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The effects of consuming eggs for lunch on satiety and subsequent food intake

S. POMBO-RODRIGUES[1], W. CALAME[2], & R. RE[1]

[1]*Nutrition Research, Leatherhead Food Research, Randalls Road, Leatherhead, Surrey, UK, and* [2]*StatistiCal BV, Consultancy in Statistics and Experimental Design, Wassenaar, The Netherlands*

Abstract

The aim of the present work was to investigate the effects of eggs consumed for lunch on satiety, satiation and subsequent energy intake at the next meal. Thirty-one healthy male and female subjects participated in a randomized, three-way, crossover study. Following consumption of a standard breakfast, participants were asked to consume three isocaloric test lunches: omelette, jacket potato and chicken sandwich. Subjective measures of satiety were recorded using visual analog scales at regular intervals throughout the day. Energy intake at the next meal was assessed 4 h after lunch with an *ad libitum* meal. The egg lunch showed a significantly stronger satiating effect compared with the jacket potato meal. No effect on energy intake was seen. These data indicate that consumption of an omelette meal consumed at lunch could increase satiety to a greater extent than a carbohydrate meal and may facilitate reduction of energy consumption between meals.

Keywords: *Protein, lunch, appetite, visual analog scale*

Introduction

Obesity is considered a public health issue, with average body weights increasing worldwide. It is currently thought that approximately 1.6 billion people are overweight, of which almost 400 million are obese (Malterud and Tonstad 2009). This increase has been observed in all age groups and ethnicities, with the prevalence of obesity in the USA and the UK currently around 34% and 20%, respectively (Flegal et al. 2010). Being overweight and obese increases the risk of cardiovascular disease, which is currently one of the main causes of premature death in the UK (British Heart Foundation 2010). This is due to the association of obesity with a number of risk factors for cardiovascular disease including hypertension, type 2 diabetes and dyslipidemia. Although the mechanisms involved are complex, involving hormonal, genetic, and metabolic processes as well as environmental and behavioral factors (Westerterp-Plantenga and Lejeune 2005, Tremblay et al. 2007), the major causes of obesity are considered to be excessive energy intake and insufficient physical activity. The control of energy intake is vital for body weight control, with satiety (the feeling of fullness following food consumption) contributing to a complex system of appetite control that regulates how much we consume. Thus, highly satiating foods could represent useful tools for weight management. Indeed, studies on different isocaloric breakfasts have found that as satiety increases, energy intake at the next meal decreases (Holt et al. 2001, Leidy et al. 2007, Paddon-Jones et al. 2008, Benelam 2009).

It is well established that different foods exert different effects on satiety, with protein thought to be the most satiating macronutrient, followed by carbohydrate and then fat (Poppitt et al. 1998). Specifically, there is evidence that increasing the amount of dietary protein, while controlling total energy intake, may improve weight management and facilitate fat loss (Layman 2004, Westerterp-Plantenga et al. 2004, Layman et al. 2005). Several studies have

Correspondence: Sonia Pombo-Rodrigues, Leatherhead Food Research, Randalls Road, Leatherhead, Surrey KT22 7RY, UK. Tel:44 1372 822 293. E-mail: spombo@leatherheadfood.com

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demonstrated that protein has a stronger effect on satiety than equivalent quantities of energy from other macronutrients (Lleidy et al. 2007, Mahon et al. 2007, Paddon-Jones et al. 2008). The mechanisms involved relate to increased thermogenesis, as a result of a greater energy requirement for protein digestion and absorption (Halton and Hu 2004). Other reasons why some proteins may yield high satiety include delayed gastric emptying, glucagon release, and release of gut peptides (Batterham et al. 2006, Blom et al. 2006, Karamanlis et al. 2007, Ma et al. 2009).

