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Changes in the sensation of hunger and well-being before and after meals in overweight/obese women following two types of hypoenergetic diet

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Abstract

Objective: To analyse changes in the sensation of hunger and the sensation of well-being of young overweight/obese women following two hypoenergetic diets.
Design, setting and subjects: Fifty-seven women (BMI = 24–35 kg/m^2) were randomly assigned to one of two hypoenergetic diets: diet V, in which the consumption of vegetables was increased; or diet C, in which the consumption of cereals (especially breakfast cereals) was increased. Dietetic and anthropometric data and an evaluation of the sensation of hunger and well-being were collected at the start and end of the study, 6 weeks later.
Results: The diets led to a reduction in weight and BMI in both groups. The sensation of hunger at the end of meals was higher at the end of the study than at the start in both groups. At 6 weeks, the sensation of well-being after breakfast, morning snack and lunch, as well as the mean sensation of well-being after all meals, was greater in diet C. Compared with that recorded at the beginning of the study, the capacity to experience satiety at the end of meals also increased with diet C, as did the capacity to experience well-being at 6 weeks (for breakfast, lunch, dinner and for the mean for all meals). This capacity to experience well-being was also greater in diet C than in diet V with respect to the mid-morning snack and lunch.
Conclusion: The more positive results obtained with diet C may contribute to the increased weight loss seen in that group and their lower withdrawal rate.

Keywords
Sensation of hunger
Sensation of well-being
Cereals
Vegetables
Dietary intervention
Women

Obesity is an important and growing public health problem[1]. Nevertheless, most weight-loss diets remain dissociated and unbalanced, and can harm nutritional status and health when followed for prolonged periods[2]. Moreover, these diets tend to fail because subjects experience hunger[3,4].

Hunger is increasingly recognized as having an important effect on body weight regulation, body composition, success in achieving short-term weight loss and the maintenance of long-term weight loss[5–8]. Any programme aimed at weight loss which achieves a reduction in hunger will have a higher probability of success[9].

There is a greater discrepancy between the recommended and real consumption levels of cereals and vegetables than for any other foods. A relative increase in their intake could facilitate an approximation to the theoretical dietary ideal and yet help achieve weight loss[2]. The aim of the present study was to analyse changes in the sensation of hunger and well-being in overweight women following hypoenergetic diets involving relative increases in the intake of vegetables or cereals.

Subjects and methods

Study subjects

The study subjects were fifty-seven women aged 20 to 35 years (mean 27·8 (SD 4·7) years); most were university students. They enrolled through a public offer to take part in a study on 'The assessment of nutritional status and improvement of weight control'. Enrolment was open to young women. The study was publicized using posters, radio announcements and via publications directed towards young female university students.

Initially, all interested parties were interviewed by telephone to ensure that they met the inclusion criteria, which were:

1. Female sex.
2. Age between 20 and 35 years.
3. BMI between 24 and 35 kg/m^2.
4. In the case of ex-smokers, not having quit in the previous two months.
5. To be free of all diseases that might interfere with the results, such as diabetes, hyperthyroidism or other

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metabolic disease, hypertriacylglycerolaemia, lactose or gluten intolerance (coeliac disease), food allergies, etc.
6. Not to be currently involved in a weight-loss programme.
7. Not to have lost more than 4·5 kg in the two months prior to the study.
8. Not to have lost or gained more than 3 kg between the first interview and the start of the study.
9. To have a regular menstrual cycle.
10. To take no more than two alcoholic drinks daily.
11. To be neither pregnant nor lactating.

Those interested in taking part, who declared themselves to meet all inclusion criteria, were invited to the Department of Nutrition at the University Complutense of Madrid. Here, their weights and heights were recorded, and questionnaires were completed to collect personal, health and dietary information. All persons who were confirmed as meeting the inclusion requirements were informed of the aim of the study, of the clinical tests they would undergo, and of the number and type of interviews and testing to which they would be subject. According to the requirements of the Ethics Committee of the Faculty of Pharmacy, all subjects signed a witnessed form of consent to be included.

