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Does a high-protein diet improve weight loss in overweight and obese children?

Paul J Gately,[1] Neil A King,[2, 3] Hannah C Greatwood,[1] Lauren C Humphrey,[1] Duncan Radley,[1] Carlton B Cooke,[1] and Andrew J Hill.[4]

Author affiliations

[1]School of Sport, Exercise and Physical Education, Leeds Metropolitan University, Fairfax Hall, Headingley Campus, Leeds, LS6 3QS, UK.

[2]Institute of Psychological Sciences, University of Leeds, UK.

[3]Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Australia.

[4]Academic Unit of Psychiatry and Behavioural Sciences, Leeds University School of Medicine, UK.

Corresponding author and reprints

Paul J Gately

School of Sport, Exercise and Physical Education, Leeds Metropolitan University, Fairfax Hall, Headingley Campus, Leeds, LS6 3QS, UK.

Tel. +44 113 283 2600 ext. 3579. Fax. +44 113 283 7575

Email: p.gately@leedsmet.ac.uk.

Running title

High-protein diet, appetite and weight-loss.

Abstract

Objective: To evaluate the effect of a high-protein diet on anthropometry, body composition, subjective appetite and mood sensations in overweight and obese children attending a residential weight-loss camp.

Research Methods and Procedures: 120 overweight and obese children (BMI 33.1±5.5 $kg.m^{-2}$; age 14.2±1.9 years) were randomly assigned to either a standard or high-protein diet group (15% vs 22.5% protein respectively). All children engaged in 5 hours/d of physical activity and 5 educational classes per week for 2-6 weeks. All children were assessed at baseline and at the end of the camp for anthropometry, body composition and blood pressure. Subsamples were used to obtain data on biochemical variables (n=27) and subjective appetite and mood sensations (n=50).

Results: Attendance at the weight-loss camp resulted in significant improvements in most measures. Campers lost 5.5±2.9 kg in body weight (p<0.001), 3.8±5.4 kg in fat mass (p<0.001), reduced their BMI sd score by 0.27±0.1 (p<0.001) and their waist circumference by 6.6±2.8 cm (p<0.001). Subjective sensations of hunger increased significantly over the camp duration but no other changes in appetite or mood were observed. There were no significant differences between the two diets on any physical or subjective measures.

Discussion: Weight-loss camps are effective in assisting children to lose weight and improve on a range of health outcomes, independent of the protein content of the diet. The implications of an increase in hunger associated with weight loss needs to be considered. Further work is warranted into whether higher levels of dietary protein are feasible or effective in longer-term weight-loss interventions of this type.

Key words: Obesity, residential camp, hunger, satiety.

Introduction

Like adult obesity, childhood obesity prevalence is rising (1), making it imperative that treatment programmes are developed and supported. As these children move into adulthood this will lead to an associated increase in physical and psychological morbidity (2). It is vital to treat obesity in childhood, as lifestyle behaviours that contribute to and sustain obesity in adults are less well established in children and may be more amendable to change (3).

Short-term weight loss in paediatric patients has previously been achieved in trials involving various methods for the control of both diet and activity level. These include energy and fat reduction (4), adherence to a low-carbohydrate diet (5), participation in structured, vigorous physical activity (6) and a reduction in sedentary behaviour (7). However, one of the consequences of achieving a dietary-induced negative energy balance is an increase in hunger, at least in adults. There are many examples of energy restriction giving rise to hunger and increased food intake (8-10). It is also reported that combining an acute increase in exercise-induced energy expenditure with energy restriction fails to kerb the increase in hunger and food intake (11). Finding ways of preventing the automatic increase in hunger in response to a dietary-induced negative energy balance may improve adherence to weight loss programmes.