Eggs are a key source of macronutrients and micronutrients, with protein representing approximately 35% of their total energy content. Therefore the inclusion of eggs in the diet should be recommended; however, increased egg consumption has previously been advised with caution due to the cholesterol content of eggs. Research over the past decade has shown no correlation between cholesterol consumption and risk of coronary heart disease or stroke, and this is no longer considered to be a causative factor in coronary heart disease through its association with serum cholesterol (Hu et al. 1999, Nakamura et al. 2006, Gray and Griffin 2009). In relation to satiety, consumption of eggs at breakfast has previously been shown to correlate with greater satiety scores and reduction of short-term energy intake (Holt et al. 1995, Vander Wal et al. 2005, 2008, Ratliff et al. 2010). Although the effects of eggs consumed at breakfast on satiety have been investigated, equivalent studies investigating consumption at lunch have not been conducted. We predict that consumption of eggs at lunch will produce similar, if not the same, satiating effects as when consumed at breakfast. This will be assessed using subjective ratings of satiety and subsequent energy intake at the next meal.

Methods

Subjects

The study was submitted to and approved by Kent Research Ethics Committee (LREC reference: 09/H1101/83). Subjects identified from Leatherhead Food Research's volunteer database and the surrounding community were initially screened according to the inclusion/exclusion criteria stipulated in Table I. Based on previous power calculations (Flint et al. 2000), 35 participants were recruited and 31 completed the study. Potentially eligible participants were invited to an information session and informed consent was obtained.

Study design

This was a randomized controlled study, in which consumption of three different lunches was tested following a double Latin square randomized crossover design, with a 1-week washout period between each test day. Before the start of each session, subjects were asked to maintain their normal lifestyle and consume their evening meal no later than 20:00 h. On the first test day, subjects arrived at 08:30 h in the morning following an overnight fast, and were asked to dispense their own habitual portion of cornflakes and semi-skimmed milk for breakfast. This was weighed and recorded and the same amount was provided to them in the following sessions. Four hours after breakfast, participants were provided with one of the three test lunches and were given 20 min to completely finish eating them. Four hours later, energy intake was assessed by providing participants with an *ad libitum* portion of pasta for their evening meal. Consumption of water or black tea/coffee was permitted during the day, and the amount was recorded on the first session and repeated to ensure consistency throughout the

Table I. Inclusion and exclusion criteria for the present study.

Inclusion criteria
Age at start of the study ≥ 20 and ≤ 60 years
Body mass index ≥ 18.5 and $\leq 25\,kg/m^2$
Apparently healthy: measured by questionnaire: no reported current or previous metabolic diseases or chronic gastrointestinal disorders
Reported dietary habits: no medically prescribed diet, no slimming diet, used to eat three meals a day, macro-biotic or biologic dynamic food habits
Used to eating cereal for breakfast
No blood donation during the study
Reported intense sporting activities ≤ 10 h/week
Reported alcohol consumption ≤ 21 units/week (female) or ≤ 28 units/week (male)
Informed consent signed
Recruitment form filled out
Exclusion criteria
Smoking
Dislike, allergy or intolerance to test products (egg, dairy or chicken)
Possible eating disorder (measured by sick/control/one/fat/food questionnaire)
Not high or very high restrained eaters (≥ 15 according to Polivy et al. (1978)
Reported lactating (or lactating $<$ 6 weeks ago), pregnant (or pregnant $<$ 3 months ago) or wish to become pregnant during the study
Reported medical treatment that may affect eating habits/satiety
Reported participation in another biomedical trial 1 month before the start of the study

study. During the study period, visual analog scale (VAS) ratings for 'how strong is your desire to eat', 'how full do you feel', 'how much do you think you can eat' and 'how hungry do you feel' were answered at 30-min intervals, commencing immediately prior to consumption of the test lunch ($t = 0$ min) and finishing after the *ad libitum* dinner ($t = 240$ min). The VAS ratings are validated tools as reported by Flint et al. (2000). VAS scales were anchored at the low end with the lowest intensity feelings (e.g. not at all), and with opposing terms at the high end (e.g. very high) (see Figure 1). Subjects were asked to indicate which place on the scale best reflected their feeling at that moment. Ratings were then quantified by measuring the distance from the left end of the line to the mark. In addition, subjects were also asked to record VAS values for product liking immediately after consumption of test meals.

