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A Randomized Controlled Trial to Study the Effects of Breakfast on Energy Intake, Physical Activity, and Body Fat in Women

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ABSTRACT

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PURPOSE: The purpose of this study was to determine the effects of eating breakfast on energy intake, physical activity, body weight, and body fat in women who were nonhabitual breakfast eaters over a one-month period. METHODS: We tested 49 premenopausal, nonhabitual breakfast-eating women to compare the effects of eating breakfast versus not eating breakfast. Each participant was randomized to one of two conditions: breakfast or no breakfast. Breakfast eaters were required to eat within an hour and a half of awakening and had to be finished eating their breakfast meal by 8:30 A.M. Non-breakfast eaters were defined as not consuming a snack or meal (with the exception of water) until after 11:30 A.M. Participants assigned to the breakfast condition consumed at least 15% of their daily energy requirement for breakfast. Weight and body fat were assessed at the baseline and after one month of intervention. Body fat was measured by dual-energy x-ray absorptiometry (DXA). Participants completed seven 24-hour recalls to assess dietary intake during the intervention. Physical activity was measured by accelerometry for 32 consecutive days. RESULTS: On average, the participants randomized to eat breakfast consumed 266 ± 496 ($F = 12.81$; $P = 0.0043$) more calories per day over the course of the study and weighed 0.6 ± 0.81 kg ($F = 7.81$; $p = 0.0076$) more at the end of the intervention. There was no observed caloric compensation at subsequent meals and no change in self-reported hunger or satiety. There was also no physical activity compensation with the addition of breakfast. CONCLUSION: The findings of our study showed that requiring non-breakfast eaters to eat breakfast resulted in higher caloric intake and weight gain. Future research should evaluate this relationship for a longer period of time to see if adding breakfast to the diet of women who generally do not eat breakfast results in adaptive behavior change over time.

Keywords: breakfast, morning meal, daily energy intake, physical activity, body fat, body composition

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Introduction

Breakfast has often been called the most important meal of the day, however, approximately 25% of the U.S. population omits breakfast from their daily meals [1]. Eating breakfast stimulates positive mental and emotional health [2]. Moreover, breakfast is associated with improved cognitive function, better memory recall, and improved mood in both children and adults [3-5]. The benefits of eating breakfast even extend to an increased health-related quality of life [6].

While the evidence supporting the positive relationship between breakfast intake and increased cognitive function, memory recall, and improved mood is substantial, researchers have more recently investigated the role of breakfast in weight regulation and energy balance. The inclusion of breakfast would be a good weight management strategy because it may promote satiety, regulate plasma glucose, and is associated with higher physical activity levels [7-9]. One of the reasons that breakfast is thought to improve satiety is because it promotes better regulation of the hormones that control appetite such as Peptide YY and ghrelin [8, 10]. It is hypothesized that eating breakfast prevents excess hunger later in the day, which in turn prevents overeating [10, 11]. These speculations are supported by the circumstantial evidence that the majority of people who are successful at losing weight and maintaining their weight loss for at least a year eat breakfast [7].

Despite this evidence, the true role of breakfast consumption on weight regulation in adults is still debatable. While some cross-sectional and longitudinal observational studies support a relationship between breakfast consumption and a lower BMI [6, 12-17], other cross-sectional studies have shown no relationship between breakfast consumption and BMI [13, 18].

Schusdziarra et al. even found that individuals who consumed more energy at breakfast tended to consume more energy throughout the day, which eventually leads to an increase in BMI [19].

In addition to the observational research, the relationship between breakfast consumption and energy intake has been examined through experimental studies. These studies have generally used crossover designs to study this connection; however, conflicting results have been found in the studies, leaving the relationship between breakfast and energy intake ambiguous. For example, in one study it was found that breakfast consumption increased daily energy intake [20]. However, other studies concluded breakfast had no effect on daily energy intake [10, 21, 22]. Meanwhile, another study found a decrease in daily energy intake with the consumption of breakfast [11]. It was also found that eating breakfast was not beneficial in aiding in weight loss [23, 24].

Although the findings of these studies have been largely inconsistent, important factors unique to these studies may have contributed to these irregularities—namely, the method of participant selection, as well as the design of the study. Overall, the number of participants in the experimental studies has been limited, generally less than 13 participants. Most of these studies have also been relatively short in duration (lasting between 3 to 14 d), which does not allow time for behavioral change to take place. In addition to this short-term approach, studies have often mixed both habitual and nonhabitual breakfast eaters together. This lack of consistency among the subjects could have minimized or exaggerated the impact of the intervention—especially when paired with a short-duration treatment period. For example, if a non-breakfast eater was randomized to a no breakfast eating condition, it is likely that there would be a much smaller impact on energy balance than if a non-breakfast eater was randomized to a breakfast eating condition. This is likely because fewer behavioral changes are required.

