content and the earlier implications in coronary heart disease risk. However, recent data from the Nurses Health Study showed that egg consumption did not contribute to the risk of coronary heart disease or stroke [15]. In addition, compared to a ready-to-eat breakfast cereal or white bread, eggs have 50% greater SI [16] as well as a greater satiety value than other common breakfasts [3] at least among non-obese subjects. These attributes suggest that eggs would be good candidates to test their role in reducing energy intake.

Although previous research has generally supported the satiety inducing effects of protein, evidence regarding the subsequent impact on energy intake is less certain due to methodological concerns. Moreover, unlike studies that have examined the impact of varying macronutrients, eggs may yield additional benefits due to evidence of their relatively strong satiety value. The effect of a breakfast consisting of eggs versus a commonly consumed, isocaloric, and equal weight bagel-based breakfast on satiety and subsequent energy intake of obese people is unknown. Therefore, the purpose of the present study was to test the hypothesis, that among overweight and obese participants, a breakfast consisting of eggs would a) induce greater satiety and reduce lunch-time energy intake; b) reduce total energy intake for 24 hours; and c) reduce perceived cravings for some tasty and energy dense foods in comparison to an isocaloric equal-weight bagel-based breakfast.

MATERIALS AND METHODS

Materials

Demographic Characteristics. Demographic characteristics were ascertained at the introductory session, including gender, diabetic statues, age, BMI and weight loss history. Height and weight were obtained after the removal of heavy outer clothing.

Food Intake. The pasta was weighed before and after serving to determine the amount consumed. The apple was sliced and the number of slices eaten was counted. Weights of additional helpings were also recorded.

24-Hour Dietary Records. The research coordinators, who were also qualified dietitians, trained participants in the recoding of food intake with food models after the introductory session and before the participants left for the day. Participants completed 24-hour food records at the completion of each study session which they later reviewed with the dieticians for clarification and promotion of thoroughness and accuracy. Responses were analyzed with Total Dietary Assessment software from Saunders College Publishing, Version 2.0; ISBN # 0-03-025895-2; Science and Application 2000, Harcourt, 1997, and summary values, including energy (kJ) and grams of protein, carbohydrate, and fat were entered into SPSS for further analysis.

The State-Trait Food Cravings Questionnaire—State Subscale (FCQ-S; 17) is a 15-item measure of state-based changes in the motivation to consume foods. Responses are made on a 5-point likert scale with response categories ranging from 1 "strongly disagree" to 5 "strongly agree." The scale yields a total as well as 5 subscale scores, including an intense desire to eat, anticipation of positive reinforcement that may result from eating, anticipation of relief from negative states and feelings as a result of eating, obsessive preoccupation with food or lack of control over eating, and craving as a physiological state. In a validation study, the scores on the FCQ-S decreased substantially as participants went from a food deprivation to satiation state. The FCQ-S has excellent internal consistency, $\alpha = .94$ [17], and the factor structure has been cross-validated in samples of young adults.

Fullness Questionnaire (FQ; 16) is an equilateral seven-point rating scale used to measure hunger. The scale was similar to one in previous studies of this phenomenon [18,19], but had greater test-retest reliability and participants found it easier to use and understand. The scale is anchored from −3, "extremely hungry," −2 "hungry," −1 "semi-hungry," 0 "no particular feeling," 1 "semi-satisfied," 2 "satisfied," and 3 "extremely full." The FQ has been shown to correlate with the serving weight of foods, ($r = .66$), the protein, fiber, and water content of foods ($r = .37$, $r = .46$, and $r = .64$, respectively), and negatively with fat content ($r = -.43$) and palatability ratings ($r = -.64$). The FQ had also been negatively correlated with the amount of energy consumed 120 minutes after a test meal ($r = -.37$) [16].

Subjects

The study was approved by the institutional review boards of Wayne State University and Crittenton Hospital, MI and informed written consents were obtained from the participants. First, the respondents to study announcements were screened according to study inclusion criteria which included being female, non-diabetic, between the ages of 18 and 60 years, body mass index (BMI) of at least 25 and no more than 35 kg/M^2, and no weight loss $\geq$ 6.82 kg (15 lb) in the past 6 months. Potentially eligible participants were invited to an introductory session where the study was explained, eligibility criteria confirmed, and informed written consent obtained. Thirty women were recruited for the study. Two women experienced sudden and acute psychologically stressful events (unrelated to the study), which would potentially influence their food intake. These two women were asked to discontinue the study, leaving the data from 28 women available for analysis. The mean age of the women was 44.6 $\pm$ 9.8 y ranging from 25.2 to 60.7 y.