The final number of subjects aspiring to take part was 193; 114 were excluded in the initial phases, two during the interview stage and ten finally decided not to take part in the study. Of the remainder, sixty-seven began the study and fifty-seven concluded the 6-week dietary intervention period; these fifty-seven made up the study population analysed.

Interventions

The diets were designed to provide a mean of approximately 20 % less than the theoretical energy requirements of the subjects. Theoretical energy expenditure was established by taking into account the body weight, age and physical activity of all subjects, using equations proposed by WHO[10]. Both diets were structured with the idea of approximating them to the theoretical ideal by increasing the relative consumption of either vegetables or cereals; earlier studies have shown that these foods are those with the greatest differences between their observed and recommended intakes[11,12].

The subjects were then randomly assigned to one of two dietary intervention groups.

1. Diet C: With this diet, the weight-control measures were based on restricting the consumption of energy-rich foods and increasing the consumption of cereals. Whole-grain breakfast cereals and cereal bars were particularly recommended (a minimum of 3 servings daily) since, apart from carbohydrate, they also provide fibre, vitamins and minerals. For breakfast subjects had to include 30 g cereal, and for dinner 40–60 g. They also had to include a cereal bar as a mid-morning snack. For their mid-afternoon snack they could eat a cereal bar or skimmed yoghurt or skimmed milk, although the cereal bar was recommended. In addition, the subjects were also advised to eat other cereals. At lunch time they had to eat 30–40 g bread and rice or pasta as an accompaniment.
2. Diet V: With this diet, the weight-control measures were based on restricting the consumption of energy-rich foods and increasing the intake of greens and vegetables (minimum of 3 servings daily). Subjects had to eat a salad at lunch and at dinner as well as vegetables as the main course of one of these meals.

The full characteristics of the diets followed and other methodological details are described elsewhere[13].

Compliance with dietary rules

Over the intervention period (a total of 6 weeks), the subjects attended a weekly appointment to record anthropometric data and to discuss (and solve) any difficulties in following the diet assigned.

Methods

The following data were collected from all subjects during the pre-intervention stage and again at week 6.

Physical activity

The subjects completed a questionnaire on their normal physical activity; this information was used to calculate their energy expenditure[14]. Subjects indicated the length of time spent sleeping, eating, playing sport, etc. during both working days and weekends. An activity coefficient was established for each subject[14].

Anthropometric information

Weight and height were determined using a Seca Alpha digital electronic balance (range 0·1–150 kg) and a Harpenden digital stadiometer (range 70–205 cm), respectively. For both measurements, subjects were barefoot and wore only underwear. All data were collected at the Department of Nutrition by trained personnel following norms set out by the WHO[15]. BMI was calculated as weight (kg)/[height (m)]^2.

Health variables

Information was collected on any disease problems, the use of medications and supplements and the consumption of manufactured diet foods.

Dietetic study

A 'food and drink record' was used to register all intakes (both at home and away) for 3 d, including Sunday[16]. Subjects were instructed to record the weights consumed if possible and specify household measurements (spoonfuls, cups, etc.) if not. The aim was to obtain the maximum accuracy possible; the women were encouraged

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Table 1 Dietetic and anthropometric data at the beginning and end of the intervention: young overweight/obese Spanish women following two types of hypoenergetic diet

