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Research report

Higher proportion of total and fat energy intake during the morning may reduce absolute intake of energy within the day. An observational study in free-living Japanese adults ☆

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ABSTRACT

Background: Although the distribution of energy intake throughout the day appears to impact overall daily energy intake, little is known about the *ad libitum* distribution of energy intake. *Objective:* Our aim was to investigate associations between the distribution of energy intake during the day and subsequent or overall energy intake, and food choice in free-living adults. *Design:* A total of 119 women and 116 men completed 16-day semi-weighed dietary records. The longitudinal dietary intake data for each participant were analyzed using a mixed model to examine the effect of energy intake at various times of day on subsequent or overall energy intake. *Results:* Mean proportion of total energy intake in the morning (4:00 a.m.–10:29 a.m.), afternoon (10:30 a.m.–4:59 p.m.) and evening (5:00 p.m.–3:59 a.m.) meal was 22.6%, 33.8% and 43.6% in men, and 24.7%, 36.5%, 38.8% in women, respectively. Proportion of energy intake (%) in the morning meal was significantly and negatively associated with energy intake (kcal) in the subsequent afternoon and evening meals, and consequently in the whole day in both sexes. This significant and negative association was also observed for proportion of energy intake (%) of fat, but not of carbohydrate or protein, in both sexes. Proportion of energy intake (%) in the morning meal was negatively associated with overall energy intake (kcal) from the group of meats, fish, and eggs in both sexes, and from the group of confectioneries and soft drinks in women. *Conclusions:* More energy in the morning meal may reduce energy intake, especially that from fat, in the subsequent meals, and consequently in the whole day.

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Introduction

The prevalence of obesity has increased globally during the last decades (Swinburn et al., 2011). One important step in overcoming obesity is to identify strategies to reduce energy intake from each meal. A primary contributor to obesity is the recent increase in unhealthy eating habits, with emphasis on breakfast skipping. Breakfast consumption in children, adolescents, and adults has dramatically declined over the last decades in the US (Haines, Guilkey, & Popkin, 1996; Siega-Riz, Popkin, & Carson, 1998). Skipping breakfast or consuming a smaller breakfast is associated with an array of unhealthful outcomes (Keski-Rahkonen, Kaprio, Rissanen, Virkkunen, & Rose, 2003), including body weight gain, overweight and obesity (de Castro, 2004; Purslow et al., 2008; Song, Chun, Obayashi, Cho, & Chung, 2005; van der Heijden, Hu, Rimm, & van Dam, 2007), and obese individuals are more likely to skip breakfast or consume less energy at breakfast (Bellisle, Rolland-Cachera, Deheeger, & Guilloud-Bataille, 1988; Berteus Forslund, Lindroos, Sjostrom, & Lissner, 2002; Ortega et al., 1996). However, the proportion of energy intake in the morning meal that is most effective in reducing overall energy intake is unknown.

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The timing of energy intake during the day also appears to impact total energy intake. Normal and underweight persons take in more energy in daytime than those with obesity (Bellisle et al., 1988; Berteus Forslund et al., 2002). Higher proportional consumption of energy and macronutrients in the morning meal is associated with lower overall energy intake whereas higher proportional consumption in the evening meal is associated with higher overall intake (de Castro, 2004). Under a cross-over design, eating restriction at night decreased total energy intake and weight change in healthy young men (LeCheminant, Christenson, Bailey, & Tucker, 2013). Moreover, moderately obese women lost more weight when they consumed 70% of their daily energy intake before noon instead of in the afternoon and evening meals (Keim, Van Loan, Horn, Barbieri, & Mayclin, 1997). These findings suggest that the timing of energy intake during the day might influence total daily energy intake. However, few studies have quantified what proportion of energy intake in the morning meal is necessary to reduce subsequent or overall energy intake. Moreover, these previous studies characterized influences on energy intake simply by the amount of energy, and did not describe the source of energy intake.

Macronutrient contents of the diet also may influence energy intake. A high-protein breakfast reduced subsequent energy intake compared with a normal-protein breakfast, high-carbohydrate breakfast, or high-fat breakfast (Fallaize, Wilson, Gray, Morgan, & Griffin, 2013; Leidy & Racki, 2010), and a high-fat and high-protein lunch reduced subsequent energy intake compared with a high-carbohydrate lunch in lean subjects (Brennan et al., 2012). However, other studies were inconsistent with these studies (Blatt, Roe, & Rolls, 2011; Raben, Agerholm-Larsen, Flint, Holst, & Astrup, 2003). Meal timing and macronutrient contents appear to influence its satiating properties. Specifically, protein consumed at the morning meal leads to greater initial and sustained feelings of fullness, increased satiety and reduced levels of ghrelin compared to the afternoon or evening meal (de Castro, 2007; Leidy, Bossingham, Mattes, & Campbell, 2009; Leidy, Mattes, & Campbell, 2007; Leidy & Racki, 2010). It has also been shown that the addition of carbohydrates to protein leads to an additional reduction of hunger and increased satiety (Astbury, Taylor, & Macdonald, 2011; Holt, Delargy, Lawton, & Blundell, 1999; Isaksson et al., 2011).