These studies have also failed to examine other factors which could account for the mixed findings, namely differences in physical activity and body fat percentage. A subject's physical activity level would be a key component to study because of its relation to energy balance. To date, Halsey et al. has been the only breakfast intervention study to measure physical activity and did so with pedometers and heart rate monitors [25]. Also, body fat has not been examined in relation to breakfast, most likely due to the short length of the studies.

More research is needed to help resolve the disparities found in the literature and to better establish the true relationship between breakfast consumption and energy balance. This need includes studies that are longer in duration and have larger sample sizes. In addition, recruiting more subjects, particularly only non-breakfast eaters, could help to determine how adding breakfast might influence total energy intake, physical activity and body fat in someone who does not currently eat breakfast. Only non-breakfast eaters were studied, based on the premise that eating breakfast is a healthful habit to adopt. The goal of our study was to determine the effects of breakfast on energy intake, physical activity, and body weight/fat in women who were nonhabitual breakfast eaters. We hypothesized that women in the breakfast condition would have an increase in daily energy intake, an increase in body weight, an increase in body fat, and no change in physical activity level.

Methods

Research Design

We performed a randomized controlled (pretest/posttest) trial. We tested 49 premenopausal women to compare the effects of eating breakfast versus not eating breakfast on energy and macronutrient intake and physical activity for a 1 mo period. We believed 1 mo would be enough time to see adaptations [26]. Each participant was randomized to one of two different conditions: breakfast or no breakfast. Breakfast eaters were required to eat within 1.5 h of awakening and had to be finished eating their breakfast meal by 8:30 A.M. Non-breakfast eaters were defined as not consuming a snack or meal (with the exception of water) until after 11:30 A.M. Participants assigned to the breakfast condition consumed at least 15% of their daily energy requirement for breakfast. Fifteen percent was chosen as the minimum energy intake for breakfast because it was between the 10% used by Astbury et al. and the 24% used by Leidy et al. [10, 21] and represents a meaningful amount of food. We multiplied the Harris-Benedict equation by an activity factor of 1.4 to determine total energy needs [27].

Participants

Participants ranged in age from 18–55 years old. The participants were also habitual non-breakfast eaters (eat breakfast ≤ 2 d/wk). Participants were regular sleepers who got at least 6 h of sleep a night and woke up consistently before 8:00 A.M. Participants were weight stable for the 3 mo prior to the study and apparently healthy as indicated by a health history questionnaire. Participants were excluded for the following: tobacco or alcohol use, night shift workers, current dieting, eating disorders—including anorexia, bulimia, or instances of binge-eating, digestive disorders, medications that alter metabolism, the presence of a metabolic disease that affects energy balance (e.g., diabetes mellitus, cancers, heart disease, etc.), excessive exercise training (vigorous-intensity activity >4 d/wk and 30 min per session), participation in college athletics or any elite sport, and inability to exercise at a moderate-intensity level (3.0-6.0 METs). Participants were recruited through flyers, word of mouth, electronic announcements, and Facebook. As part of recruitment, all interested participants were screened via e-mail to ensure they fit within the inclusion/exclusion criteria discussed above. All participants gave their informed consent prior to beginning the study and were given a copy of the consent form.

Procedures

The complete study protocol included four lead-in days of no intervention measuring eating habits and assessing dietary intake and physical activity to establish a baseline. Following this, the participants were randomized to one of two treatments. One group of participants was monitored for a 4-wk period in which dietary intake and physical activity with the consumption of breakfast was measured. The other group underwent a 4-wk period in which they were monitored for dietary intake and physical activity with the absence of breakfast.

Visit 1: After the initial screening to determine if interested participants were qualified for participation in the study and met the inclusion criteria, they fasted overnight and reported to the Human Performance Research Center (HPRC). The protocol for the study was discussed and participants received answers to questions they had regarding the study. When they agreed to sign the consent form, the first phase of the study commenced. In addition, body weight, body composition, and anthropometrics were assessed at this time. Each participant was trained on how to complete a computerized 24-hr food recall by completing one for the previous day. The recall takes between 20 and 45 min to complete. This was done in the presence of a member of the research staff. The entire appointment took 30–60 min.

