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Meal timing influences daily caloric intake in healthy adults

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ABSTRACT

The role that meal pattern plays in weight regulation is a popular topic of scientific and common debate. The goal of this study was to evaluate the relationship between meal timing with caloric intake and body mass index (BMI). We hypothesized that late meal timing and eating closer to sleep onset time would be associated with greater energy intake and higher BMI. Participants included 59 individuals recruited from the community. Rest/activity patterns were assessed using 7 days of wrist actigraphy, and caloric intake was evaluated using 7 days of diet logs. Results demonstrated that the timing of meals was associated with overall energy intake but not with BMI. In multivariate analyses controlling for age, sex, sleep duration, and timing, eating more frequently, later timing of the last meal, and a shorter duration between last meal and sleep onset predicted higher total caloric intake. In a mediational model, eating frequency explained the relationship between eating closer to sleep onset and total caloric intake. Results suggest that later relative timing of meals, particularly eating close to sleep, could lead to weight gain due to a greater number of eating occasions and higher total daily caloric intake. These findings have important implications for the development of novel, time-based interventions for weight management.

1. Introduction

The role of meal pattern and timing in weight management is not well understood, with most weight loss interventions focusing primarily on total energy intake and less on timing of meals. However, recent evidence from several animal studies suggests that alterations in the timing of feeding impact weight gain [1-3]. Arble et al [1] observed a greater weight gain in mice fed only during the light phase (normal rest period), compared to mice fed only during the dark phase (normal active period). This finding was replicated by Fonken et al [2] who found that when mice were kept in constant light, they gained more weight than mice under a light/dark cycle; however, when feeding was restricted to the normal feeding time (biological night), the effects of the constant light were no longer observed. In addition, a more recent study, using a restricted feeding regime with similar caloric intake in mice, suggests that the duration of fasting countered the adverse effects of a high-fat diet [3].

Abbreviations: BMI, body mass index.

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There are few published studies that have examined meal timing specifically in humans, and most have only focused on breakfast consumption and regularity of eating [4]. In the few human meal timing studies [5-8], the findings are mixed. Obese men had double the energy intake between 10 PM and 4 AM than normal weight men (8% vs 4%) [5]; and in a more recent study of women, the only difference in meal timing reported between obese and normal weight women was that normal-weight women eat dinner later on the weekends [6]. Night eating or eating most calories either in the evening or after sleep onset is also associated with a higher body mass index (BMI) in obese individuals [9]. These studies highlight the need for additional investigation into the role played by the timing of meals in human weight regulation.

Recent research by our group indicated that eating after 8 PM was associated with a higher BMI, even after controlling for sleep timing and duration [10]. The goal of the current study is to evaluate the relationship between the timing of meals with caloric intake and BMI while controlling for the timing and duration of sleep. Typical meal timing and caloric intake were determined using 7-day food diaries. We hypothesize that later meal timing and eating closer to sleep onset time will be associated with greater energy intake and higher BMI.

2. Methods and materials

2.1. *Participants*

Via advertisements, participants (males and females) were recruited from the community for a larger study of circadian rhythms targeting "healthy sleepers" and "night owls or larks." The study was approved by the Northwestern University Institutional Review Board, and all participants gave written informed consent before enrollment. Exclusionary criteria included elevated depressive symptoms, as indicated by a score of greater than 20 on the Center for Epidemiologic Studies Depression Scale [11]. None of the participants reported employment involving shift work.

2.2. *Procedure*

Participants underwent preliminary screening via telephone or email to determine eligibility and willingness to participate in the study. Once informed consent was obtained, participants were provided with 7 days of diet logs, sleep logs, and a wrist actigraph (AW-L Actiwatch; Mini Mitter Co, Inc, Bend, OR, USA), which was worn for at least 7 days [12]. In the daily diet logs, the participants were asked to list a description of each food (quantity, preparation, name brand, etc) as well as the time and location in which the meal or snack was consumed. In the sleep logs, participants were asked to report sleep and wake times, which were used in combination with the actigraphy (Actiware-Sleep 3.4 software; Mini Mitter Co, Inc, Bend, OR, USA) to determine sleep duration and sleep quality [13].

2.3. *Measures*

Participants were screened for depression with the Center for Epidemiologic Studies Depression Scale; this widely used 20-item questionnaire reports adequate internal consistency [11]. As based upon self-reported height and weight, BMI was calculated as kilograms per square meter. The BMI was calculated in this manner because objective height and weight were not obtained, as many of the assessments were conducted exclusively via mail and telephone.

2.4. *Dietary assessment*

Dietary intake was assessed using a diet log in which participants recorded all food and drinks for a 7-day period [10]. We asked participants to record the time the food or drink was consumed; type of meal (breakfast, lunch, dinner, or snack); type of food (with brand name, if possible); the location (ie, home or restaurant) where the meal or snack was consumed; portion size; and whether it was a day they consumed less than a typical diet, more than a typical diet, or a typical diet. Along with the diet logs, participants were provided with 2 pages of instructions for completing the diet logs. The first page of the instructions indicated for the participants to include portion size (cups, ounces, and pieces), brand, information on the preparation method (eg, boiled, fried in oil, eaten with refuse), and condiment usage as well as break up the foods into component parts (eg, sandwich is 2 pieces of wheat bread, 2 oz of turkey breast). The second sheet was a portion size guide, and it provided suggestions for how to judge portions without measuring (eg, the size of a deck of cards, ping pong ball, your fist).

Diet logs were analyzed using publicly available nutrition information (www.sparkpeople.com) as well as restaurant and manufacturer Web sites. Daily, caloric intakes for each meal and for each entire day were computed, and then the mean was computed for the 7-day period. Meals were classified as breakfast, lunch, or dinner, based upon the designation the participant indicated in the diet log. Meals listed as "brunch" were considered neither and included only as meal 1 (where appropriate) and in the total nutrition analyses for the day, but not as a meal type (breakfast, lunch, dinner, snack), to avoid redundancy. Logs were considered valid if there were at least 2 weekdays and 1 weekend day completed, to provide a representative average of a typical week. Dietary logs were excluded if total calories per day were less than 500. If participants had less than 7 days recorded, all of the available data were used; alternatively, if an excess of 7 days was completed, the investigators used the first 7 consecutive days that best coincided with the actigraphy recordings. Timing of a meal was listed at the start time in the log. In case of skipping meals, meal times and caloric content were only calculated if at least 3 of that particular meals episode (that day's meal episodes) were consumed. Meal episodes were calculated as foods consumed within a 30-minute duration. For example, if a snack was consumed at 1:00 and another at 1:45, the latter would be considered a separate meal. Because an eating occasion designated by the participant as "breakfast" or "dinner" may not have been the first or last meal consumed in a given day, 2 additional variables were calculated to represent the first ("first meal") and last ("last meal") intake of food or drink (other than water) of each day. In some cases, first and last meal could be the same as a designated meal (ie, breakfast, lunch, dinner) or a snack. In the case of conflicting data, such as a breakfast time