Methods

A randomized cross-over design was used in which all subjects attended 2 test days (Egg Day and Bagel Day) 2 weeks apart. The sequence of the test days was randomly determined. On the day of the test, participants reported to the clinic at 8:00 AM, after a 12 h fast and left in the afternoon after lunch. After completing a 7-point equilateral category rating scale (Fullness Questionnaire, 16) and State Subscale of the State-Trait Food Cravings Questionnaire [17], they were offered either an egg or bagel-based breakfast. The egg breakfast was comprised of 2 eggs-scrambled, 2 slices of toast, and 1 tablespoon of reduced calorie fruit spread. The bagel-based breakfast was comprised of a 3.5 inch diameter bagel, 2 tablespoons of cream cheese, and 3 oz of non-fat yogurt. The nutritional content of both breakfasts is provided in Table 1. The weight and energy content of the "egg breakfast" and the "bagel breakfast" were similar. Leftover breakfast was weighed to determine the intake.

Participants completed the fullness and food craving questionnaires 15 min after finishing the breakfast and then twice more, 90 min apart. Participants spent about 195 min reading, listening to music or watching movies that did not have references to food/eating. Lunch, comprised of pasta with marinara sauce and sliced apples, was offered 3.5 hours after completion of the breakfasts. Subjects were encouraged to eat as much food they wanted. Food intake was monitored discretely to determine the weight and caloric content of the food consumed. Weight of food offered was noted and each remaining food component was separately weighed after the breakfast and lunch. Subjects were urged to not drink water during lunch. Water was offered ad-libitum after lunch. Participants were allowed to leave at this time, but were asked to keep a food-intake and activity diary for the next 24 hours. Detailed instructions on keeping the food diary were provided. To prevent bias on the fullness and cravings questionnaires and the food intake, participants were told that the purported aim of the study was to monitor the effect of breakfast on blood pressure and alertness. Alertness assessment questionnaires were given and blood pressure was measured along with the fullness and food craving questionnaires.

Power and Statistical Analysis

In the absence of our own preliminary data to calculate power, we turned to a study by Holt et al [4] in which a within subjects design was used to assess fullness following consumption of four breakfast meals. The two test meals of greatest similarity to the proposed study included a breakfast of eggs and bacon versus a croissant. Using the means and standard deviations reported, a very large effect size of $d = 1.69$ [20] was calculated (although they failed to control for food weight). Thus, assuming a large effect size, but more conservatively estimated at $d = 1.0$, an alpha level of .05, and a desired power of .80, 26 subjects were deemed sufficient to test the hypothesis regarding satiety. Anticipating a possible 15% attrition rate, 30 subjects were recruited.

Analyses included paired sample t-tests and within subjects repeated measures analysis of variance with within subjects contrasts to assess for quadratic and cubic effects. The significance level was set at $p < .05$.

RESULTS

Baseline Characteristics

Participants consumed similar amounts of the egg and bagel breakfasts with only 4 participants failing to consume the entire

Table 1. Nutrient Composition of Breakfasts Offered and Consumed (n = 28)

	Breakfasts offered		Breakfasts consumed	
	Egg	Bagel	Egg	Bagel
Weight (g)	189.0	188.0	188.7 $\pm$ 1.3	187.0 $\pm$ 3.2
Energy (kJ)	1479.8	1452.1	1478.1 $\pm$ 9.1	1437.6 $\pm$ 48.4
Protein (g)	18.4	13.6	18.3 $\pm$ 0.0	13.5 $\pm$ 0.2
Carbohydrate (g)	31.7	47.87	31.6 $\pm$ 0.5	47.8 $\pm$ 0.1
Fat (g)	17.0	11.2	17.0 $\pm$ 0.0	10.9 $\pm$ 1.1
Drinking water (g)	240.0	240.0	222.1 $\pm$ 40.0	217.9 $\pm$ 48.0

breakfast. The nutrient composition of the breakfasts as eaten is given in Table 1. Overall, participants consumed similar amounts of the two breakfasts (188.7 ± 1.3 g vs 187.0 ± 3.2 g, for Egg and Bagel breakfasts, respectively). Participants consumed 1.7 ± 3.5 g more of the egg breakfast; an energy difference of only 40.5 ± 49.7 kJ. Similarly, the amount of water consumed with the egg breakfast (222.1 ± 40.0 mL was highly similar to that which was drunk with the bagel breakfast (217.9 ± 48.0 mL).

