



## Regular article

Loneliness predicts postprandial ghrelin and hunger in women<sup>☆</sup>

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## ABSTRACT

Loneliness is strongly linked to poor health. Recent research suggests that appetite dysregulation provides one potential pathway through which loneliness and other forms of social disconnection influence health. Obesity may alter the link between loneliness and appetite-relevant hormones, one unexplored possibility. We examined the relationships between loneliness and both postmeal ghrelin and hunger, and tested whether these links differed for people with a higher versus lower body mass index (BMI; kg/m<sup>2</sup>). During this double-blind randomized crossover study, women ( $N = 42$ ) ate a high saturated fat meal at the beginning of one full-day visit and a high oleic sunflower oil meal at the beginning of the other. Loneliness was assessed once with a commonly used loneliness questionnaire. Ghrelin was sampled before the meal and postmeal at 2 and 7 h. Self-reported hunger was measured before the meal, immediately postmeal, and then 2, 4, and 7 h later. Lonelier women had larger postprandial ghrelin and hunger increases compared with less lonely women, but only among participants with a lower BMI. Loneliness and postprandial ghrelin and hunger were unrelated among participants with a higher BMI. These effects were consistent across both meals. These data suggest that ghrelin, an important appetite-regulation hormone, and hunger may link loneliness to weight gain and its corresponding negative health effects among non-obese people.

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## Introduction

The desire for close and caring relationships motivates a wide range of human behavior (Leary and Cox, 2008; Maslow, 1968). This need to belong likely stems from the importance of group living for humans' survival throughout their evolutionary past; being allied with a network of people who were mutually invested in each other's welfare increased the likelihood of survival and the potential to thrive (Tooby and Cosmides, 1996). Over time, this ultimately developed into a basic need to form close and caring bonds with other people (Baumeister and Leary, 1995).

Because the need for social connection is fundamental to human nature, the failure to fulfill this need should have negative mental and physical health consequences. Indeed, loneliness, an interpersonally stressful state of perceived social disconnection, is strongly linked to poor health (Hawkley and Cacioppo, 2010). For example, lonely people had 45% lower odds of survival compared with those who were not lonely, even after accounting for important sociodemographic and health-relevant risk factors (Holt-Lunstad et al., 2010). In addition, lonelier people experienced more chronic diseases, reported worse physical health, and were more likely to develop coronary heart disease than those who were less lonely (Sugisawa et al., 1994; Thurston and Kubzansky, 2009).

Appetite dysregulation is one potential pathway through which loneliness and other forms of social disconnection may influence health. A person's appetite and eating behavior are strongly linked to obesity (Arora and Anubhuti, 2006), which contributes to a host of medical problems, including type 2 diabetes, cardiovascular disease, and premature mortality (Billington et al., 2000). Ghrelin, an appetite-stimulating hormone, fuels food consumption (Klok et al., 2007). For instance, pre-meal hunger increases are related to similar rises in ghrelin (Cummings et al., 2004). Furthermore, ghrelin reliably surges before a meal and

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decreases after eating (Cummings et al., 2001). One novel study demonstrated that a ghrelin injection caused people to feel hungrier and consume more food compared with saline (Wren et al., 2001).

Recent research supports the argument that social disconnection may be implicated in appetite dysregulation. Specifically, non-obese women who experienced more interpersonal stressors had higher ghrelin and lower leptin, an appetite-suppressing hormone, than non-obese women who experienced fewer interpersonal stressors (Jaremka et al., 2014b). Supporting the hormone data, non-obese women who experienced more interpersonal stressors had a typical diet that was significantly higher in calories, fat, carbohydrates, protein, sugar, sodium, and fiber, and marginally higher in cholesterol, vegetables (but not fruits), vitamin A, and vitamin C. These data demonstrate that interpersonal stressors are linked to appetite-relevant hormones and food consumption. However, it is unclear if these results extend to other forms of social disconnection, such as loneliness.

Obesity may alter the link between social disconnection and ghrelin, one unexplored possibility. Obese people have lower fasting ghrelin levels than those who are overweight or a healthy weight (Buss et al., 2014; Klok et al., 2007; Shiiya et al., 2002). They also have lower postprandial ghrelin compared with normal weight people (Carlson et al., 2009; le Roux et al., 2005). Importantly, a recent study demonstrated that ghrelin was linked to caloric intake and hedonic eating among overweight but not obese people (Buss et al., 2014). Taken together, these data suggest that ghrelin may differentially affect obese compared with non-obese people. Accordingly, the link between social disconnection and ghrelin may be attenuated among obese people. Based on this rationale, we examined whether loneliness would be related to postprandial ghrelin and hunger increases for people with a lower body mass index (BMI; kg/m<sup>2</sup>), but not among people with a higher BMI. We conducted secondary analyses from a parent study about fast-food-type-meals and fatigue to investigate these possibilities.