The main purpose of the four lead-in days were to gather baseline data and to ensure participants were committed to the study. In addition, each participant was asked to go about her usual schedule and to eat according to her usual patterns. During the lead-in days, participants were asked to complete an additional multiple-pass, computerized 24-hr food recall on the weekend. Participants were not informed in advance of which days they were to complete the recall. To do this, a member of the research team contacted the participants via phone/email in the morning to inform them that they should complete the computerized 24-hr recall for the previous day. Participants were instructed on how to wear an accelerometer and that they were to wear it continuously for the remainder of the study (with the exception of showering and swimming).

Visit 2: After the last day of the 4-day lead-in, each participant reported again to the HPRC. This appointment was approximately 30–45 min. The participants were weighed. Participants had their data downloaded from their accelerometers by a research assistant and performed another 24-hr dietary recall. They were informed which condition (breakfast or no breakfast) they were assigned to and instructed about the protocols/ expectations of this condition. They were then instructed to complete two 24-hr recalls for the upcoming week. These recalls were assigned to random days of the week, and participants were not informed as to which days the recalls were to be completed until the following morning. They were contacted in the morning and asked to complete the 24-hr recall for the previous day as well as asked to contact the research team once they had completed it. We continued to follow-up with them throughout the day until it was completed. They were also instructed to wear an accelerometer (see below) continuously (except when in water) over the course of the next week. Participants were trained on how to complete a breakfast log for the duration of the study, and the logs were reviewed by research assistants during their weekly appointments. Participants also received extra training and reminders on determining if their breakfast was 15% of their daily energy intake. They were not informed on how many calories they were to consume throughout the day; they were only informed whether their breakfast met the minimum requirement of 15%. Examples of breakfasts that meet this requirement were shown in pictures. If participants did not comply with this energy level they were re-educated on how to meet the minimum energy intake for breakfast.

Visits 3–5: These visits were the same as Visit 2 (one visit per week in the three weeks following Visit 2) with the exception of Visit 5 where participants were given multiple visual analog scales (VAS) to complete prior to each meal for the week.

Visit 6: After the fourth week of their condition, participants returned for another appointment at the HPRC. This appointment took approximately 20–30 min. Their body weight, composition, and anthropometrics were assessed and they received a voucher for $100 for completion of the study.

In summary, participants came to the HPRC on six separate occasions (approximately once per week) for various assessments, completed a total of 10 days of 24-hr food recalls (one hour per week), wore an accelerometer for a total of 32 days, and completed six days of VAS.

Measurements

Health History Questionnaire: A health history questionnaire was used to assess participants' demographic information, health levels, and to determine whether they were fit to participate in the study [28].

Body Composition and Anthropometric Measures: In order to establish a baseline, we assessed body weight, composition, and anthropometric measures prior to the first week of the treatment. Body weight was measured using a digital scale (Tanita Corp., Inc., Japan; modified by Life Measurement, Inc., Concord, CA) accurate to ± 0.01 kg with participants barefoot and wearing standardized one-piece swimsuits. Height was obtained using a stadiometer (SECA, Chino, CA) and BMI was calculated as kg/m^2.

Dual-energy x-ray absorptiometry (DXA) (GE Lunar iDXA, Madison, WI) was used to assess fat mass, fat free mass, and body fat percentage. Studies have shown that the use of DXA for assessing body composition is valid [29]. Based on hydrostatic weighing, DXA gives similar results in determining body composition [30, 31]. Same-day test/retest on 80 men and women has been conducted with the DXA used in this study and the machine has demonstrated excellent reliability with an intra-class correlation of 0.99 and a mean absolute measurement error of ± 0.3 percent body fat. The DXA is also able to detect small changes in body composition, even accompanied with changes in hydration status [32].

Energy and Macronutrient Intake: Using the Automated Self-administered 24-hour Dietary Recall (ASA24) computerized, multiple-pass 24-hr recall instrument (National Cancer Institute Applied Research, Bethesda, MD), we assessed energy and macronutrient intake to determine a comprehensive listing of time food was consumed, as well as how much and what type. This recall is found to be most effective because it ensures the least amount of response bias and participant burden [33]. Twenty-four hour recalls are a valid measure of dietary intake. The method of web-based dietary recalls has been shown to be a good way of gathering dietary data and better than traditional paper food frequency questionnaires [34]. Online dietary recalls are seen as a better way to reflect a person's diet because of the convenience, accessibility, and low participant burden compared to obtaining a diet history [35]. The USDA completed a study using various food recall systems and the most valid measurement that correlated best with total energy intake was the USDA automated multiple-pass method [36, 37]. ASA24 is based on the USDA automated multiple-pass method. This dietary analysis was used to assess daily energy intake. Daily energy intake was measured in calories.