One approach might be to increase the proportion of dietary protein consumed. Weigle et al. (12) suggest that there are two mechanisms by which increased dietary protein impedes an increase in the drive to eat usually experienced during negative energy balance. The first is the capacity of dietary protein to increase energy expenditure, partly due to greater diet-induced thermogenesis after protein consumption than after consumption of equal calorific loads of carbohydrate or fat (13). The second is the greater satiating power of protein compared with the other macronutrients (14-16). Weigle et al. (12) demonstrated that an increase in protein intake from 15% to 30% of energy, at a constant carbohydrate intake of 50% of energy, resulted in subjects reporting a clear decrease in hunger and increase in fullness. This effect has been demonstrated in short-term feeding studies (17), in long-term studies with imposed caloric restrictions (18, 19), and in spontaneous energy intake where participants consuming more dietary protein consumed less energy in subsequent meals (20).

An additional body of evidence has shown that the substitution of dietary carbohydrate with protein in low-fat diets (<30%) enhances weight loss and has several beneficial effects on body composition and cardiovascular risk (19, 21, 22). Furthermore, a high-protein diet has been shown to be prevent weight regain (18). These authors found that increasing protein from 15% to just 18% of energy intake significantly improved weight maintenance over a period of 3 months, although this may not be extended up to 12 months (23). In summary, high-protein acute and longer term diet manipulations are associated with greater satiety and improved weight loss in adults. Very little is known about how obese children respond to a high-protein, energy controlled diet and whether it is associated with similar weight loss and satiety-enhancing properties.

We have recently reported the short-term benefits to overweight and obese children attending a residential weight-loss camp (24). Over a period of 4 weeks these children lost an average of 6.0kg, reduced their BMI by 2.4 $kg.m^{-2}$ and BMI sds by 0.28. However, we have also observed a significant increase in hunger and a decrease in fullness over the course of the camp programme (25).

The residential weight-loss camp provides an opportunity to achieve good control over variables that affect energy balance over a medium term period, whilst maintaining free living conditions. Although the camp focus is on participation in a variety of physical activities, children's food intake is carefully controlled. As such, it is possible to alter the nutrient profile of the food offered and increase the protein content of the diet. The aim of the present study therefore was to compare the effect of a higher protein diet (22.5% of total energy intake) with a standard protein diet (15% protein) on weight loss and hunger and satiety in a controlled environment. It was hypothesized that children consuming the higher protein diet would experience greater weight loss and improved satiety compared with children consuming the standard diet.

Research Methods and Procedures

Subjects and study design

Subjects were 120 children attending the Carnegie International Camp, a residential weight-loss camp for overweight and obese children in Leeds, England in 2004. Of these, 22 children were excluded prior to randomisation (exclusion criteria included learning disability and taking prescribed medication). There were 38 boys (mean age 14.0 ± 1.4 years) and 60 girls (14.4 ± 2.1 years) with an overall BMI of 33.1 ± 5.5 $kg.m^{-2}$ (range 23.1 to 52.6 $kg.m^{-2}$). Basal metabolic rate (BMR) for the sample was determined from equations devised by Schofield (26). Children were assigned to one of four food energy groups (1300, 1800, 2300 or 2800 $kcal.day^{-1}$) based on their BMR. Participants were randomised using a stratified block procedure (energy group, age, and duration of stay) into one of the two diet groups (protein or standard) for the duration of their stay. The duration of residence at the camp varied between 2 to 6 weeks (mean 29 days). Ten children withdrew from the study before the end for reasons including homesickness, illness, injury and family holidays. Due to incomplete data, 29 boys and 51 girls (mean age 14.3 ± 2.0 years) were included in the analysis.

Children (aged 11 to 17 years) were accepted on to the program contingent on having a BMI above the cut-off for overweight (27) and following a health screen by their family physician.

Sixty-two children who had enrolled for a minimum of four weeks volunteered to participate in the subjective appetite, mood and taste sensations part of the study. This involved completing subjective ratings periodically during a day at baseline and four weeks later. Children were trained how to complete subjective sensations. There were incomplete appetite data for 12 children. Four had a fault with the electronic recording device, 3 did not complete the recordings correctly and 5 left early (as reported above).

The study was granted Ethical Approval by the Leeds Metropolitan University Ethics Committee. All children and parents gave written consent to participate in the study.