Test foods and ad libitum *food intake*

The three test lunches were isocaloric (~1,466 kJ/350 kcal) and consisted of: a two-egg omelette (produced using Micromark omelette express maker MM9878; Micromark), a slice of buttered bread and a side salad (meal O); a jacket potato with cheddar cheese and a side salad (meal P); and a chicken and mayonnaise sandwich with a side salad (meal C). Meal P was chosen as an example of a carbohydrate-rich hot meal, whereas meal C was considered as an alternative source of dietary protein, similar to that provided by meal O. The nutritional content of all three lunches is shown in Table II. For the *ad libitum* dinner, volunteers were provided with a large portion (~1.4 kg) of pre-weighed food (pasta with a tomato and cheese sauce). Volunteers were instructed to remain seated and silent for a 30-min period and were asked to eat until 'comfortably full'. Their food consumption was measured and the energy intake calculated.

Statistical analysis

Statistical analysis was performed using STATA, version 10 (StataCorp LP, College Station, TX, USA) and Microsoft Excel (Redmond, WA, USA).

How strong is your desire to eat?

Very Weak |--| Very Strong

How full do you feel?

Not at all full |--| Extremely full

How much do you think you can eat?

Nothing at all |--| A lot

How hungry do you feel?

Not hungry at all |--| Have never been hungrier

Figure 1. Scheme for VAS scales.

Table II. Nutrient composition of the test lunches consumed.

	Lunch consumed		
Nutrition	Egg	Potato	Chicken sandwich
Energy (kcal)	351	353	350
Protein (g) (% energy)	20.7 (24%)	14.5 (16%)	19.2 (22%)
Carbohydrate (g) (% energy)	16.2 (18%)	48.7 (55%)	30.0 (34%)
Fat (g) (% energy)	22.7 (58%)	11.2 (29%)	17.1 (44%)

In order to determine which statistical test to use, normality of the data was addressed using gamma-3 and gamma-4 distribution parameters. To analyze the differences in energy intake during the *ad libitum* meal, paired *t*-tests were applied. With respect to the impact of the various lunches on VAS scores, changes in scores per person per time interval were calculated by subtracting the scores at each time interval from the paired observation obtained at time 0 min. Paired VAS data were recorded as delta results (change in outcome) per person per time interval. These data were analyzed in two ways: plotting mean data points ± standard error of the mean (SEM) for each test meal over time; or analysis of variance (ANOVA), fitting the model by *F*-test and stepwise multiple regression (Kleinbaum et al. 1998, Armitage et al. 2002). For ANOVA and regression analysis, the following model was applied:

$$\Delta y = (a_1) \times \text{dummy} + (a_2) \times \text{time} + (a_3) \times \text{dummy} \times \text{time} + (a_4) \quad (1)$$

in which Δy is the difference in outcome between an outcome at a specific time interval to that at the start; *time* is the interval after the start; *dummy* is the control sample (one particular type of lunch, taking the value '0'), versus test sample (other type of lunch, taking the value '1'); $a_1 - a_3$ are coefficients in the model; and a_4 is the rest coefficient.

Using the above-explained methodology, not only the difference in VAS scores over the entire interval can be analyzed between the various lunches (as presented by the dummy) but also the difference in a potential time-dependent effect (as presented by time x dummy). Throughout the study, two-tailed statistical analysis was performed, and $P < 0.05$ was considered significant.

Results

Of the 35 recruited participants, three withdrew at the start of the study for non-study-related reasons, while one failed to complete all three sessions. Of the remaining 31 participants (10 male and 21 female), the mean ± standard deviation age and body mass index were 37.5 ± 9.97 years and 22.5 ± 2.0 kg/m^2, respectively. VAS values (mean ± SEM) for 'product liking' of meals O (73.2 ± 3.8), P (78.7 ± 3.8) and C (82.4 ± 2.5) showed no significant differences in preference between meals O versus P and meals P versus C. However, a significant difference in liking was observed between meals O versus C.

