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Research report

Capsaicin increases sensation of fullness in energy balance, and decreases desire to eat after dinner in negative energy balance ☆

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ABSTRACT

Addition of capsaicin (CAPS) to the diet has been shown to increase satiety; therefore, CAPS is of interest for anti-obesity therapy. We investigated the effects of CAPS on appetite profile and *ad libitum* energy intake in relation to energy balance. Fifteen subjects (seven women and eight men, age: 29.7 ± 10.8yrs, BMI: 23.3 ± 2.9 kg/m^2) underwent four conditions in a randomized crossover design in 36 hour sessions in a respiration chamber; they received 100% of their daily energy requirements in the conditions “100%Control” and “100%CAPS”, and 75% of their daily energy requirements in the conditions “75%Control” and “75%CAPS”, followed by an *ad libitum* dinner. In the 100%CAPS and 75%CAPS conditions, CAPS was given at a dose of 2.56 mg (1.03 g of red chili pepper, 39,050 Scoville heat units) with every meal. Satiety ($P < 0.05$) and fullness ($P = 0.01$) were measured every waking hour and before and after every meal using visual analogue scales, and were higher in the 100%CAPS *versus* 100%Control condition. After dinner desire to eat, satiety and fullness did not differ between 75%CAPS and 100%Control, while desire to eat was higher ($P < 0.05$) and satiety ($P = 0.06$) and fullness ($P = 0.06$) tended to be lower in the 75%Control *versus* 100%Control condition. Furthermore, *ad libitum* intake ($P = 0.07$) and overconsumption ($P = 0.06$) tended to decrease in 100%CAPS *versus* 100%Control. In energy balance, addition of capsaicin to the diet increases satiety and fullness, and tends to prevent overeating when food intake is *ad libitum*. After dinner, capsaicin prevents the effects of the negative energy balance on desire to eat.

Introduction

Obesity is the result of an energy imbalance that develops when energy intake exceeds energy expenditure. Obesity raises the risk of developing Type 2 Diabetes, cardiovascular diseases and several cancers (Haslam & James, 2005). Capsaicin (CAPS) is the major pungent principle of red chili pepper, which limits energy intake while it contains only negligible amounts of energy itself (Ludy & Mattes, 2011; Westerterp-Plantenga, Smeets, & Lejeune, 2005; Yoshioka et al., 1999). Therefore, CAPS might be an interesting target for anti-obesity therapy. To quantify the pungency of hot peppers, the Scoville test is used; the number of Scoville heat units (SHU) indicates the amount of CAPS present in the pepper. The CAPS level in peppers can vary from plant to plant. If a pepper contains 50,000 SHU, this means that its alcoholic extract needs to be diluted 1:50,000 to be pungent on the human tongue (Szallasi & Blumberg, 1999). Red chili pepper can be ingested orally or in capsule form. In a previous study on the relative oral and gastrointestinal contribution to capsaicin-induced effects on food intake, the decrease in energy intake was larger when red chili pepper was ingested orally compared with administration in capsule form. So, oral exposure to red chili pepper is more effective to achieve the maximum effect (Westerterp-Plantenga et al., 2005).

Several human studies have shown that the addition of CAPS to a diet enhances anorexigenic sensations, including satiety and fullness in energy balance (Smeets, Janssens, & Westerterp-Plantenga, 2013; Westerterp-Plantenga et al., 2005). Moreover, CAPS has been reported to suppress orexigenic sensations, it might decrease desire to eat (Ludy & Mattes, 2011) and hunger (Westerterp-Plantenga et al., 2005) in energy balance as well as in positive energy balance (Reinbach, Smeets, Martinussen, Moller, & Westerterp-Plantenga, 2009). In addition, several studies have shown that CAPS

Abbreviations: AUC, Area under the curve; BMI, Body mass index; CAPS, Capsaicin; FM, Fat mass; FMI, Fat mass index; PAL, Physical activity level; SHU, Scoville heat units; SNS, Sympathetic nervous system; TBW, Total body water; VAS, Visual analogue scale; WHR, Waist-to-hip ratio.

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decreases *ad libitum* food intake (Ludy & Mattes, 2011; Westerterp-Plantenga et al., 2005; Yoshioka et al., 1999). The exact mechanism of action is not fully understood; however, CAPS has been shown to increase concentrations of the anorexigenic hormone glucagon-like peptide 1 and to decrease concentrations of the orexigenic hormone ghrelin (Smeets & Westerterp-Plantenga, 2009).

Furthermore, a study in rats using a diet containing CAPS has shown that CAPS causes an increase in catecholamine secretion from the adrenal medulla (Watanabe, Kawada, Yamamoto, & Iwai, 1987). This catecholamine secretion is caused by activation of the central nervous system (Watanabe, Kawada, Kurosawa, Sato, & Iwai, 1988). There is an association between sympathetic nervous system (SNS) activity and food intake behavior; food intake decreases when SNS activity increases (Russek et al., 1987). The increase in SNS activity after ingestion of CAPS suggests that the reduction in energy intake could be due to the anorexigenic effect of catecholamines (Yoshioka et al., 1999).