The dietary programme

The standard camp diet was 15% protein, 30% fat, 55% carbohydrate and followed the food choice principles in the balance of good health (28). The high-protein study diet comprised 22.5% protein, 30% fat and 47.5% carbohydrate. The composition of the diets were designed by a Registered Dietitian. All meals were served by staff guided by the Dietitian. Table 1 shows a sample menu for each dietary group. The aim of the dietary intervention was to provide sufficient daily energy to meet the individual requirements of each child based on their BMR, such that they could fully engage in all parts of the camp programme. Children were not informed which energy group they were in or which diet they had been allocated to. Children were observed during all meals to ensure they did not abstain from eating and that they did not consume food other than that allocated to them.

- Table 1 near here –

Programme and procedure

All children who attended the camp were residents in boarding school premises that provided catering, residential, educational and high quality indoor and outdoor sports facilities. All staff were housed on site throughout the summer period. The program aim was to provide a safe, supportive environment where children could reduce their body mass whilst having fun. In addition, a child centered approach was used that focused on providing children with positive experiences and appropriate strategies which they could continue when returning home.

Children were divided by age and sex into four groups for all aspects of the camp program (9-14 and 15-18 year olds, girls and boys). The daily schedule of physical activity combined a range of structured fun-type, skill-based activities consisting of six 1-hour sessions each day: one aerobic (e.g. dance or aerobics), one water-based (e.g. canoeing or swimming), two camper-choice sessions, and 2 games-based sessions (e.g. netball or rugby). The aims of the physical activity sessions were to develop skills and competence in a range of activities with enjoyment and choice being fundamental components of this educational process. All activities were led by physical education teachers and qualified sports coaches.

Children also took part in four educational sessions per week, conducted by the education team at the camp. These covered issues such as changing food choices, maintaining behaviour change and addressing bullying.

Body weight and composition

Body weight and stature were measured using standard apparatus and BMIs ($kg.m^{-2}$) calculated for each participant. BMI standard deviation scores (sds) were calculated using the 1996 revision of the Child Growth Foundation's growth reference programme (29). Percentage body fat was assessed using air-displacement plethysmography (Life Measurement Inc, Concord, CA) (30). Fat mass (FM) and fat free mass (FFM) were derived from this assessment. This method is accurate, quick to use, non-invasive, and has been shown to be valid in this population (31). Waist circumference was assessed based on principles recommended by Lohman et al (32).

Blood pressure was measured using a mercury sphygmomanometer with diastolic pressure recorded at the 5th phase of Korotkoff sounds.

Biochemistry

A sub-sample of 33 children (standard diet n=17, high-protein diet n=16) provided blood samples. Fasting blood samples were drawn into fluoride oxalate, serum separator and ethylene diamine tetra acetic acid (EDTA) BD Vacutainer™ tubes by venepuncture. Appropriately qualified personnel undertook this procedure. The samples were then transported to the Department of Chemical Pathology at Leeds General Infirmary. Data reported below include total cholesterol, HDL, triglyceride and LDL.

Subjective appetite and mood

The Electronic Appetite Rating System (EARS) is an electronic method of measuring subjective appetite in the free-living and laboratory using visual analogue scales (33). The use of electronic VAS recording has been validated and is well established (34, 35). The EARS has been used to monitor subjective states in laboratory based appetite studies (36) and in clinical studies using renal patients (37, 38). The method uses a hand held Psion organiser (Psion Plc, London, UK) to administer the VAS. The EARS automatically quantifies and time stamps each subjective rating completed. Each child completed their rating of the following states on 100mm scales ranging from 'Not at all' to 'Extremely': hunger, fullness, irritability, mental alertness, contentedness, tiredness and meal palatability (end of meal only). The ratings were made immediately before and after each of the three fixed meals (breakfast, lunch and dinner) and 2hr after each meal. Therefore, participants made ratings at 9 time points across the day. These data are expressed as diurnal ratings to demonstrate the temporal changes and as an area under the curve (AUC) to provide a single day average for the whole day.

Procedure

Body weight was recorded at the start of camp and weekly thereafter. Height, body composition, blood pressure, blood lipids and appetite and mood variables were recorded prior to breakfast on the first and last days of each child's stay. All assessments were made by the same personnel and children wore bathing suits for measurements.