Post-Breakfast Energy Intake

During the post-breakfast lunch, participants who had consumed the egg breakfast consumed significantly less energy (Table 2, $p < .0001$) as well as grams of protein ($p < .0001$), carbohydrate ($p < .0001$), and fat ($p < .0001$). There were no differences in the amount of water consumed (p = ns).

Energy intake for the entire day following the egg breakfast remained lower by about 1104 kJ (7463.7 ± 1788.4 vs 8567.6 ± 2037.8 kJ, Egg vs Bagel breakfasts, $p < 0.05$; Fig. 1) and g of carbohydrates (204.5 ± 49.5 vs 263.2 ± 60.1, Egg vs Bagel breakfasts, $p < 0.0001$). Furthermore, for the entire study period, from breakfast until noon of the next day, energy intake after the egg breakfast was lower by 1759 kJ (8652.3 ± 2418.9 vs 10411.7 ± 3221.6, Egg vs Bagel breakfasts, $p < .001$; Fig. 1) as well as protein (83.8 ± 25.8 g vs 97.1 ± 32.0 g, Egg vs Bagel breakfasts $p < .05$) and carbohydrate intake (247.4 ± 69.7 g vs 317.3 ± 85.6 g, Egg vs Bagel breakfasts, $p < .0001$). Although persons who had eaten the egg breakfast ate fewer grams of fat, this difference was not statistically significant.

Satiety

A within subjects repeated measures analysis of variance with food type (egg versus bagel) and time (pre-breakfast, and 15, 90, and 180 minutes post-breakfast) as within subjects factors was conducted on the satiety rating scale. Results of the within subjects contrasts showed a significant cubic effect for the food by time interaction, $F(1, 27) = 14.70$, $p < .001$, suggesting that there was a significant increase in satiety following consumption of the breakfast followed by a gradual reduction in satiety, which was greater for those who had consumed the egg breakfast than for those who ate the bagel breakfast. Repeated measures contrasts showed that the egg breakfast promoted greater satiety from baseline to 15 minutes post-breakfast, $F(1, 27) = 9.71$, $p < .01$ and from 15 to 90 minutes post-breakfast, $F(1, 27) = 54.87$, $p < .0001$. There was a non-significant trend for greater satiety from 90 to 180 minutes post-breakfast, $F(1, 27) = 3.77$, $p < .07$. These differences are graphically displayed in Fig. 2.

Table 2. Composition of Post-Breakfast Lunch Consumed (Mean ± SD [n = 28])

	Post Egg breakfast	Post Bagel breakfast	t
Energy (kJ)	2405.6 ± 550.0	3091.3 ± 445.5	7.79*
Protein (g)	16.8 ± 4.2	22.3 ± 3.4	7.79*
Carbohydrate (g)	83.1 ± 20.2	110.9 ± 18.7	7.44*
Fat (g)	19.4 ± 5.1	22.8 ± 3.2	4.66*
Drinking water (g)	630.4 ± 252.7	613.4 ± 252.0	0.38

* $p < 0.0001$.