Food Logs: The participants in the breakfast condition reported their first meal eaten in their food log with the date and time they awoke, the time breakfast was eaten, and the foods eaten. Participants in the condition of no breakfast were also required to keep a log and report the date and time of their first meal/snack eaten for the day and the time they awoke. This log was kept throughout the entire study and was used for tracking purposes on whether or not participants were eating breakfast. The logs were also used to give feedback to the participants if they needed to consume more food during breakfast.

Premeal Hunger Levels: Premeal hunger levels were assessed each day during the fourth week of each condition. Participants rated their hunger before each meal using multiple VAS. The VAS asked "How hungry do you feel right now?", "How thirsty do you feel right now?", "How full do you feel right now?", "How much stomach discomfort do you feel right now?", and "On average my energy level is ___." Participants answered by marking somewhere along the 100 mm line starting on the left side with the words "not at all" and on the right side with the words "extremely." VAS have been used to assess food motivation [38]. They have been found to be valid and reliable within subjects to predict meal initiation and amount eaten [38].

Physical Activity: Physical activity was assessed using Actigraph GT3X accelerometers (Actigraph LLC, Fort Walton Beach, FL) worn over the left hip for the entire length of the condition. Accelerometers were not worn when showering or swimming. While accelerometers are relatively small in size, they register movement of all intensities. Accelerometers have been shown to be an accurate way of measuring differences in low-, moderate-, and high-intensity activity levels [39] and are valid measures of evaluating activity in a free living population [40, 41]. The accelerometers have been found to be very reliable, with a coefficient of variation of 2% between instruments and 5% within each instrument [42]. Actigraph counts of less than 250 counts per minute were defined as sedentary. Light exercise was defined as Actigraph counts of 250–2,020 counts per minute. Actigraph counts of 2,020–5,999 counts per minute were defined as moderate exercise. Vigorous exercise was defined as Actigraph counts of greater than 6,000 counts per minute. For data analysis, nonwear time was conservatively defined as 20 or more consecutive epochs with zero values. The day was considered good if the participant wore the monitor 80% of the time between 7 A.M. and 11 P.M. Daily activity was averaged over the baseline and intervention periods.

Data Analysis

The statistical software PC-SAS (version 9.3, SAS Institute, Inc., Cary, NC) was used to analyze the data. Alpha was set at $p < 0.05$. Means and standard deviations were calculated for variables of interest. Independent T-tests were used to examine differences between groups at baseline. If differences existed between any variable after randomization, the variable served as a control variable in all subsequent statistical models. Mixed effects models were used to analyze differences between groups in all dependent variables. The variance structure for the mixed models was auto regressive. To compare food consumption during periods of the day, the following eating periods were used for data analysis, breakfast was 4 A.M.–11 A.M., lunch was 11 A.M.–4 P.M., dinner was 4 P.M.–10 P.M., and night eating was 10 P.M.–4 A.M. Food consumption during these times was summed and the average of 7 d was reported.

Results

A total of 160 women were screened for participation in the study (Figure 1). Fifty-four women randomized to the breakfast (n = 28) and no breakfast (n = 26) conditions. Of these women, 26 completed the breakfast condition and 23 completed the no breakfast condition. Reasons for drop out are reported in Figure 1. There were no differences in baseline percent body fat, physical activity or energy intake for those who completed or did not complete the study. All participants who completed the intervention were included in the analysis. Compliance to the study protocol was 90% for the breakfast group and 98% for the no-breakfast group. In other words the breakfast group consumed a breakfast of at least 15% of their calculated daily energy needs 90% of the time, and the no-breakfast group did not consume any food until 11:30 A.M. 98% of the time. On average the breakfast condition consumed 21.7% of their daily energy intake at breakfast during the intervention.

Demographic data for the women included in the study are reported in Table 1 by condition. Following randomization there were no group differences in height, percent body fat, and age. Similarly, there were no group differences in objectively measured physical activity, dietary energy, carbohydrates, fat, and protein intake (see Table 3). However, there were group differences for weight, BMI, and total fat mass (see Table 3). Because of this, baseline weight was used as a covariate for data analysis.