Statistical analysis

Data are reported as mean (±SD) and statistical analysis were performed by using SPSS for WINDOWS software (version 12; SPSS Inc, Chicago, IL). Diet groups were compared on all outcome measures at the start of the study. Analysis of variance, with main effects of time and diet and group x time interaction were used with the main outcome measures. Paired t-tests compared differences between means as a post-hoc test. During preliminary analysis girls and boys' responses were compared. There were no main effects of sex and girls and boys data are not reported separately. Significance was set at $p \leq 0.05$.

Results

Anthropometric and biochemical outcomes

Overall, children had a BMI sds of 3.0 and 42% of their body weight was fat. There was a significant main effect of time on all of the outcome measures apart from height (p< 0.05). However, there was no main effect of diet group or any time by diet group interaction ($p > 0.05$). Combining all children from both diet groups, there was a significant weight loss (5.3±2.8kg; $p < 0.001$), reductions in BMI sds (0.27±0.1; $p < 0.001$), % body fat (2.0±6.3%; $p < 0.001$), fat mass (3.8±5.4kg; $p < 0.001$), fat free mass (1.5±5.3kg; $p < 0.05$) waist circumference (6.2±2.6cm; $p < 0.001$) and blood pressure (systolic 5.4±8.2mmHg; $p < 0.001$, diastolic 5.7±8.6mmHg; $p < 0.001$; Table 2) and improvement in all blood lipid measures ($p < 0.01$). It should be noted, however, although not significant, there is a four-fold difference of fat free mass loss between the standard and protein diet groups (2.4kg and 0.6kg respectively).

- Table 2 near here –

Subjective hunger and mood

Children who completed ratings of hunger and mood did not differ from the rest of the sample in weight or body composition at baseline. ANOVA showed a significant increase in AUC hunger at the end compared with the start of the camp in both diet groups ($p < 0.001$; Table 3). However, neither fullness nor any of the mood ratings differed significantly over the course of the camp ($p > 0.05$). There was no main effect of diet group, or group by time interaction on the subjective sensations ($p > 0.05$).

- Table 3 near here –

Figure 1 represents the diurnal profile of subjective hunger across the day at the start and end of camp for the two diet groups pooled. Children rated hunger at the end of camp significantly higher at breakfast, mid-morning and after lunch ($p < 0.05$). There were no differences observed from dinner time into the evening.

- Figure 1 near here -

There was no significant time by diet interaction in palatability of the two diets indicated by the perceived tastiness ratings ($p = 0.33$) (55.7±18.5 start camp, 61.2±14.8 end camp; 55.7 ±18.5 start camp, 58.6±14.8 end camp for standard and high-protein diet respectively). In general both diets were relatively palatable. .

Discussion

This study has shown that a 50% increase in daily energy intake provided by protein had no significant impact on changes in body weight, body composition, appetite, mood or perceived palatability. Regardless of the protein composition of their diet, these children lost similar amounts of weight, derived similar physiological benefit, and experienced similar changes in motivation to eat.

The absence of greater weight loss on high-protein diets is not without dispute. A review of the literature concluded that there was no effect of high-protein intake on body fat loss or body weight change during negative energy balance when energy intake was fixed, regardless of whether the diets were ketogenic or non-ketogenic (16). However, our results show that despite a non significant difference between groups the change in FFM of the standard diet group was four times that of the change in FFM within the higher protein group. These findings are supported by Layman et al. (39), who reported that consuming a diet high in protein (30%) increased weight loss, increased loss of body fat and minimised the loss of fat free mass. One of the only other studies involving children or adolescents that we are aware of was a dietary intervention aimed at massively obese 11-16 year olds, which compared the effectiveness of diets differing in protein in a boarding school environment over a period of a year (40). The children lost a large amount of weight over this period but the high-protein diet did not influence weight change or FFM change either during or after the intervention.