	Pre-intervention data				Results at 6 weeks				ANOVA
	Diet V (n 28)		Diet C (n 29)		Diet V (n 28)		Diet C (n 29)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Energy (MJ/d)	8·75	2·42	10·05†	2·12	6·64**	1·14	6·73***	117	p ($F_{1,55}$ = 71·46; P < 0·0001)
Energy (kcal/d)	2092	578	2401†	507	1586**	273	1608***	280	
Under-reporting (%)	12·4	24·9	0·5	26·4	32·8**	14·5	32·7***	14·2	p ($F_{1,55}$ = 52·03; P < 0·0001); i ($F_{1,55}$ = 4·08; P = 0·0483)
Consumption of food groups (servings/d)									
Cereals	3·9	1·5	4·1	1·5	3·8	1·3	4·9*††	1·1	d ($F_{1,55}$ = 5·15; P = 0·0271); i ($F_{1,55}$ = 4·72; P = 0·0342)
Pastries	0·6	0·5	0·9	0·7	0·3*	0·5	0·1***	0·2	p ($F_{1,55}$ = 34·06; P < 0·0001); i ($F_{1,55}$ = 6·06; P = 0·0170)
Vegetables and greens	2·8	1·2	3·1	1·3	4·8***	1·5	3·5††	1·2	p ($F_{1,55}$ = 36·36; P < 0·0001); i ($F_{1,55}$ = 15·40; P = 0·0002)
Fruits	1·0	0·7	1·3	1·0	3·7***	1·7	3·5***	1·1	p ($F_{1,55}$ = 142·89; P < 0·0001)
Milk products	1·8	1·0	2·1	0·7	1·9	0·8	1·9	0·7	NS
Meat, fish and eggs	3·7	1·7	4·0	1·6	2·3**	1·1	2·5***	1·0	p ($F_{1,55}$ = 38·57; P < 0·0001)
Anthropometric data									
Weight (kg)	72·2	7·2	76·8	10·6	70·1***	7·3	74·0***	10·9	p ($F_{1,55}$ = 190·76; P < 0·0001); i ($F_{1,55}$ = 5·01; P = 0·0292)
BMI (kg/m²)	27·6	2·5	28·3	3·4	26·8***	2·6	27·3***	3·6	p ($F_{1,55}$ = 194·43; P < 0·0001); i ($F_{1,55}$ = 4·37; P = 0·0411)

Diet V, increased consumption of vegetables; diet C, increased consumption of breakfast cereals; d, diet; p, period; i, interaction.
Mean values were significantly different from those of the pre-intervention group: *P < 0·05, **P < 0·01, ***P < 0·001.
Mean values were significantly different from those of the diet V group: †P < 0·05, ††P < 0·01, †††P < 0·001.

to complete the record truthfully even when they failed to keep to their diet.

The energy content of these foods was then calculated using food composition tables[17]. The DIAL software package was used to process all data[18].

For each subject, energy needs (theoretical energy expenditure, TEE) were established by using equations proposed by WHO[10] for the calculation of BMR and multiplying the answer by the corresponding activity coefficient[10]. As a measure of the discrepancy between energy intake and expenditure, the following was calculated: (TEE − estimated intake) × 100/TEE.

For the pre-intervention phase of the study, during which the subjects maintained a stable weight, the discrepancy between TEE and the theoretical intake provided a measure of the possible underestimation of energy intake. Once the intervention phase had begun, a positive discrepancy was expected (expenditure always greater than intake); the larger the difference, the greater the chance of losing weight.

Subjective evaluation of degree of well-being and hunger

The degree of well-being and hunger at various times during the day (before and after breakfast, before and after lunch, before and after dinner, and before and after snacks) was measured using a 0 to 10 cm visual analogue scale (the divisions of which the subjects were not allowed to see). Mean hunger and well-being (before and after meals) were calculated taking into account the mean initial feeling of hunger ($\sum$ initial feeling/number of meals) and the mean final feeling of hunger ($\sum$ final feeling/number of meals). The satiety quotient (SQ) for each meal and the mean SQ were also calculated. The SQ represents a good marker of an individual's satiety signal capacity in response to a meal. This variable was calculated for each meal using the equation of Drapeau *et al.*[19]:

$$SQ = \frac{(\text{fasting SH} - \text{post-meal SH})}{\text{energy consumed at a meal}},$$

where SH is the sensation of hunger. All SQ values were multiplied by 100 to obtain a more meaningful range.

The well-being quotient (WQ) was also calculated, the higher the WQ the higher the well-being signal capacity conditioned by a specific meal (or by all meals taken together), as follows:

$$WQ = \frac{(\text{post-meal SW} - \text{fasting SW})}{\text{energy content of a meal}},$$

where SW is the sensation of well-being.