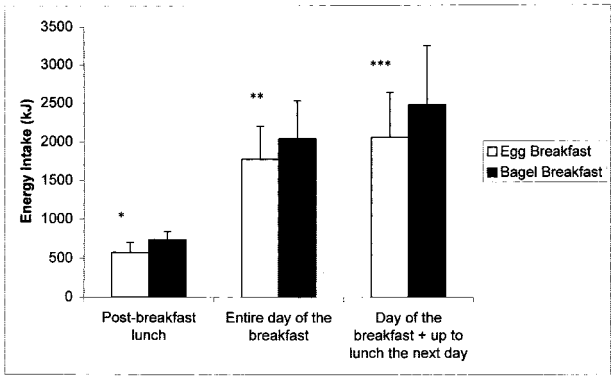

Fig. 1. Difference in energy intakes after the egg or the bagel breakfasts. Twenty-eight overweight or obese women were offered isoenergetic and equal weight egg or bagel breakfasts on two days at least two weeks apart. Following the egg breakfast, mean energy intake was significantly lower for lunch (post-breakfast lunch, * $p < 0.0001$), for the entire day of the breakfasts including all meals (entire day of the breakfast, ** $p < 0.05$) and, for the day of the breakfast and the breakfast and lunch of the next day (Day of the breakfast + up to lunch the next day; *** $p < 0.01$).

Next, the Food Craving Scale was used as the dependent variable to determine whether there were differences in specific types of cravings following the egg versus bagel breakfasts. Overall, within subjects contrasts showed significant quadratic effects for the food by time interaction on the subscales of desire for food, $F(1, 27) = 4.84$, $p < .05$ and for anticipation of positive reinforcement from food, $F(1, 27) = 4.27$, $p < .05$. Repeated measures contrasts showed that only the overall effects were statistically significant and that differences between individual time points were not statistically significant. No significant effects were found for the subscales of anticipation of negative reinforcement, lack of control over eating, nor sensations of physiological hunger.

DISCUSSION

The results supported the hypothesis that a breakfast consisting of eggs, in comparison to an isocaloric and equal-weight bagel-based breakfast, would reduce lunch time energy intake among overweight and obese participants. Furthermore, it was observed that the energy deficit was not compensated for at least 24 h after the breakfast. These findings extend previous work [4] and demonstrate that isocaloric and equal-weight breakfasts of differing satiety values impact subsequent energy

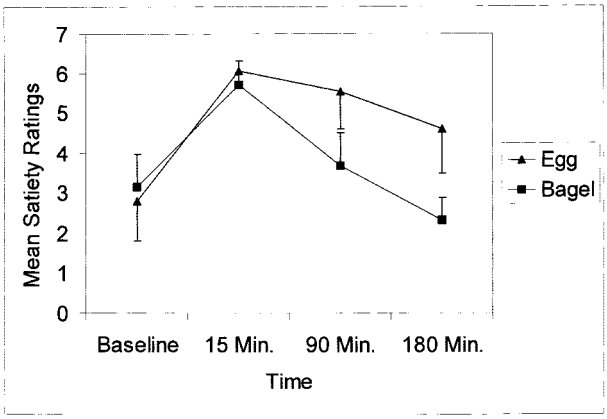

Fig. 2. Mean satiety rating scale scores over time. Twenty-eight overweight or obese women were offered isoenergetic and equal weight egg or bagel breakfasts on two days at least two weeks apart. Satiety scores were determined by the Fullness questionnaire at baseline (before eating breakfasts) and 15, 90 and 180 min following the breakfasts. A within subjects repeated measures ANOVA with food type and time showed a significant increase in satiety following consumption of the breakfast, followed by a gradual reduction, which was greater after the egg breakfast than the bagel breakfast ($p < 0.001$). Repeated measures contrasts showed that the egg breakfast promoted greater satiety from baseline to 15 minutes post-breakfast, ($p < 0.01$) and from 15 to 90 minutes post-breakfast ($p < 0.0001$). There was a non-significant trend for greater satiety from 90 to 180 minutes post-breakfast ($p < .07$).

intake. Unlike previous studies, the current study allowed for the detection of the impact on subsequent food intake due to subtle methodological improvements, including the measurement of the test-meal in a laboratory setting, the provision of breakfasts of similar weight and caloric content, and the provision of breakfast meals small enough to allow hunger to develop. In addition, unlike previous studies, the inclusion of overweight and obese persons rather than average-weight controls may have had an influence on the results. Overweight and obese persons have been shown to differ from their average-weight counterparts on the important parameters of fasting stomach volume, food intake following consumption of a high-fat meal, and cerebral blood flow [11–14]. For the energy reducing effect of egg breakfasts to be relevant, it was appropriate to test the responses of a group of subjects who may potentially benefit from such a satiating effect.