The menus provided in the present study and by Rolland-Cachera et al (40) resulted in relatively modest differences in daily protein content (15 vs 22.5%, and 15 vs 19%, respectively). The main strategy to increase dietary protein intake was by offering larger portions of familiar higher protein foods in children's usual meal plan, a difference that went unnoticed by most participants. This contrasts with the literature on the effects of single preloads or high-protein meals on satiety and subsequent energy intake (16). In these studies, the high-protein preloads or meals averaged at over 50% of food energy in the form of protein, a level sometimes achieved by supplementation or presenting the preloads in liquid form. Their impact on hunger suppression and reduced food intake is marked. It may be therefore that the proportion of dietary protein in longer-term studies needs to be greater than 22% to impact on either satiety or weight loss. However, long-term exposure to very high-protein diets is practically and financially challenging, and has been argued as potentially unsafe. Interestingly, the Institute of Medicine (41) has recently identified a normal protein intake range for children to be 10% - 30% of food energy, while that for adults is 10% - 35%. A valuable future research objective would be to look at the weight and hunger suppressing potential of long-term diets nearer the upper level of this range.

Consistent with previous findings (25), the present study found an increase in rated hunger over the duration of the camp. Therefore, although the appetite system was unresponsive to differences in protein intake it showed sensitivity to prolonged negative energy balance. This effect was apparent in the difference between start and end of camp hunger ratings and in the diurnal profiles, most particularly during the early part of day.

A medium-term increase in hunger associated with weight loss has management implications. Potentially, children could regain weight if the increase in hunger leads to a compensatory increase in food intake. The motivation to eat consequences of a dietary and exercise-induced weight loss needs to be considered. Especially in children returning to their habitual, free-living environments. There is likely to be individual variation in this increase but familiarity and coping with hunger during camp may prepare these children for continued weight management when they return home. It also confirms that obese individuals, like their lean counter-parts, show sensitivity in their appetite control mechanisms (42).

The lack of measurement of *ad libitum* food intake did not provide the opportunity to detect differences in food intake between the two dietary manipulations. Therefore, the subjective appetite sensation measurements provided the only opportunity to detect an increased satiating effect of the HP diet. Visual analogue scales have been shown to be sensitive to acute manipulations in macronutrient composition (e.g. (43, 44)) and are commonly used as a measure of satiety in the absence of *ad libitum* food intake. Therefore, it is unlikely that the absence of a difference in subjective appetite sensations between the two diets was due to the insensitivity of the measurement.

One important study limitation was some imprecision in monitoring the foods consumed by individuals. This was inevitable given the cafeteria style presentation of meals and the free-living nature of the intervention. It prevented, for example, the weighing of individual plate waste. However, in the kitchen the food was prepared and served under the guidance of a Dietitian who weighed out a portion of each meal on electronic scales prior to the meals being served. Due to time constraints each meal could not be individually weighed and therefore portion sizes were estimated from the pre-weighed measures. In addition, the daily schedule was highly structured and left few opportunities for children not to be engaged in similar activities (i.e. the camp programme prescribed all activities included rest and relaxation within the 8 am to 10 pm programme). Participants had little opportunity to buy food, being 20 minutes from the nearest shop, and children were required to open posted packages in communal areas, preventing any contraband.

In conclusion, this study has confirmed the capacity for a summer residential activity-based camp to help overweight and obese children to lose weight. It also supports the observation that prolonged negative energy balance is associated with an increase in hunger motivation. However, randomising children to a high-protein diet failed either to facilitate weight loss or to suppress hunger. Further work is warranted into whether higher levels of dietary protein are feasible or effective in longer-term weight loss interventions of this type.

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Table 1

Sample menus for the standard and high protein diets

	Standard	**High protein**
Breakfast		
Bacon	2 rashers	3 rashers
Toast	2 slices	1 slice
Tomato	1 large	1 large
Fruit	1 piece	1 piece
Orange juice	1 glass	1 glass
Or		
Cereal	1 small bowl	1 small bowl
Milk (s.skimmed)	1 ladle	1 ladle
Toast	1 slice	- -
Margarine	medium spread	- -
Jam	medium spread	- -
Low calorie yoghurt	- -	1 small pot
Mixed nuts	- -	1 tablespoon
Fruit	1 piece	1 piece
Orange juice	1 glass	1 glass
Lunch		
Jacket potato	1 medium	½ medium
Filling (cheese,		