Weight and Body Composition

Following the intervention, there was a significant interaction between groups for body weight and body fat (see Table 2). The breakfast condition saw a 0.6 ± 0.8 kg increase ($F = 7.81$; $p = 0.0076$) in weight over the 1 mo period, while the no-breakfast condition remained weight stable. Similarly, there was a significant interaction between groups for total fat mass (see Table 2). Total fat mass increased by 0.5 ± 0.6 kg in the breakfast condition ($F = 8.17$; $p = 0.0063$) and did not change within the no-breakfast condition.

Dietary Intake

All participants completed a total of ten 24-hr dietary recalls (3 at baseline and 7 during the intervention). Table 3 displays the dietary data by condition and period. This includes total energy, carbohydrates, fat, and protein intake. There was a significant condition by period interaction for both calories ($F = 6.54$; $p = 0.0138$) and carbohydrate ($F = 9.87$; $p = 0.0029$) consumption (see Table 3). Participants in the breakfast condition increased caloric intake by 266 ± 496 ($F = 12.81$; $P = 0.0043$) calories per day and consumed 43 ± 71 grams more of carbohydrate (F = 16.24; P = 0.0011) per day over baseline. The no-breakfast condition did not statistically change calorie or carbohydrate consumption. When analyzing diet by time of day, there was a significant meal-by-condition interaction in caloric intake for breakfast (see Table 4). There was no interaction observed for lunch, dinner or night eating.

Physical Activity

Using the mean 28-day physical activity counts as measured by accelerometry, there was no condition-by-period interaction (F = 2.37; P = 0.1302). Similarly, there was no condition-by-period interaction in total inactivity (F = 0.30; P = 0.5861, light activity (F = 0.38; P = 0.5391), moderate activity (F = 0.73; P = 0.3976), nor vigorous activity (F = 0.92; P = 0.3413). There were no differences in total physical activity between conditions at any time nor was there a change in physical activity within either condition from baseline to follow up.

Visual Analog Scales

There was no significant meal-by-condition interaction for self-reported hunger, thirst, or fullness. However, there was a significant meal-by-condition interaction for self-reported discomfort (F = 7.67; p = 0.0058) and energy level (F = 7.91; p = 0.0050). Women in the breakfast condition had significantly higher self-reported energy and more discomfort at lunch (see Table 5). There was no difference at dinner.

Discussion

In this study, our goal was to determine the effects of eating breakfast on energy intake, physical activity, body weight, and body fat in women who were nonhabitual breakfast eaters. On average, the participants randomized to eating breakfast consumed 266 more calories per day over the course of the study and weighed 0.6 kg more at the end of the intervention. This weight gain is likely due to the lack of compensation for the extra calories consumed with the addition of breakfast to the diet.

Breakfast is generally considered part of a healthy lifestyle and has been related to lower body weight. The majority of correlational studies have found that people who eat breakfast tend to have lower BMIs [6, 12-17]. In contrast, while there have not been many randomized studies examining this relationship, based on the current evidence there is a general lack of support for breakfast having a positive impact on weight management [20-24]. These studies have primarily resulted in no weight change. Our study also does not support the proposed beneficial impact of breakfast on body weight; it actually resulted in some weight gain. The reason weight gain was observed may be because our study is the only one that exclusively recruited women who did not habitually consume breakfast.

The results of our study showed that the consumption of breakfast not only increased daily energy intake but also increased weight. A few cross-sectional studies have found that people who eat breakfast tend to eat more calories throughout the day [19, 43]. In addition, other studies, including prospective and experimental trials, have shown that energy intake for the day was reported higher for breakfast eaters than non-breakfast eaters [20, 44]. Our study supports these findings and indicates that breakfast consumption in habitual non-breakfast eaters tends to increase caloric intake. Meal consumption was essentially the same as it had been during baseline for the breakfast group.

However, there are several cross-sectional and randomized trials that have found that mean daily energy intake was not different for breakfast eaters compared to non-breakfast eaters [7, 10, 25, 45, 46]. While it is not completely clear why there is not better agreement among studies, this could at least be partially a result of differences in the design of the studies including both correlational and experimental. This includes how breakfast was defined, the measurement of energy intake, as well as low sample size, which limits the ability of the study to see a difference when one does exist.

While the majority of studies showed increased energy intake or no difference in energy intake, there is one study that showed a decrease in daily energy intake with the consumption of breakfast [11]. One possible explanation why this study revealed less daily energy intake may be found in its strict definition of breakfast (consuming 45 g of whole-grain cereal and 200 mL of 2% fat milk between the hours of 7:00 A.M. and 8:00 AM); not only were there rigid guidelines regarding how much could be consumed at breakfast, but there were also limitations on what could be consumed, as well as set time periods for both breakfast and lunch [11].