This kind of study requires participants to consume a fixed, artificial amount of food, which may differ from the amount they usually consume or would consume *ad libitum*. As a consequence, these studies have received little attention. In fact, one *ad libitum* study in US adults suggested that although a higher proportion of carbohydrate and fat intake in the morning meal reduced overall energy intake, the proportion of protein intake did not affect overall intake (de Castro, 2007). With regard to *ad libitum* macronutrient intake, its role on overall energy intake is also unknown.

Our present study had several objectives. First, we wanted to describe the distribution of *ad libitum* daily energy and macronutrient intake in Japanese adults. Second, we wanted to investigate associations between the proportion of energy intake in the morning, afternoon, and evening meals and subsequent or overall energy intake in free-living adults. Third, we wanted to assess the intake pattern of macronutrients throughout the day, and the effects of the timing of each macronutrient intake on energy intake. Last, we wanted to investigate associations between the proportion of energy intake in the morning meal and subsequent food choice.

Methods

Study subjects

Details of the study design, participant characteristics, and dietary assessment methods of semi-weighed dietary records (DRs) have been reported elsewhere (Kobayashi et al., 2012; Murakami et al., 2008). Briefly, the study was conducted in four areas in Japan with large differences in geographic conditions and dietary habits, namely: Nagano (Matsumoto City; rural inland), Osaka (Osaka City; urban), Tottori (Kurayoshi City; rural coastal), and Okinawa (Ginowan City; urban island). In each area, the registered dietitians at the municipal government recruited apparently healthy women aged 30–69 years who had a high possibility of participation with a cohabiting husband. The subjects were volunteers and were asked by local staff (registered dietitians) to participate in the study. Subject recruitment was continued until a sufficient number of participants was obtained. In each of the four areas, each 10-year age band (30–39, 40–49, 50–59, and 60–69 years) included 8 women; the age of the husband was not considered. Thus, a total of 128 women and 128 men were invited. Dietitians were excluded from the study. None of the subjects had recently received dietary counseling from a doctor or dietitian or had a history of educational hospitalization for diabetes or nutritional education from a dietitian. The study was conducted between November 2002 and September 2003. The study did not undergo ethical approval because it was conducted before ethical guidelines for epidemiologic research were enforced in Japan. However, the study was conducted according to the principles of the Helsinki declaration. Before the start of the study, group orientations were held to explain the study purpose and design and written informed consent was obtained from each subject. Use of data from this study was approved by the Ethics Committee of The University of Tokyo Faculty of Medicine (No. 3421).

Diet record

Between November 2002 and September 2003, each subject completed four 4-nonconsecutive-day semi-weighed DRs, one in each of the four seasons (total 16 days) at intervals of approximately three months. The four recording days consisted of three randomly selected weekdays (Monday through Friday) and one weekend day (Saturday through Sunday). During the orientation session, local staff (registered dietitians) gave subjects both written and verbal instructions on how to keep the dietary record, using a completed recording sheet as an example. Subjects were also instructed on how to weigh each food item and drink and were asked to record all foods and drinks, and the time they started and finished consumption on each recording day. All collected records were checked by trained registered dietitians in each local center and then again in the data center. The coding of records and conversion of measurements into grams were performed by trained registered dietitians in the survey center in accordance with uniform procedures. A total of 1398 food and beverage items appeared in the dietary records. Dietary data were converted into energy using the Standard Tables of Food Composition in Japan (Science and Technology Agency, 2010). Total intake of energy, carbohydrate, fat, protein and alcohol were calculated by summing the contributions of the individual items. A total of 119 women aged 30–69 years and 116 men aged 30–76 years who completed the 16 DRs and times of consumption were included in the present analysis.

Timing of dietary intake

To analyze energy and nutrient intake distribution during the day, the starting time of each meal was considered the time of intake. Energy intake in the three periods of morning (4:00 a.m.–10:29 a.m.), afternoon (10:30 a.m.–4:59 p.m.), and evening (5:00 p.m.–3:59 a.m.) was calculated to investigate the effect of energy intake in each period on that in subsequent meals and overall intake. The morning period was specifically defined to capture most of “breakfast” but not lunch. Similarly, the afternoon period was defined to capture most of “lunch” and afternoon snack, while the evening period was determined to capture most of “dinner” and evening snack (de Castro,

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