Statistical analysis

Means and standard deviations were calculated for all variables. Two-way repeated-measures ANOVA was used to analyse the change in the measured variables over time in each diet group. The comparison of group C and group V results, and the comparison of the initial and final

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values for the measured variables in each group, was undertaken using the Student *t* test (or the Mann–Whitney test if the distribution of results was not homogeneous). Pearson linear correlation coefficients were also calculated. All calculations were made using the SAS for Windows statistical software package (SAS Institute, Cary, NC, USA). Significance was set at $P < 0{\cdot}05$.

Results

No differences were found for age (mean 27·0 (SD 4·3) years *v.* 28·6 (SD 5·0) years) or BMI (Table 1) between groups (C and V) at the beginning of the study.

Good compliance with the diets was achieved. The diet C women increased their intake of cereals and the diet V women increased their intake of vegetables. Both also increased their intake of fruits and reduced their intake of pastries and meat+fish+eggs (Table 1). Energy from carbohydrates at the end of the study was higher in diet C than in diet V (50·7 (SD 5·4) % *v.* 46·6 (SD 8·0) % respectively, $P < 0{\cdot}05$). As a consequence of the intervention, energy intake, weight and BMI decreased both in diet C women and diet V women (Table 1).

No differences were seen between the two groups in terms of the sensation of hunger or well-being at the start of the study (Tables 2 and 3), with the exception of hunger before breakfast, which was greater in diet C than in diet V subjects (both at the start and the end of the study). Nevertheless, the mean sensation of hunger after meals was greater both in diet C women and diet V women after 6 weeks of intervention compared with that at the beginning (Table 2).

When analysing the sensations of hunger and well-being declared by the subjects (i.e. all the women together) before the intervention (Tables 2 and 3), the maximum feeling of hunger appeared before lunch, with a significant difference with respect to breakfast ($P < 0{\cdot}01$) and dinner ($P < 0{\cdot}05$). The sensation of well-being was lowest before breakfast, with a significant difference compared with that experienced before lunch ($P < 0{\cdot}01$) and dinner ($P < 0{\cdot}05$).

At 6 weeks, the sensation of well-being after breakfast, after the morning snack and after lunch, as well as the mean sensation of well-being (after all meals as a whole), was greater in diet C than in diet V subjects (Table 3).

Higher BMI was positively correlated with higher hunger sensation at lunch ($r = 0{\cdot}3120$; $P < 0{\cdot}05$) and after the afternoon snack ($r = 0{\cdot}4665$; $P < 0{\cdot}05$). It was also found that higher waist:hip ratio at the start of the study was positively associated with greater total initial hunger (mean of all initial hungers; $r = 0{\cdot}4114$; $P < 0{\cdot}01$), mean hunger ($r = 0{\cdot}3085$; $P < 0{\cdot}05$), pre-evening snack hunger ($r = 0{\cdot}4478$; $P < 0{\cdot}05$) and pre-dinner hunger ($r = 0{\cdot}2819$; $P < 0{\cdot}05$), compared with lower waist:hip ratio.

At the same time, thinner women (BMI < P50 (50th percentile); 27·3 kg/m^2) declared a greater sensation of well-being before dinner (6·0 (SD 2·3) cm) than those with BMI ≥ P50 (4·7 (SD 2·2) cm) ($P < 0{\cdot}05$). Though their feeling of well-being increased after dinner, this increase was less than in heavier women (1·2 (SD 2·4) cm *v.* 2·4 (SD 2·5) cm).

It was also observed that women who declared a greater pre-dinner sensation of well-being were those who experienced least hunger at that moment ($r = -0{\cdot}4383$; $P < 0{\cdot}001$). Those who experienced hunger < P25 (4·3 cm) at the start of dinner consumed less

Table 2 Differences in initial and final sensation of hunger depending on the time and type of intervention: young overweight/obese Spanish women following two types of hypoenergetic diet