Mean VAS scores over time

The mean subjective ratings (± SEM) at each time point for the three test products in response to the four satiety questions (desire to eat, levels of fullness 'feelings of hunger' and 'prospective food consumption') are reported in Figure 2. The results of the regression analysis on all four questionnaires are presented in Table III. The various VAS values for all

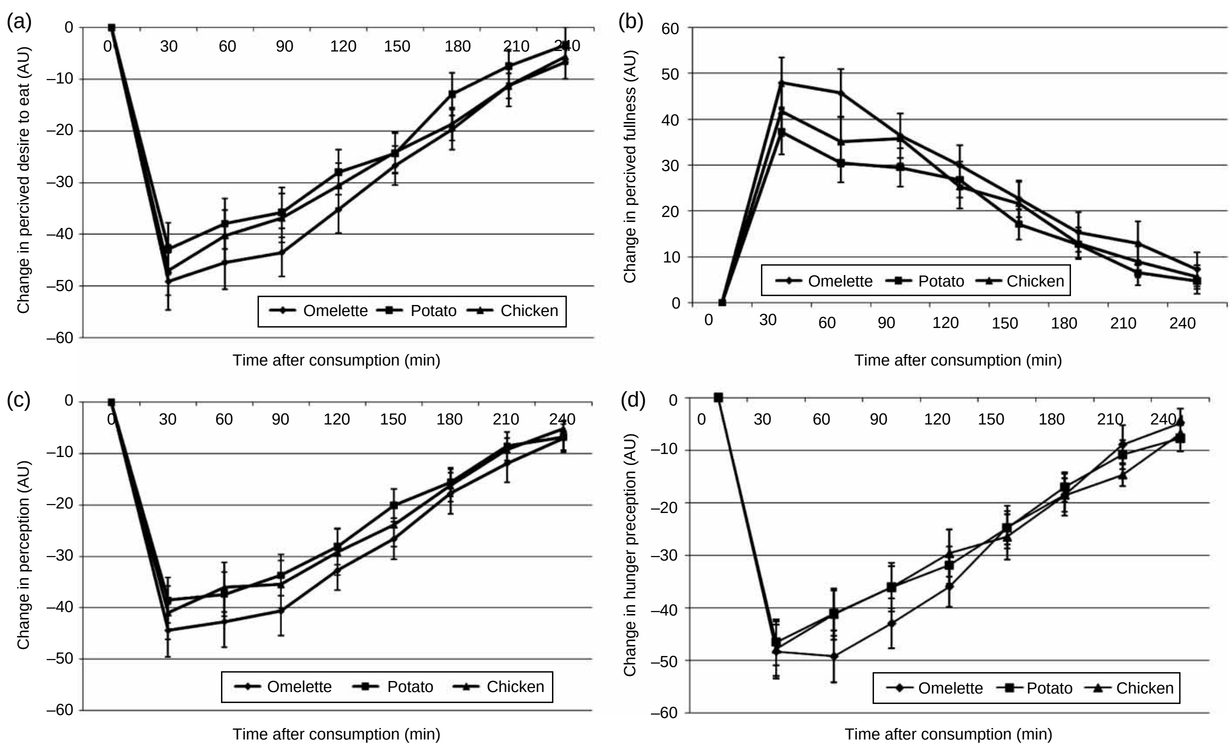

Figure 2. VAS ratings after test food consumption: (a) desire to eat, (b) fullness, (c) prospective food consumption and (d) hunger. Values expressed as the mean ± SEM for $n = 31$.

Table III. VAS scores: results of the stepwise regression analysis.

	Dummy		Time		Dummy x Time			ANOVA (model)	
Combination	Coeff.	P	Coeff.	P	Coeff.	P	Rest coeff.	F	P
How strong is your desire to eat?									
O vs. P	5.625	0.01	0.208	0.000			−57.756	88.9	0.000
O vs. C			0.207	0.000			−56.144	183.2	0.000
P vs. C			0.197	0.000			−52.076	173.0	0.000
How hungry do you feel?									
O vs. P			0.214	0.000			−56.985	178.5	0.000
O vs. C			0.212	0.000			−56.996	174.5	0.000
P vs. C			0.191				−53.140	165.8	0.000
How full do you feel?									
O vs. P	−6.629	0.002	−0.184	0.000			52.072	76.5	0.000
O vs. C			−0.193	0.000			51.419	132.6	0.000
P vs. C			−0.171	0.000			45.120	127.1	0.000
How much do you think you can eat?									
O vs. P	4.387	0.026	0.182	0.000			−52.562	84.3	0.000
O vs. C			0.186	0.000			−51.340	152.0	0.000
P vs. C			0.174	0.000			−47.486	159.2	0.000