The difference in energy consumption between groups observed in our study was largely driven by increased carbohydrate consumption in the group randomized to consume breakfast. When non-breakfast eaters are randomized to consume breakfast, they tend to eat more carbohydrates. This is supported by Martin et al. who also found a significant increase in carbohydrate consumption as well as no difference in protein or fat consumption in the group randomized to consume breakfast [20]. This increase in carbohydrate consumption with breakfast is not surprising since the most common breakfast foods consumed contain high levels of carbohydrates; breads and ready-to-eat cereals are the two types of breakfast most consumed in the United States [12].

Even though participants who consumed breakfast had a meal in the morning, there was no compensation at meal periods during the rest of the day. We found no significant difference in the participants' subjective measurements of hunger, thirst, or fullness at any subsequent meal, which would account for no observed differences in caloric intake during lunch, dinner and/or night eating. Because of this, it seems the amount of calories consumed at breakfast (as opposed to other eating periods) largely become extra calories. These results are supported by Martin et al., who also found that there was no caloric compensation between meals with breakfast consumption [20].

While energy intake increased with breakfast consumption, we observed no change in habitual physical activity. While physical activity is an important part of energy balance, there is only one study that we are aware of that has experimentally examined how breakfast influences physical activity. The results of this study support our findings and also found that physical activity did not change with breakfast consumption [25].

The lack of compensation in physical activity may seem counterintuitive for two reasons: first, correlational studies have shown that breakfast is associated with higher physical activity levels [7-9]; second, spontaneous movement has been shown to decrease with energy restriction [47], therefore it may be conjectured that spontaneous movement would increase with increased energy intake. In addition, subjective data from our study suggested that the women who consumed breakfast reported greater feelings of energy at lunch. It may be that eating breakfast is simply an indicator of an overall healthy lifestyle. This may in turn explain the correlation between higher physical activity and eating breakfast and why randomized studies have not supported this relationship [7-9]. Changing one behavior does not necessarily mean that it will impact other behaviors such as increasing physical activity.

As with any study, there are limitations to this study. Despite randomization, the two groups ended up being different at baseline for body weight. A posthoc look at the participants in the study revealed that the five heaviest women were randomized into the breakfast condition resulting in differences in weight between conditions at baseline. Since each participant was randomized individually, this difference in groups happened by chance. There was no difference in other variables of interest and controlling for weight had a statistically negligible impact on the results. While the duration of the study was twice as long as previous investigations, the duration of the study may not have been long enough to allow women to adapt to breakfast consumption and may be why compensation in energy intake did not occur. Additionally, participants in the breakfast condition were required to eat a minimum amount of calories based on daily energy needs. While some education on what to consume was provided, there was no effort made to dictate a certain macronutrient composition of the diet. Participants were allowed to eat *ad libitum* and were able to select food that they wanted to eat. While we are aware that composition does have an impact on satiation and satiety, we chose to not control for this. We believe this method adds strength to our study, since calories and composition were not strictly regulated. The results reflected more of a free-living situation and what would likely happen in the real world. We also only examined non-breakfast eaters to test the hypothesis that breakfast is beneficial to health. However, non-breakfast eaters may have self-selected this behavior for weight management purposes and by adding breakfast they went out of energy balance.

Despite these limitations, our study examined a larger sample of participants for a longer duration than had previous studies. We also investigated the effect of breakfast on weight and body fat, unlike most studies which investigated the influence of breakfast. We furthermore objectively measured physical activity for 32 consecutive days. Lastly, we also specifically studied non-breakfast eaters based on the assumption that adding breakfast would be beneficial to those who do not currently eat breakfast.

Conclusion

The findings of our study showed that requiring non-breakfast eaters to eat breakfast results in higher caloric intake and weight gain. There was no observed caloric compensation at subsequent meals and no change in self-reported hunger or satiety. There was also no physical activity compensation with the addition of breakfast. Even though the participants gained weight in the short term, we cannot make the conclusion that eating breakfast will cause weight gain in the long term. Future research should evaluate this relationship for a longer period of time to see if adding breakfast to the diet of women who generally do not eat breakfast results in adaptive behavior change over time.