	Pre-intervention data				Results at 6 weeks				
	Diet V (*n* 28)		Diet C (*n* 29)		Diet V (*n* 28)		Diet C (*n* 29)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	ANOVA
Initial hunger (cm)									
Breakfast	4·5	3·0	6·5††	2·4	5·5	2·5	6·9†	2·1	d ($F_{1,52} = 10{\cdot}67$; $P = 0{\cdot}0019$)
Mid-morning snack	6·9	2·1	6·2	1·8	5·7	2·5	5.4	2·3	NS
Lunch	7·6	2·1	6·7	2·5	6·7	1·9	7·5	2·6	i ($F_{1,54} = 4{\cdot}82$; $P = 0{\cdot}0331$)
Mid-afternoon snack	6·2	2·6	5·7	3·1	5·2	2·1	5·0	2·2	NS
Dinner	6·2	1·8	6·1	2·9	6·4	2·1	6·7	2·4	NS
Mean	6·2	1·4	6·3	1·3	5·9	1·5	6·4	1·2	NS
Final hunger (cm)									
Breakfast	1·7	1·3	1·4	1·1	2·0	1·4	2·1**	1·2	p ($F_{1,52} = 6{\cdot}04$; $P = 0{\cdot}0176$)
Mid-morning snack	2·3	1·9	3·2	2·7	3·2*	1·9	2·1†	1·3	NS
Lunch	1·2	1·2	1·5	1·8	2·0	1·5	1·6	1·6	NS
Mid-afternoon snack	3·4	1·8	2·6	2·2	3·4	2·0	2·7	2·2	NS
Dinner	1·4	1·4	1·4	1·6	2·5	1·7	2·1	1·9	p ($F_{1,52} = 7{\cdot}75$; $P = 0{\cdot}0076$)
Mean	1·6	1·0	1·7	1·3	2·5**	1·1	2·1*	0·9	p ($F_{1,54} = 13{\cdot}12$; $P = 0{\cdot}0007$)
Mean hunger (cm)	3·9	0·9	4·0	1·1	4·2	1·0	4·2	0·9	NS

Diet V, increased consumption of vegetables; diet C, increased consumption of breakfast cereals; d, diet; p, period; i, interaction.
Mean values were significantly different from those of the pre-intervention group: *$P < 0{\cdot}05$, **$P < 0{\cdot}01$, ***$P < 0{\cdot}001$.
Mean values were significantly different from those of the diet V group: †$P < 0{\cdot}05$, ††$P < 0{\cdot}01$, †††$P < 0{\cdot}001$.

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Table 3 Differences in initial and final sensation of well-being depending on the time and type of intervention: young overweight/obese Spanish women following two types of hypoenergetic diet

	Pre-intervention data				Results at 6 weeks				
	Diet V (*n* 28)		Diet C (*n* 29)		Diet V (*n* 28)		Diet C (*n* 29)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	ANOVA
Initial well-being (cm)									
Breakfast	3·7	2·0	4·5	2·4	4·0	2·2	4·1	2·3	NS
Mid-morning snack	4·7	2·0	4·5	2·7	5·0	2·2	5·1	2·3	NS
Lunch	4·6	2·1	5·3	2·4	4·8	2·1	4·3	2·3	NS
Mid-afternoon snack	4·9	2·0	5·1	2·8	5·4	1·8	5·6	2·1	NS
Dinner	5.6	1·8	5·2	2·7	4·8	2·4	5·0	2·3	NS
Mean	4·5	1·5	5·0	1·6	4·7	1·7	4·7	1·7	NS
Final well-being (cm)									
Breakfast	6·3	1·8	7·1	1·8	6·5	1·8	7·5†	1·3	d ($F_{1,52} = 5·89$; $P = 0·0188$)
Mid-morning snack	7·1	1·2	6·7	2·4	6·3	1·5	7·5†	1·2	NS
Lunch	7·0	1·8	7·4	1·6	6·6	1·8	7·9††	1·4	d ($F_{1,54} = 4·83$; $P = 0·0323$)
Mid-afternoon snack	6·5	1·3	7·3	1·7	6·5	1·7	7·0	1·3	NS
Dinner	7·3	1·5	7·0	1·6	6·5	2·2	7·2	1·6	NS
Mean	6·8	1·3	7·1	1·4	6·5	1·5	7·3†	1·0	d ($F_{1,54} = 4·56$; $P = 0·0373$)
Mean well-being (cm)	5·6	1·0	6·1	1·3	5·6	1·3	6·0	1·1	NS

Diet V, increased consumption of vegetables; diet C, increased consumption of breakfast cereals; d, diet; p, period; i, interaction.
Mean values were significantly different from those of the pre-intervention group: *$P < 0·05$, **$P < 0·01$, ***$P < 0·001$.
Mean values were significantly different from those of the diet V group: †$P < 0·05$, ††$P < 0·01$, †††$P < 0·001$.