The coefficients and subsequent P values are shown for the optimal model explaining the outcome between two various lunches. Coeff., coefficient.

four measures were consistently higher (more outspoken) for meal O than observed for meal P or C. Within the conditions of the present study, consumption of meal O resulted in a significantly ($P = 0.01$) lower desire to eat, significantly ($P = 0.002$) higher feeling of fullness and a significantly ($P = 0.026$) lower estimation of how much the subjects thought they could eat compared with meal P (Table III). There was a very significant ($P < 0.0001$) effect by time on all of the VAS questions. A major observation was the absence of any lunch type x time effect, which means that over the complete interval as used in the present study the difference in VAS scores remained constant between the various lunches consumed. A difference gained at the start remained for the complete 2 h.

Energy intake at the next meal

The total energy consumed during the *ad libitum* meal 4 h after consumption of the test product is shown in Table IV. No significant differences in energy consumption were observed for participants consuming any of the three lunches.

Discussion

The consumption of eggs at breakfast has previously been associated with increased weight loss in overweight and obese subjects (Vander Wal et al. 2008). As the control of body weight is influenced by satiety, the present study aimed to determine whether consumption of eggs at lunch had a significant effect on satiety. Using ANOVA/regression analysis, we demonstrate significantly greater satiety levels in healthy normal weight individuals after consuming eggs for lunch (meal O) when compared with the potato test meal (P). This finding was also observed in the analysis of mean VAS values plotted over time, where increased levels of fullness were found up to 60 min after consumption of meal O in comparison with meal P. These results are comparable with the previously reported effects of eggs on satiety when consumed for breakfast (Vander Wal et al. 2005, Ratliff et al. 2010). However, our findings showed that increased satiety after consumption of eggs at lunch may be relatively short-lived (lasting up to 1 h), suggesting beneficial effects may be in the form of reducing the urge to snack between meals, rather than the reduction of energy intake at dinner. This hypothesis was supported by the statistically equal energy intake observed during the *ad libitum* dinner, irrespective of the test lunch consumed. Many other factors can cause the cessation of a meal, including environmental and emotional cues, which may result in people eating more in a subsequent meal (Blundell 2010). This is mirrored in many other satiety studies, whereby a reduction in energy intake at the next meal is not observed despite significant differences in VAS scores (Diepvens et al. 2008, Benelam 2009, Veldhorst et al. 2009). Subjects were allowed to drink water during the study period, which could have affected their feelings of hunger; however, the amount consumed by each individual was repeated during each visit to ensure consistency and avoid any differences this may have caused. The observed increases

Table IV. Energy intake at the next meal.

Lunch consumed	Energy consumption
Omelette (O)	3,820 ± 1,097 kJ (913 ± 262 kcal)
Jacket potato (P)	3,594 ± 1,087 kJ (859 ± 260 kcal)
Chicken sandwich (C)	3,808 ± 1,105 kJ (910 ± 264 kcal)

Data presented as the mean ± standard deviation.

subjective feelings satiety after consumption of meal O compared with meal P was accompanied with a decrease in desire to eat in our ANOVA/regression analyses. Again, this finding agrees with previous studies on the effects of consumption of eggs for breakfast. Together, these data suggest that the satiating effects of eating eggs apply when consumed at lunch as well as at breakfast, supporting the growing body of evidence indicating that eggs could form an important part of a diet aimed at controlling body weight.