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Table 1. Demographics of participants at baseline

Variable	Condition	Baseline	F-Value	p-Value
Height (cm)	Breakfast	167.8 ± 7.3	2.92	0.0926
	No Breakfast	165.0 ± 6.2		
Age (years)	Breakfast	23.7 ± 7.5	0.63	0.4313
	No Breakfast	23.6 ± 5.0		
Weight (kg)	Breakfast	66.4 ± 15.4	8.75	0.0044
	No Breakfast	59.1 ± 10.2		
Percent Body Fat	Breakfast	33.8 ± 7.9	1.43	0.2368
	No Breakfast	31.5 ± 6.8		
Energy Intake (kcal)	Breakfast	1688.5 ± 562.1	0.18	0.7691
	No Breakfast	1696.4 ± 475.4		
Total Activity	Breakfast	284.5 ± 106.7	2.37	0.1302
	No Breakfast	272.0 ± 71.3		

F and p-values evaluate mean differences between conditions
Activity counts divided by 1,000 for reporting purposes

Table 2. Anthropometrics of participants by condition at baseline and after one-month of intervention

Variable	Condition	Baseline	1-Month	F-Value	p-Value
Total Body Mass (kg)	Breakfast	66.4 ± 15.4*	67.0 ± 15.2	7.81	0.0076
	No Breakfast	59.1 ± 10.2	58.7 ± 9.5		
Total Fat Mass (kg)	Breakfast	23.4 ± 10.6*	23.9 ± 10.7	8.17	0.0063
	No Breakfast	19.0 ± 6.8	19.0 ± 6.8		
Total Lean Mass (kg)	Breakfast	40.6 ± 5.8	40.7 ± 5.7	0.23	0.6361
	No Breakfast	37.4 ± 3.7	37.4 ± 4.0		
Percent Body Fat	Breakfast	33.8 ± 7.9	34.2 ± 8.0	2.22	0.1432
	No Breakfast	31.5 ± 6.8	31.7 ± 6.6		

F and p-value evaluate the interaction between condition and period.
* Indicates a significant change from baseline ($p \leq 0.05$)

Table 3. Energy and macronutrient intake of each condition (breakfast and no breakfast) during baseline and intervention

Variable	Condition	Baseline	Follow-up	F-Value	p-Value
Energy Intake (kcal)	Breakfast	1688.5 ± 562.1*	1951.7 ± 527.2	6.54	0.0138
	No Breakfast	1696.4 ± 475.4	1685.4 ± 552.5		
Carbohydrates (g)	Breakfast	214.0 ± 75.5*	257.5 ± 73.9	9.87	0.0029
	No Breakfast	207.3 ± 77.2	201.3 ± 70.9		
Total fat (g)	Breakfast	67.5 ± 26.9	74.3 ± 24.5	0.85	0.3608
	No Breakfast	70.8 ± 19.4	72.6 ± 25.4		
Protein (g)	Breakfast	63.0 ± 27.8	70.5 ± 19.7	2.59	0.1144
	No Breakfast	63.1 ± 22.9	61.3 ± 22.3		

F and p-value evaluate the interaction between condition and period.

* Indicates a significant change from baseline ($p \leq 0.05$)

Table 4. Energy intake at baseline and during the intervention for each condition by time of day

Energy (kcal)	Condition	Baseline	Follow-up	F-Value	p-Value
Breakfast	Breakfast	98.6 ± 128.2*	424.3 ± 135.0	45.29	< 0.0001
4:00 A.M.–11:00 A.M.	No Breakfast	66.8 ± 123.9	3.02 ± 14.5		
Lunch	Breakfast	664.6 ± 276.0	701.1 ± 289.0	2.56	0.1124
11:00 A.M.–4:00 P.M.	No Breakfast	831.6 ± 273.3	774.5 ± 280.2		
Dinner	Breakfast	840.5 ± 396.0	746.0 ± 254.5	0.74	0.3918
4:00 P.M.–10:00 P.M.	No Breakfast	695.7 ± 329.2	836.7 ± 304.9		
Night eating	Breakfast	112.3 ± 191.0	88.0 ± 113.6	0.10	0.7593
10:00 P.M.–4:00 A.M.	No Breakfast	104.7 ± 146.9	79.8 ± 115.7		

F and p-value evaluate the interaction between condition and period.