Attributes of the breakfast meals that may have contributed to differential effects on satiety and food intake included the satiety index and macronutrient composition. The greater impact of the egg breakfast on subsequent satiety and food intake may be attributed to the relatively higher satiety value of eggs in comparison to bagels. Although the egg breakfast had a slightly greater proportion of calories from protein (20.8% versus 15.7%) which may have helped promote satiety, the egg breakfast also had a greater proportion of calories from fat (42.2 versus 29.1) which has been linked to early development of subsequent hunger and greater food intake [9]. Clearly, the satiety impact of various foods is impacted by additional factors beside simple macronutrient composition.

One factor that may influence the satiety index is macronutrient composition. In general, dietary protein helps regulate food intake by increasing the sensation of satiety and increasing the thermic effect of feeding [5]. One study noted that both a high protein and a high carbohydrate breakfast diminished hunger to a greater extent than a high fat breakfast during the pre-lunch period [8]. However, the high protein breakfast reduced hunger to a greater extent over the ensuing 24-hour period. A study showed that participants who ate a high protein or balanced breakfast were less hungry before lunch than those who ate a high carbohydrate or high fat breakfast [9]. In contrast, no differences in the impact of protein, carbohydrate, fat, or alcohol on subsequent satiety over the next five hours have also been reported [7]. The size of the breakfasts (2499.5 kJ for women; 2997 kJ for men) or the ten subsequent blood draws via an indwelling catheter may have reduced the appetites of the participants. de Graaf et al [6] found no differential impact of protein, fat, or carbohydrate on subsequent measures of satiety either at lunch nor during the remainder of the day. However, provision of the meals in liquid suspensions may have adversely impacted sensations of satiety. None of the studies found a differential impact of protein versus carbohydrate on subsequent food intake either at lunch [6–10] or over the course of the day [6,8]. Methodological problems may have precluded the ability to detect significant differences, including reliance on self-reported lunch-time and subsequent energy intake [6], the use of repeated post-breakfast blood draws [7], and the provision of breakfast meals so high in caloric content (5179.1–5836.4 kJ) that development of subsequent hunger, particularly over the short-term, was unlikely [8,9].

The nutrients in eggs responsible for promoting satiety observed in the current study, as well as the mechanism involved are unknown. Breakfasts containing egg proteins resulted in lower insulin responses compared to otherwise identical breakfasts containing ham proteins [21]. Reduced blood glucose and insulin response was observed after breakfast with whole eggs or yolk [22], which also increased cholecystokinin and gastric inhibitory peptide levels and delayed gastric emptying. The potential role of delayed gastric emptying and reduced glycemic index of eggs contributing to satiety was not determined in our study. The current study was restricted to evaluating the potentially greater satiety value of an egg-breakfast over another conventional non-egg breakfast. Identifying a specific macro or micronutrient of an egg responsible for the effect was beyond the scope of the experimental design. Regardless of the macronutrient responsible for the effect, the fact that an egg-breakfast has greater satiety value compared to another breakfast of equal calories is an important finding potentially useful in weight management diets.

The current study also suggests that there may be multiple facets of satiety and that eggs may have an impact on the desire for food and anticipation from positive reinforcement from

eating. However, the satiety rating scale used in the present study was a simple 7-point scale. Similarly, other studies have used various types of simple visual analogue scales to assess terms including the following: hunger, satiety, fullness, appetite, appetite for a meal, appetite for a snack, urge to eat, desire to eat, cravings for foods, desire for something salty, desire for something sweet, desire for something fatty, preoccupation with thoughts of food, prospective food consumption, alertness, liveliness, and thirst. These types of scales neither encompass the full range of satiety nor do they possess desirable psychometric properties. Clearly, satiety (or conversely, a desire for food) can be conceptualized as multidimensional motivational states.

In summary, these data show that despite equal energy content and weight, in the short-term, an egg breakfast had a greater satiating effect compared to a bagel breakfast, which translated into a lower energy intake at lunch and that the resulting decrease in energy consumption lasted for at least 24 h after the egg-breakfast. These results have potentially significant implications. Eggs are an integral and established part of breakfast in numerous cultures and the satiating effect of eggs may be useful in reducing energy intake thereby promoting weight management. The role of eggs in sustaining reduced energy intake has not been tested. These results provide a stimulus to test the long-term effect of egg breakfasts in reducing energy intake required for weight loss treatments.

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