Table 4 Satiety quotient (SQ) and well-being quotient (WQ) for every meal, plus mean values for the entire study period: young overweight/obese Spanish women following two types of hypoenergetic diet

	Pre-intervention data				Results at 6 weeks				
	Diet V (*n* 28)		Diet C (*n* 29)		Diet V (*n* 28)		Diet C (*n* 29)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	ANOVA
SQ (cm/kcal)									
Breakfast	0·9	1·1	1·4	0·9	1·3	1·0	1·8	0·9	d ($F_{1,52} = 4·73$; $P = 0·0342$); p ($F_{1,52} = 7·05$; $P = 0·0107$)
Mid-morning snack	5·6	4·5	3·2	2·7	2·2	2·4	2.9	2·1	NS
Lunch	0·8	0·4	0·6†	0·3	0·7	0·4	0·9**	0·5	i ($F_{1,54} = 4·58$; $P = 0·0374$)
Mid-afternoon snack	7·4	18·9	2·9	2·8	1·9	2·3	2·6	2·5	NS
Dinner	1·0	0·8	0·7	0·4	1·0	0·7	1·4**	1·0	p ($F_{1,54} = 7·05$; $P = 0·0106$)
Mean	0·2	0·1	0·2	0·1	0·2	0·1	0·3**†	0·1	p ($F_{1,54} = 4·23$; $P = 0·0447$); i ($F_{1,54} = 8·19$; $P = 0·0060$)
WQ (cm/kcal)									
Breakfast	0·9	0·9	0·7	0·6	1·0	1·0	1·3*	1·2	p ($F_{1,52} = 4·68$; $P = 0·0356$)
Mid-morning snack	2·2	2·2	2·6	5·0	1·0	1·5	2·1†	1·8	NS
Lunch	0·3	0·3	0·2	0·3	0·3	0·3	0·5*†	0·5	p ($F_{1,54} = 4·98$; $P = 0·0310$)
Mid-afternoon snack	35·7	110·6	1·5	2·1	1·3	2·0	1·6	2·3	NS
Dinner	0·3	0·4	0·3	0·4	0·5	0·8	0·7**	0·8	p ($F_{1,54} = 7·87$; $P = 0·0072$)
Mean	0·1	0·1	0·1	0·1	0·1	0·1	0·2**	0·1	p ($F_{1,54} = 5·69$; $P = 0·0209$); i ($F_{1,54} = 8·38$; $P = 0·0056$)

Diet V, increased consumption of vegetables; diet C, increased consumption of breakfast cereals; d, diet; p, period; i, interaction.
Mean values were significantly different from those of the pre-intervention group: *$P < 0·05$, **$P < 0·01$, ***$P < 0·001$.
Mean values were significantly different from those of the diet V group: †$P < 0·05$, ††$P < 0·01$, †††$P < 0·001$.

energy at this meal (2·53 (SD 0·73) MJ, 604 (SD 175) kcal) than those who started this meal with hunger >P75 (7·8 cm; these subjects consumed 3·27 (SD 1·05) MJ, 781 (SD 250) kcal; $P < 0·05$). In general, hunger waned more during dinner since more energy was consumed ($r = -0·2860$; $P < 0·05$), but the more hunger was decreased, the less weight loss was achieved ($r = 0·2666$; $P < 0·05$).

SQ at lunch at the start of the study was smaller in diet C women than in diet V women, but this difference disappeared by week 6. This capacity increased during the course of diet C. By the end of the study it increased with lunch and dinner, as did the mean SQ (for all meals taken as a whole) (Table 4). Further, the mean SQ was greater in diet C women than in diet V women at the end of the study.