Many trials have investigated the comparison between high-protein, low-carbohydrate diets and low-fat, high-carbohydrate diets, with greater weight losses observed in high-protein diets (Brehm et al. 2003, Yancy et al. 2004, Nickols-Richardson et al. 2005, Larsen et al. 2010, Papadaki et al. 2010). In general, most studies have shown that sufficiently high levels of protein have a stronger effect on satiety compared with equivalent energy derived from other macronutrients (Benelam 2009). This could explain the higher levels of fullness obtained in the present study with meal O compared with a carbohydrate-based lunch, such as meal P. This trend mirrors the majority outcome of the analysis by Halton and Hu (2004) of 15 acute crossover studies looking at the effects of high-protein and low-protein meals of equal caloric value, where over one-half showed a significant decrease in food intake after the high-protein meal. Interestingly, no significant differences in satiety were observed between meal C and meal O or P. This could be considered surprising, as meals O and C contained equal amounts of protein; however, the levels of both carbohydrate and lipid in these two meals were very different. It is unclear from this study whether this effect is a result of the differing levels of carbohydrate, or more probably lipid (having an effect on gastric retention times) or the type of protein. This has been noted in other studies looking at the effect of different proteins on satiety (Uhe et al. 1992, Borzoei et al. 2006). Borzoei et al. found a non-significant increase in satiety and a significant decrease in energy intake after consumption of a fish meal compared with a beef meal. Other studies have compared different types of isolated protein on satiety and have given inconsistent results (Lang et al. 1999, Hall et al. 2003, Anderson et al. 2004). Although not statistically significant, there is a clear trend for meal O to be more satiating than meal C when looking at subjective responses of desire to eat and fullness. Significant differences in palatability were observed between the two protein meals, with meal O being less palatable than meal C. This may therefore have had an influence on the subject's VAS scores. Palatable stimuli act on hedonic pathways in the brain, stimulating the drive to consume greater quantities and more frequently (Berthoud 2007), therefore a less palatable meal (O) may reduce the desire to eat and hence increase satiety.

Conclusion

The results presented here suggest that consumption of eggs for lunch has a stronger effect on satiety than other typically consumed carbohydrate-based lunches, and could represent a beneficial component of a diet aimed at controlling weight. However, although significant differences in VAS scores were achieved, the physiological impact may well be limited. Follow-up studies of a larger scale would be required to determine the effect of mid-term to long-term consumption of eggs at lunch on appetite and weight. However, it is important to bear in mind that regardless of how effective an ingredient may be in enhancing satiety, people in real-life situations do not always respond well to internal cues, and with a constant increase in sedentary lifestyles, more is required in order to help counteract the worldwide obesity epidemic. Therefore, egg-based meals could be part of a diet influencing feelings of satiety in conjunction with other macronutrients or lifestyle factors to elongate the beneficial effect over time.

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References

Anderson GH, Tecimer SN, Shah D, Zafar TA. 2004. Protein source, quantity and time of consumption determine the effect of proteins on short-term food intake in young men. J Nutr 143: 3011–3015.

Armitage P, Berry G, Matthews JNS. 2002. Statistical Methods in Medical Research. 4th ed. Oxford: Blackwell.

Batterham RL, Heffron H, Kapoor S, Chivers JE, Chandarana K, Herzog H, Le Roux CW, Thomas EL, Bell JD, Withers DJ. 2006. Critical role for peptide YY in protein-mediated satiation and body-weight regulation. Cell Metab 4(3):223–233.

Benelam B. 2009. Satiation, satiety and their effects on eating behaviour. Nutr Bull 34:126–173.

Berthoud HR. 2007. Interactions between the 'cognitive' and 'metabolic' brain in the control of food intake. Physiol Behav 91(486):498.

Blom WAM, Lluch A, Stafleu A, Vinoy S, Holst JJ, Schaafsma G, Hendriks HFJ. 2006. Effect of a high-protein breakfast on the postprandial ghrelin response. Am J Clin Nutr 83(2):211–220.

Blundell J, de Graaf C, Hulshof T, Jebb S, Livingstone B, Lluch A, Mela D, Salah S, Echuring S, van der Knaap H, Westerterp M. 2010. Appetite control: methodological aspects of the evaluation of foods. Obesity reviews 11:251–270.

Borzoei S, Neovius M, Brakeling B, Teixeira-Pinto A, Rössner S. 2006. A comparison of effects of fish and beef protein on satiety in normal weight men. Eur J Clin Nutr 60:897–902.

Brehm BJ, Seeley RJ, Daniels SR, D'Alessio DA. 2003. A randomized trial comparing a very low carbohydrate diet and a calorie-restricted low fat diet on body weight and cardiovascular risk factors in healthy women. J Clin Endocrinol Metab 88: 1617–1623.