Yoshioka et al. (1999) found that the addition of red chili pepper to breakfast decreased the protein and fat intake at lunch time; these beneficial effects of CAPS on food consumption were observed when the meals had a high fat content (energy % protein/fat/carbohydrate: 15/45/40). It still is necessary to assess whether there is a beneficial effect when CAPS is added to meals with a normal protein, fat and carbohydrate content (energy % protein/fat/carbohydrate: 15/30/55). Furthermore, the study of Yoshioka et al. (1999) was conducted in Asians with relatively high doses of red chili pepper (10 g of red chili pepper per meal). There is a difference in maximum tolerable dose of red chili pepper between Japanese and Caucasians. This difference in tolerable dose is due to the difference in habitual red chili pepper consumption. In many Asian countries, red chili pepper is more common in the food pattern. For example, the average CAPS consumption in India is 25–200 mg/day while the average daily consumption in Europe is estimated to be 1.5 mg (Astrup et al., 2010). We investigated the effect of CAPS in Caucasians and with lower doses of red chili pepper (1.03 g of red pepper per meal). For weight-reduction strategies, it is necessary to investigate whether these effects of CAPS are still present during a moderate energy deficit. Since CAPS supplementation adds only negligible amounts of energy to food intake while it may enhance anorexigenic sensations and suppress orexigenic sensations, at least in energy balance, it is of importance to study whether these characteristics may be used as a concept for prevention of the yo-yo effect when entering negative energy balance. Yo-yo effect (or weight cycling) is the principle of repeated weight loss and regain (Brownell, Greenwood, Stellar, & Shrager, 1986). Normally, introduction of a negative energy balance by reducing energy intake causes an increase in appetite (Doucet et al., 2000). We assessed whether CAPS supplementation *versus* control during negative energy balance would counteract the normal increase in appetite. Taken together, we investigated whether there is an effect of CAPS on appetite profile and *ad libitum* energy intake in Caucasians when 1.03 g of red pepper is added to meals with a normal fat and normal protein content in a 25% negative energy balance.

Methods

Subjects

Nineteen healthy Caucasian subjects, aged between 18 and 50 years and a body mass index (BMI) between 20 and 30 kg/m^2 were recruited for this study. Subjects were recruited by advertisements in local newspapers and on notice boards at Maastricht University. All subjects underwent a medical screening, including anthropometric measurements, and questionnaires related to health, smoking behavior, use of medication, use of dietary supplements, alcohol and caffeine consumption, physical activity, habitual red chili pepper intake, eating behavior, mood and anxiety.

The inclusion criteria, besides an age between 18 and 50 years and a BMI between 20 and 30 kg/m^2, were good health, non-smoking, not using dietary supplement and medication except for oral contraceptives in women, not using a more than moderate amount of alcohol (less than 10 alcoholic drinks (10 g alcohol per drink) per week) or caffeine-containing beverages (less than 2 cups per day). Subjects had to be weight stable (weight change < 3 kg during the last 6 months) and dietary unrestrained. The Three Factor Eating Questionnaire was used to determine eating behavior (Stunkard & Messick, 1985). Only non-restrained eaters (<10 scores on factor 1), these are persons who are not consciously occupied with food or who are caloric restricted, were selected (Stunkard & Messick, 1985). Subjects had to be lightly or moderately active (1–5 hours moderate exercise per week) and used to consuming spicy foods on a regular basis (1–2 days per week, in a low dosage with one meal/day). In general, they consumed red chili pepper once per week (mean intake: 0.25–0.5 g of dried red pepper or 1–2 g of fresh red pepper). Pregnant or lactating women were also excluded. Individuals with allergies for the food items used in the study were excluded from participation.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by The Medical Ethics Committee of the Academic Hospital in Maastricht. The study was conducted in de metabolic unit of Maastricht University, department of Human Biology and was registered as follows: ISRCTN, registration number NTR2944.

Subject characteristics

Body weight was measured using a digital balance and height by a wall-mounted stadiometer. BMI was calculated as body weight (kg) divided by height (m) squared. The deuterium dilution method according to the Maastricht protocol (Lichtenbelt, Westerterp, & Wouters, 1994) was used to measure total body water (TBW). The subjects were asked to collect a urine sample in the evening just before drinking a deuterium-enriched water solution. After ingestion of this solution, the subject went to bed, and no additional consumption was allowed. The following morning, another urine sample was collected. The dilution of the deuterium isotope is a measure of the TBW of the subject. Fat mass (FM) was calculated as body weight minus TBW divided by the hydration factor 0.73. Additionally, fat mass was determined by BodPod measurements (air displacement plethysmography) (Plasqui, Soenen, Westerterp-Plantenga, & Westerterp, 2011). Fat mass index (FMI) was calculated by FM (kg) divided by height (m) squared. BMI, FM (%) and FMI were used to define body composition. Waist and hip circumference were determined in standing position by a tape measure. Waist circumference was measured at the smallest circumference between rib cage and iliac crest, and hip circumference at the level of the spina iliaca anterior superior. Accordingly, waist-to-hip ratio was calculated by dividing waist by hip circumference. Waist-to-hip ratio was used to define different patterns of body fat distribution (Table 1).

Study protocol

The study had a single-blinded, randomized crossover design with four randomly sequenced experimental conditions. Subjects underwent four 36 hour sessions in a respiration chamber (Janssens, Hursel, Martens, & Westerterp-Plantenga, 2013). Two days prior to each session, subjects were provided with a standardized diet to consume at home in order to be fed in energy balance (energy % protein/fat/carbohydrate: 15/30/55), and to receive the same macronutrient proportions as during the experiment. The energy intake level was estimated as such that subjects were not in a positive or a negative energy balance before they entered the respiration