No differences were seen in WQ between diet C and diet V women at the start of the study, but after 6 weeks of dietary intervention the capacity to experience well-being with breakfast, lunch and dinner (as well as the mean WQ for all meals) increased in diet C women; this capacity was also greater in diet C women compared with diet V women with respect to the morning snack and lunch (Table 4).

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Discussion

Both dietary interventions allowed an approximation of the diet to the theoretical ideal and led to food intakes similar to those recommended. A reduction in body weight (Table 1), an improved energy profile and a better nutritional status were also obtained with both diets[13,20,21].

The women with higher BMI were hungrier at the different meal times, and women with higher waist:hip ratio at the start of the study experienced stronger initial hunger at certain meal times compared with those having lower waist:hip ratio. These results agree with those of Ronti *et al.*[22], who indicated that the increase in the production of certain 'adipokines' (bioactive peptides secreted by adipose tissue) in obesity leads to an increased sensation of hunger.

In the present work, the perception of well-being and hunger was different in women with different BMI; those with higher BMI experienced a greater improvement in their perception of well-being associated with food consumption in the later hours of the day. These sensations might be associated with energy intake and, as a consequence, might influence the regulation of weight[23].

Coinciding with the results for dinner, the women with a sensation of well-being >P50 (7·0 cm) after breakfast or >P50 (7·4 cm) after lunch had higher energy intakes at these meals compared with women whose sensation of well-being after these meals was lower (breakfast: 1·67 MJ (398 kcal) *v.* 1·39 MJ (332 kcal) respectively, lunch: 3·84 MJ (960 kcal) *v.* 3·35 MJ (800 kcal) respectively).

An increase in the sensation of hunger and the desire to eat after losing weight are common[24]. In the present study an increase was recorded in mean post-meal hunger, both for diet C women and diet V women (Table 2). However, although the women following diet C lost more weight, their sensation of hunger was no stronger (Table 2).

The increase in hunger associated with following weight-loss diets is responsible for the high withdrawal rate seen[3,4]. In the present study, only 14·9% of women abandoned (6·5% on diet C and 22·2% on diet V). They dropped out because they found the diets difficult to keep to. The smaller percentage of withdrawals in group C could be due to the fact that these women experienced no more hunger than women on diet V, yet showed a greater sensation of well-being after meals (Table 3). Other authors[25–28] have indicated that diets rich in cereals are very useful in weight-loss programmes due to their capacity to suppress hunger and subsequent energy intake.

After 6 weeks on diet C, the higher the mean SQ value (i.e. the sooner the satiety signal was reached), the lower the energy intake of the total diet ($r = -0{\cdot}4259$; $P < 0{\cdot}05$).

The greater the weight loss achieved, the greater the total well-being and the mean well-being registered after meals at the end of the study ($r = -0{\cdot}3601$; $P < 0{\cdot}01$ and $r = -0{\cdot}2859$; $P < 0{\cdot}05$ respectively). Well-being may condition the likelihood of keeping to a hypoenergetic diet; however, it could also be that as weight is lost the sensation of well-being is amplified.

It is common for weight-loss diets to cause depression, anxiety, nervousness and irritability[29,30]. Nevertheless, some authors suggest that weight loss induces an increase in well-being and vitality[31,32]; certainly, the well-being of women who followed diet C increased at the end of the study – a further advantage over diet V. Moreover, only group C subjects saw their mean WQ improve (as did those for breakfast, lunch and dinner). The WQ for the mid-morning snack and lunch at week 6 was also higher than in diet V subjects (Table 4). This agrees with the results of other investigations in which it was observed that people who consumed large amounts of carbohydrates experienced fewer episodes of anxiety and depression[33,34]. These macronutrients increase the rate at which tryptophan enters the brain, leading to an increase in serotonin levels (which modulates mood)[35].

The mean and for some meals sensation of well-being at the end of the study was higher among diet C women, and only this diet improved satiety and well-being capacity for some meals and for the mean of all meals. These more positive results may contribute to the increased weight loss seen among the diet C subjects and their lower withdrawal rate. Quantifying the perception of hunger or well-being requires further study; a better understanding of these phenomena might help explain the success or failure of many weight-control programmes.

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