British Heart Foundation. 2010. Obesity & Heart Disease [Online] Available at: http://www.bhf.org.uk/healthy_children_home/obesity__heart_disease.aspx. Accessed on 7 September 2010.

Diepvens K, Häberer D, Westerterp-Plantenga M. 2008. Different proteins and biopeptides differently affect satiety and anorexigenic/orexigenic hormones in healthy humans. Int J Obesity 32: 510–518.

Flegal KM, Carroll MD, Ogden CL, Curtin LR. 2010. Prevalence and trends in obesity among US adults, 1999–2008. J Am Med Assoc 303:235–241.

Flint A, Raben A, Blundell J, Astrup A. 2000. Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. Int J Obesity 24: 38–48.

Gray J, Griffin B. 2009. Eggs and dietary cholesterol—dispelling the myth. Nutr Bull 34:66–70.

Hall WL, Milward DJ, Long SJ, Morgan LM. 2003. Casein and whey exert different effects on plasma amino acid profiles, gastrointestinal hormone secretion and appetite. Br J Nutr 89: 239–248.

Halton TL, Hu FB. 2004. The effects of high protein diets on thermogenesis, satiety and weight loss: A critical review. J Am Coll Nutr 23:373–385.

Holt SHA, Brand-Miller JC, Petocz P, Farmakalids E. 1995. A satiety index of common foods. Eur J Clin Nutr 49:675–690.

Holt SHA, Brand-Miller JC, Stitt PA. 2001. The effects of equal-energy portions of different breads on blood glucose levels, feelings of fullness and subsequent food intake. J Am Diet Assoc 101:767–773.

Hu F, Stampfer MJ, Rimm EB, Manson EJ, Ascherio A, Colditz GA, Rosner BA, Spiegelman D, Speizer FE, Sacks FM, et al. 1999. A prospective study of egg consumption and risk of cardiovascular disease in men and women. JAMA 281:1387–1394.

Karamanlis A, Chaikomin R, Doran S, Bellon M, Bartholomeusz FD, Wishart JM, Jones KL, Horowitz M, Rayner CK. 2007. Effects of protein on glycemic and incretin responses and gastric emptying after oral glucose in healthy subjects. Am J Clin Nutr 86(5):1364–1368.

Kleinbaum DG, Kupper LL, Muller KE, Nizam A. 1998. Applied Regression Analysis & Other Multivariable Methods. 3rd ed. CA, USA: Thomson Brooks/Cole.

Lang V, Bellisle F, Alamowitch C, Craplet C, Bornet FR, Slama G, Guy-Grand B. 1999. Varying the protein source in mixed meal modifies glucose, insulin and glucagon kinetics in healthy men, has weak effects on subjective satiety and fails to affect food intake. Eur J Clin Nutr 53:959–965.

Larsen TM, van Baak M, Pfeiffer AFH, Handjieva-Darlenska T, Pihlsgård M, Saris WHM. 2010. Diets with high or low protein content and glycemic index for weight-loss maintenance. N Engl J Med 363:22.

Layman DK. 2004. Protein quantity and quality at levels above the RDA improves adult weight loss. J Am Coll Nutr 23:631S–636S.

Layman DK, Evans E, Baum JI, Seyler J, Erickson DJ, Boileau RA. 2005. Dietary protein and exercise have additive effects on body composition during weight loss in adult women. J Nutr 135: 1903–1910.

Leidy HJ, Carnell NS, Mattes RD, Campbell WW. 2007. Higher protein intake preserves lean mass and satiety with weight loss in pre-obese and obese women. Obesity 15:421–429.

Lleidy HJ, Mattes RD, Campbell WW. 2007. Effects of acute and chronic protein intake on metabolism, appetite, and ghrelin during weight loss. Obesity 15:1215–1225.

Ma J, Stevens JE, Cukier K, Maddox AF, Wishart JM, Jones KL, Clifton PM, Horowitz M, Rayner CK. 2009. Effects of a protein preload on gastric emptying, glycemia, and gut hormones after a carbohydrate meal in diet-controlled type 2 diabetes. Diabetes Care 32(9):1600–1602.