## Method

### Participants

Participants were recruited from two prior lab studies for a parent study about fast-food-type-meals and fatigue. Due to timing issues related to questionnaire collection, only women who participated in one of the two past studies comprised our analytic sample. One of these participants had diabetes and was thus excluded, leaving a total of 42 women. Due to the nature of the parent study, both breast cancer survivors ( $n = 22$ ) and non-cancer controls ( $n = 20$ , women who had an initial abnormal mammogram) participated in the study. The survivors averaged 11.96 months ( $SD = 4.15$ ) since treatment completion. Individuals were ineligible if they had significant visual, auditory, or cognitive impairments, any prior history of cancer except basal or squamous cell skin carcinomas, symptomatic ischemic heart disease, chronic obstructive pulmonary disease, liver or kidney failure, or severe gastrointestinal problems. We also excluded women with major immune-mediated conditions, and anyone who abused alcohol or drugs or used medications with major immunological consequences. The women's average age was 53.38 years ( $SD = 9.02$ , range 31–75) and they were primarily white (79%). Additional sample characteristics can be found in Table 1.

### Study procedure

The participants completed two full-day study visits at the Clinical Research Center (CRC), a hospital research unit. During this double-blind randomized crossover study, women ate a high saturated fat meal at the beginning of one visit and a high oleic sunflower oil meal at the beginning of the other. Visits were spaced 1–4 weeks apart, and the meal order was randomized between visits.

Women were told to avoid alcohol use within one day prior and strenuous physical activity within two days prior to their study visits (Lairon et al., 2007). The participants were also instructed to stop taking aspirin, vitamins, antioxidants, and any other dietary supplements for 7 days prior to each admission. On the day before each of the study visits, participants received three standardized meals from the CRC's metabolic kitchen, reducing any variability associated with recent food intake.

At each admission, women arrived after fasting for 12 h and a catheter was inserted in their arm. Following a short relaxation period, women had 20 min to eat the high saturated fat or high oleic sunflower oil meal; they were required to eat the entire meal. Ghrelin was sampled before the meal and postmeal at 2 and 7 h. Self-reported hunger was assessed before the meal, immediately postmeal, and then 2, 4, and 7 h later. This research was approved by The Ohio State University (OSU) Institutional Review Board; the participants provided written informed consent before participating.

### Standardized pre-study meals

Equations from the Dietary Reference Intakes were used to determine total kcal requirements for each participant based on age, height, weight, and physical activity (Trumbo, Schlicker, Yates, & Poos, 2002). Macronutrient targets (as percent of total energy) for the pre-study meals were 54.9 + 2.68% carbohydrate, 27.6 + 2.13% fat, and 17.6 + 0.95% protein. The fat content was 9.10 + 1.20% saturated fats, 9.43 + 1.55% monounsaturated fats, and 7.26 + 1.25% polyunsaturated fats. The participants ate their last meal no later than 7:30 pm the night before admission to the CRC; the dinner was light and low in fat (Lairon et al., 2007). Compliance was good: women consumed 91.83 + 8.41% of their pre-study meals.

### Research meals

Both the high saturated fat and the high oleic sunflower oil meals included eggs, turkey sausage, biscuits, and gravy for a total of 930 kcal, with 60 g of fat, 59 g of carbohydrates, and 36 g of protein (percent of total kcal = 60, 25, 15, respectively). In line with prior research (Poppitt et al., 2008), the saturated:unsaturated fatty acid ratio varied between the meals; the high saturated fat meal contained 16.84 g palmitic and 13.5 g oleic (ratio = 1.93) oil, compared to 8.64 g palmitic and 31.21 g oleic oil for the high oleic sunflower oil meal (ratio = 0.67). The composition of the research meals was based on the parent study; some human studies have suggested that high saturated fat meals may fuel fatigue-inducing inflammatory responses, although others have not found these effects (Heriaka and Erridge, 2014; Manning et al., 2008; Poppitt et al., 2008).

### Questionnaires and interviews

Loneliness was measured with the 8-item New York University Loneliness (NYUL) scale (Rubenstein and Shaver, 1982), which assessed the extent to which participants felt chronically alone and socially isolated. Individual items are measured on different metrics. Accordingly, each item was z-scored prior to creating the scale average (Rubenstein and Shaver, 1982). The NYUL scale demonstrates convergent validity with other loneliness measures and has good internal consistency (Rubenstein and Shaver, 1982; Russell, 1996). The NYUL was collected as part of a prior lab study that occurred an average of 5.50 ( $SD = 4.93$ ) months before participation in the current investigation (see the Participants section for additional details). Loneliness is relatively stable over time (Cacioppo et al., 2002; Kiecolt-Glaser et al., 2003). Accordingly, loneliness within the context of the present study could represent a pre-existing vulnerability for appetite dysregulation, a current risk factor, or a combination of the two, all of which are interesting possibilities.

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