* Indicates a significant change from baseline ($p \leq 0.05$)

Table 5. Subjective measures of participants' hunger, thirst, fullness, discomfort, and energy level prior to each meal rated on a 10 cm visual analog scale during the intervention at lunch

Variable	Condition	Follow-up	F-Value	p-Value
How hungry do you feel right now? (mm)	Breakfast	43.3 ± 25.8	2.53	0.1136
	No Breakfast	53.7 ± 21.3		
How thirsty do you feel right now? (mm)	Breakfast	43.7 ± 25.2	0.62	0.4327
	No Breakfast	49.4 ± 20.3		
How full do you feel right now? (mm)	Breakfast	38.1 ± 21.8	2.28	0.1328
	No Breakfast	31.1 ± 20.2		
How much stomach discomfort do you feel right now? (mm)	Breakfast	21.0 ± 20.5	3.96	0.0478
	No Breakfast	27.0 ± 23.0		
On average my energy level is? (mm)	Breakfast	41.5 ± 17.8	7.18	0.0079
	No Breakfast	38.8 ± 16.5		

F and p-values evaluate mean differences between conditions

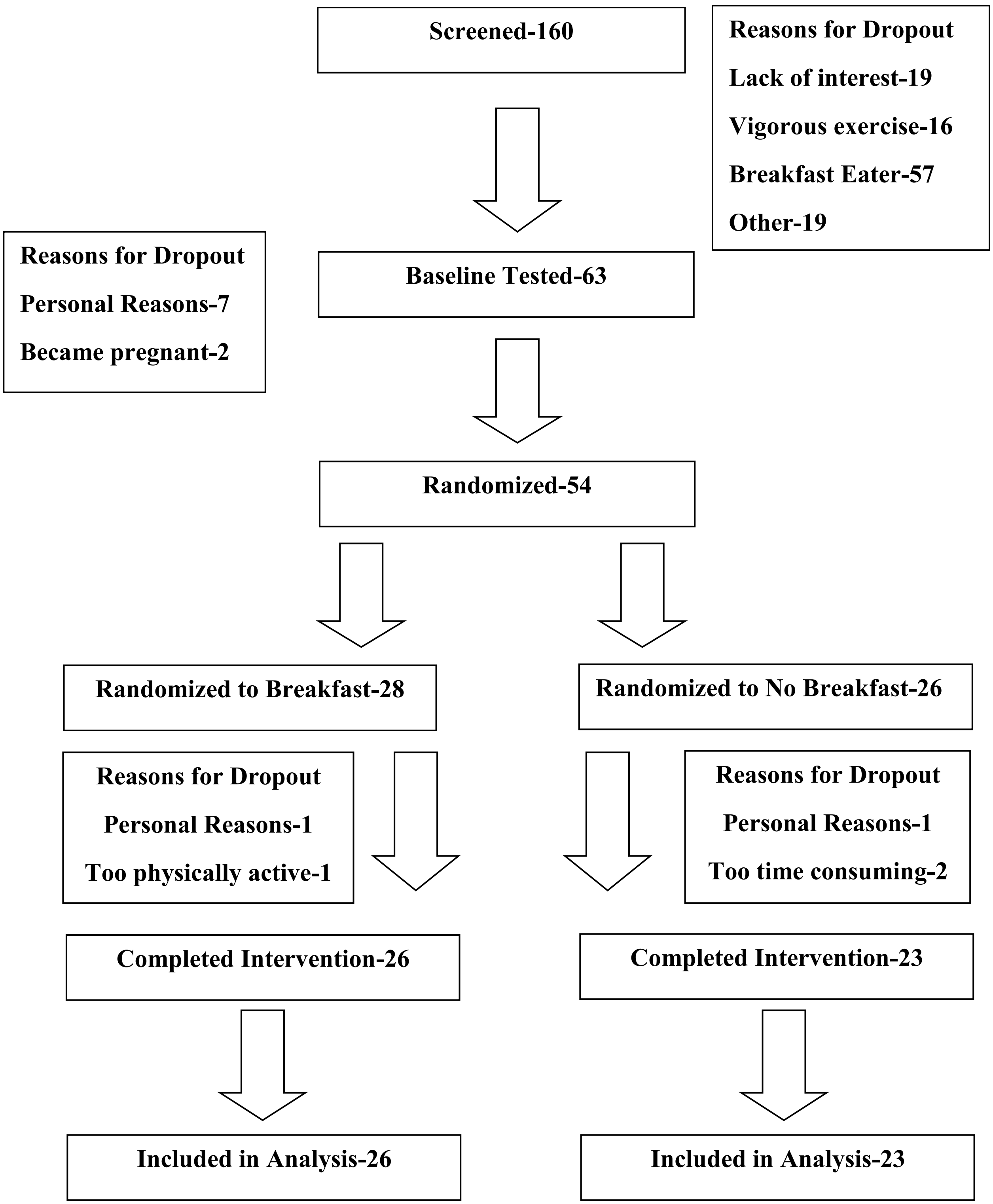

Figure 1. Consort Diagram