baked beans etc)	1 portion	2 portion
Salad	small bowl	small bowl
Low calorie yogurt	1 small pot	1 small pot
<u>Or</u>		
Pitta bread	1 medium	½ medium
Filling (cheese,		
ham etc	1 portion	2 portion
Salad	small bowl	small bowl
Low calorie yogurt	1 small pot	1 small pot
Dinner		
Spaghetti	small portion	½ small portion
Bolognaise	2 small ladles	3 small ladles
Fruit salad	1 bowl	½ bowl
Salad	1 small serving	1 small serving
Orange squash	1 glass	1 glass
<u>Or</u>		
Rice	1 cup	½ cup
Vegetable curry	2 small ladles	3 small ladles
Salad	1 small serving	1 small serving
Fruit salad	1 bowl	½ bowl
Orange squash	1 glass	1 glass

Table 2

Subject characteristics: anthropometric, body composition and physiological measures at the start and the end of camp.

	Standard diet (N=39)		High protein diet (N=41)		Pre to post both diets combined (P<)
	Start	End	Start	End	
Age (yrs)	14.4 ± 2.0	14.5 ± 2.0	14.1 ± 2.0	14.2 ± 2.0	
Duration of stay (days)	27 ± 10		27 ± 9		
Gender ratio (M:F)	12: 27		17: 24		
Height (cm)	164.2 ± 7.8	164.3 ± 7.6	164.9 ± 10.6	165.1 ± 11.0	NS
Weight (kg)	93.9 ± 22.9	88.4 ± 21.6	85.6 ± 17.2	80.4 ± 15.9	0.001
BMI ($kg.m^{-2}$)	34.5 ± 6.0	32.4 ± 5.8	31.3 ± 3.9	29.3 ± 3.5	0.001
BMI sds	3.10 ± 0.50	2.84 ± 0.58	2.83 ± 0.42	2.54 ± 0.44	0.001
% Fat	43.2 ± 7.5	42.6 ± 7.8	41.0 ± 6.3	37.7 ± 7.3	0.01
Fat mass (kg)	41.7 ± 16.3	38.5 ± 14.7	35.1 ± 9.0	30.6 ± 9.4	0.001
Fat free mass (kg)	52.3 ± 9.4	49.9 ± 10.0	50.4 ± 11.0	49.8 ± 10.1	0.05
Waist circumference (cm)	98.9 ± 13.1	92.5 ± 11.3	92.7 ± 8.8	87.4 ± 9.2	0.001
Systolic BP (mmHg)	114 ± 9	111 ± 10.0	113 ± 9	108 ± 8	0.001
Diastolic BP(mmHg)	67 ± 10	62 ± 7	64 ± 8	59 ± 6	0.001
Total cholesterol (mmol)	3.99 ± 0.73	3.25 ± 0.50	4.26 ± 0.79	3.40 ± 1.01	0.001
HDL (mmol)	1.15 ± 0.19	0.99 ± 0.17	1.14 ± 0.28	1.03 ± 0.23	0.01
Triglycerides (mmol)	0.82 ± 0.40	0.78 ± 0.28	1.05 ± 0.52	0.83 ± 0.31	0.01

LDL (mmol)	2.48 ± 0.59	1.94 ± 0.50	2.66 ± 0.68	2.03 ± 0.91	0.001

Values represent mean ± standard deviation.

Table 3

Area Under the Curve (AUC) for the subjective appetite and mood sensations at the start and end of the camp.

	Standard diet (N=26)		High protein diet (N=24)		Pre to post both diets combined (P<)
	Start	End	Start	End	
Hunger	34.8 ± 12.1	41.0 ± 12.8	34.3 ± 12.1	39.7 ± 12.8	0.001
Fullness	51.9 ± 12.7	50.0 ± 12.5	55.2 ± 12.7	54.8 ± 12.5	NS
Irritability	36.1 ± 19.6	39.0 ± 15.1	35.1 ± 19.6	36.6 ± 15.1	NS
Mentally alert	57.5± 14.8	58.0 ± 11.4	59.9 ± 14.8	59.2 ± 11.4	NS
Contentedness	58.6 ± 13.9	62.1 ± 11.9	59.2 ± 13.9	63.0 ± 11.9	NS
Tiredness	47.7 ± 15.4	45.1 ± 14.9	47.6 ± 15.4	45.2 ± 14.9	NS
Meal pleasantness	55.7 ± 18.5	61.2 ± 14.8	55.7 ± 18.5	58.6 ± 14.8	NS

Values represent mean ± standard deviation.