Mahon AK, Flynn MG, Stewart LK, McFarlin BK, Iglay HB, Mattes RD, Lyle RM, Considine RV, Campbell WW. 2007. Protein intake during energy restriction: Effects on body composition and markers of metabolic and cardiovascular health in postmenopausal women. J Am Coll Nutr 26:182–189.

Malterud K, Tonstad S. 2009. Preventing obesity: Challenges and pitfalls for health promotion. Patient Edu Couns 76:254–259.

Nakamura Y, Iso H, Kita Y, Ueshima H, Okada K, Konishi M, Inoue M, Tsugane S. 2006. Egg consumption, serum total cholesterol concentrations and coronary heart disease incidence: Japan Public Health Center-based prospective study. Br J Nutr 96:921–928.

Nickols-Richardson SM, Coleman MD, Volpe JJ, Hosig KW. 2005. Perceived hunger is lower and weight loss is greater in overweight premenopausal women consuming a low-carbohydrate/high-protein vs high-carbohydrate/low-fat diet. J Am Diet Assoc 105: 1433–1437.

Paddon-Jones D, Westman E, Mattes RD, Wolfe RR, Astrup A, Westerterp-Plantenga M. 2008. Protein Summit 2007: Exploring the impact of high-quality protein on optimal health. Protein, weight management, and satiety. Am J Clin Nutr 87: 1558S–1561S.

Papadaki A, Linardakis M, Larsen TM, van Baak MA, Lindroos AK, Pfeiffer AFH, Martinez JA, Handjieva-Darlenska T, Kunesová M, Holst C, et al. 2010. The effect of protein and glycemic index on children's body composition: The DiOGenes randomized study. Paediatrics 126:5.

Polivy J, Herman C, Warsh S. 1978. Internal and external components of emotionality in restrained and unrestrained eaters. Journal of Abnormal Psychology 87:497–504.

Poppitt SD, McCormack D, Buffenstein R. 1998. Short-term effects of macronutrient preloads on appetite and energy intake in lean women. Phys Behav 64:279–285.

Ratliff J, Leite JO, de Ogburn R, Puglisi MJ, VanHeest J, Fernendez ML. 2010. Consuming eggs for breakfast influences plasma glucose and ghrelin, while reducing energy intake during the next 24 hours in adult men. Nutr Res 30:96–103.

Tremblay F, Lavigne C, Jacques H, Marette A. 2007. Role of dietary proteins and amino acids in the pathogenesis of insulin resistance. Annu Rev Nutr 27:293–310.

Uhe AM, Collier GR, O'Dea K. 1992. A comparison of the effects of beef, chicken and fish protein on satiety and amino acid profiles in lean male subjects. J Nutr 122:467–472.

Vander Wal JS, Marth JM, Khosla P, Jen KLC, Dhurandhar NV. 2005. Short-term effect of eggs on satiety in overweight and obese subjects. J Am Coll Nutr 24:510–515.

Vander Wal JS, Gupta A, Khosla P, Dhurandhar NV. 2008. Egg breakfast enhances weight loss. Int J Obes 32:1545–1551.

Veldhorst MAB, Nieuwenhuizen AG, Hochstenbach-Waelen A, Westerterp KR, Engelen MPKJ, Brummer RJM, Deutz NEP, Westerterp-Plantenga MS. 2009. Effects of high and normal soyprotein breakfasts on satiety and subsequent energy intake, including amino acid and 'satiety' hormone responses. Eur J Nutr 48:92–100.

Westerterp-Plantenga MS, Lejeune MP. 2005. Protein intake and body-weight regulation. Appetite 45:187–190.

Westerterp-Plantenga MS, Lejeune MP, Nijs I, van Ooijen M, Kovacs EM. 2004. High protein intake sustains weight maintenance after body weight loss in humans. Int J Obes Relat Metab Disord 28:57–64.

Yancy WS, Olsen MK, Guyton JR, Bakst RP, Westman EC. 2004. A low-carbohydrate, ketogenic diet versus a low-fat diet to treat obesity and hyperlipidemia—A randomized, controlled trial. Ann Int Med 140:769–777.