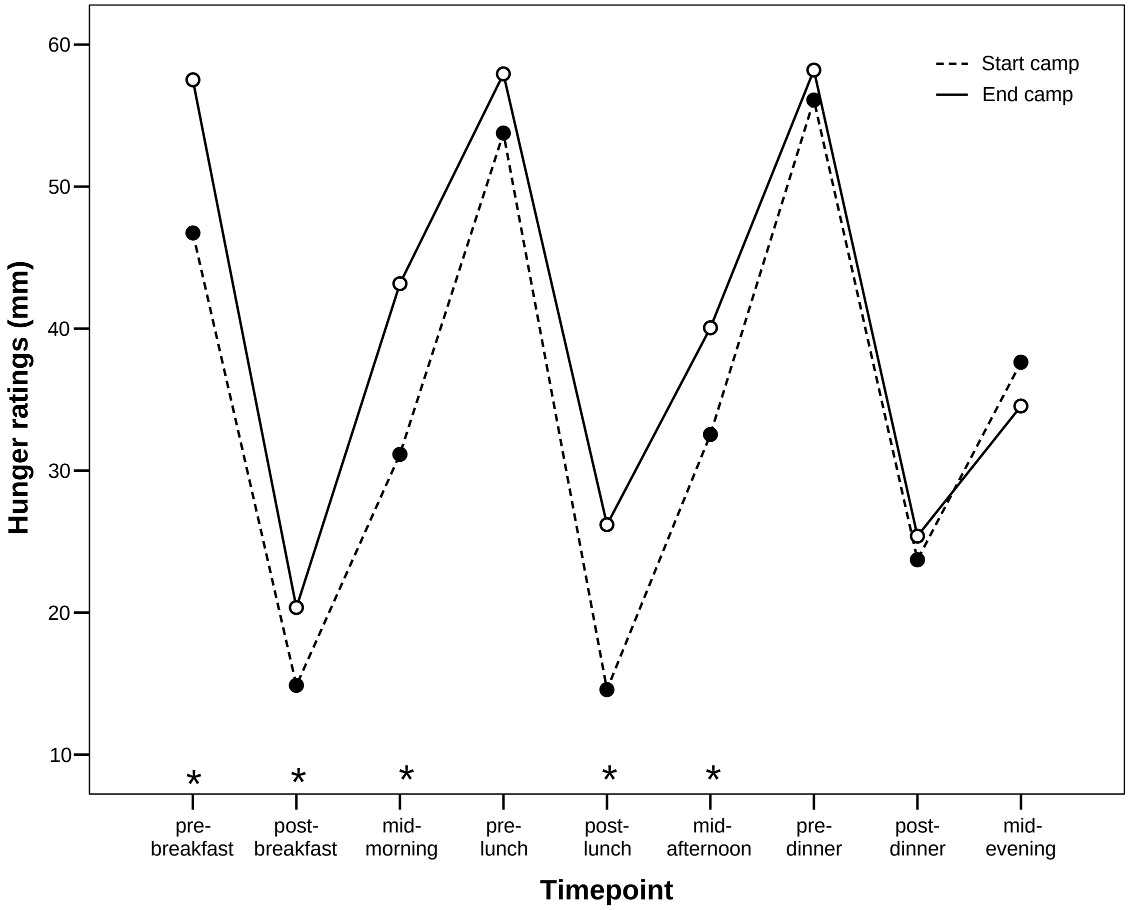

Figure 1. The diurnal profile of hunger ratings at the start and end of camp.

* indicates significant start-end camp differences at individual time points (p<0.05).