Food Choice Phenotypes: causes and consequences of habitual food selection

by

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

Abstract

The primary aim of this thesis was to investigate the characteristics of individuals defined by their contrasting habitual selection of high fat and low fat foods. Previous studies have applied the term phenotype to this classification.
The first study aimed to further characterise the eating patterns of lean high fat (HF-L) and low fat (LF) consumers. It was shown that HF-L consumed much higher amounts of fat (and energy) during the latter part of the evening (Ch 5). HF-L have to deal with this metabolic load late on in the day and during sleep. This may be the reason for a somewhat inferior sleep quality (reflected in a higher heart rate).
The second study aimed to investigate i) whether HF-L and LF have different patterns of physiological satiety signals (and therefore a different modulation of appetite control) and ii) to examine the impact of short-term changes to the habitual diet on hunger and satiety. HF-L and LF were both found to be less hungry following consumption of the meal most dissimilar to their habitual diet; perhaps indicating an up-regulation of satiety signals related to nutrients least often consumed (Ch.6). No significant difference on food preference tests was found between the two groups, indicating that the development of the dietary 'habit' may be independent of current preference, at least for normal weight individuals. HF-L were shown to significantly increase energy and fat intake following a high fat preload (Ch.7), indicating a tendency toward overconsumption under certain conditions (independent of hedonic response), and therefore representing a risk factor for obesity. In HF consumers high fat foods seemed to further disinhibit appetite leading to enhanced consumption.
The aim of the third study (Ch.8) was to define a cluster of characteristics that might ultimately diagnose susceptibility and resistance to dietary induced obesity. A third high fat-overweight phenotype (HF-O) was introduced in order to further investigate how body weight might be influenced by a high fat diet. The results of the free-living study found that both HF-O and HF-L appear to make similar habitual dietary choices in terms of energy and macronnutrient intakes, yet have (by definition) very different body compositions. One issue raised here concerns the validity of the instrument used to define dietary intakes. For example, when using the FFQ, a selection of larger portion sizes would give rise to an underestimation of energy intake from this tool. This may be the case with HF-O who were found to score more highly on the TFEQ disinhibition factor.
Studies in Ch.9 and Ch.10 indicated that HF-O actually consume greater amounts of food than HF-L and LF in a test meal situation, and display heightened hedonic responses to certain high fat foods. It may be assumed that the pleasure yielded by food influences the expression of food preferences and that these factors are important in influencing food choices (confirmed by descriptive reports in Ch.10). If food is perceived as more pleasant then this would stimulate more eating through an increased sensation of hunger and a consequent weakening of satiety.
A form of qualitative analysis was applied in Ch.10 to explore motives to eat outside of laboratory conditions. Interestingly, attitudes and intentions were poor predictors of their actual behaviour, suggesting that food choice is not under socio-cognitive control. Therefore a more unconscious or psychobiological explanation of human food selection, emphasising the interaction between biology and behaviour, may be appropriate.
The final study (Ch.11) specifically targeted motives for eating based on the distinction between liking and wanting.
What characterises individual's susceptibility to weight gain? HF-O receive pleasure from eating but in comparison to their lean counterparts this might be termed a 'super'

sensitive hedonic response to food and particularly to high fat (savoury) foods. They show a directed preference for high fat foods coupled with increased levels of disinhibition. This susceptibility to overeating along with the hedonic response to food may be responsible for the increase in meal size demonstrated in experimental situations. Small but consistent overeating is probably one of the main reasons why some individuals are overweight. It appears to be the case that psychological and physiological dispositions of the subject will effect preferences and responses to the qualities of foods (Stubbs *et al*, 2002), and that the interaction between behavioural and metabolic responses influence weight gain (Pagliassotti *et al,* 1997).

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Publications and Presentations

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Abstract submitted to 13th European Congress on Obesity, Prague, May 2004.

- Le Noury, J.C., Lawton, C. & Blundell, J.E. (2002) Food choice and hedonic responses: Difference between overweight and lean high fat phenotypes. *International Journal of Obesity,* 26(suppl 1), S125.

Presented at the International Obesity Congress, Sao Paulo, Brazil, August 2002.

- Blundell, J.E. & Le Noury, J.C. (2002) Appetite. *Encyclopaedia of Appetite and Food Culture.* In press.

- Blundell, J.E. & Le Noury, J.C. (2002) Appetite control and palatability of food in humans: Does the pleasure of eating lead to obesity? In G. Medeiros-Neto, A. Halpern and C. Bouchard (eds) *Progress in Obesity Research 9.* John Libbey Eurotext Ltd. pp. 822-825.

Presented at the International Obesity Congress, Sao Paulo, Brazil, August 2002.

- Blundell, J.E. and Le Noury, J.C. (2001) Carbohydrates and appetite control. *Australian Journal of Nutrition and Dietetics,* 58 (suppl 1), S13-S18.

- Blundell, J.E., Le Noury, J.C. and Cooling, J. (2001) Food choice phenotypes: A tool to study food selection? [published as a *Danone monograph]*.

- Le Noury, J.C., Cooling, J and Blundell, J.E. (2000) Relationships between eating and sleeping: comparison of high fat and low fat (behavioural) phenotypes. *Appetite,* p202.

Presented at the Food Choice Conference, Trinity College, Dublin, July 2000.

Chapter 1

GENERAL INTRODUCTION

1.1 Importance of Food Choice

A vast amount of knowledge is available regarding food and nutrition (that is, what is in food and how it effects the human body), however less is known about the factors that guide individual food choices. It is proposed that eating behaviour is guided by physiological, environmental and cognitive factors, which determine food intake. It is this 'behaviour' that is central to the understanding of food intake and has been described as the factor 'bridging the gap between the nutritional environment and the physiological/biochemical mechanisms of weight control' (Blundell and King, 1996). What an individual chooses to consume determines their macronutrient and energy intake. When energy intake exceeds energy expenditure, i.e. as a result of overconsumption or a sedentary lifestyle, the result is the promotion of a positive energy balance. If this situation is maintained, this will lead to weight gain and obesity. The factors influencing food choice and how these choices influence energy balance are essential in the understanding of human body weight regulation from both an individual and economic view point.

1.2 Current trends in obesity and the implications for health

Obesity can be defined as a significant increase above the ideal body weight, which maximises life expectancy. A state of obesity is generally defined as a body mass index (BMI) of >30 kg/m^2. Between 25 and 30 is regarded as overweight and a normal range is in the region of 20-25 kg/m^2. A non-smoking individual is likely to have an optimum life expectancy and disability free life if their BMI remains at ~20 kg/m^2 throughout their life (James *et al,* 2001). A report from the Department of Health in the UK (1999) stated that in 1980 8% of women in England were classified as obese, compare to 6% of men.

By 1998 the prevalence of obesity had nearly trebled to 21% of women and 17% of men. If this average rate of increase seen between 1980 and 1998 continues, it is estimated that over one fifth of men and about a quarter of women will be obese by 2005, and over a quarter of all adults by 2010. This situation is not only a problem for adults. It is estimated that 17.6 million children under five are currently overweight worldwide. In the USA alone the number of overweight children has doubled and the number of overweight adolescents has trebled since 1980 (WHO, 2003). As such, the trends in the prevalence of obesity is often referred to as an 'epidemic' implying that obesity is a characteristic of populations not only of individuals (Flegal, 1999). The increase in prevalence of obesity has raised concerns due to the comorbidities associated with the disease, such as an increased risk of diabetes, cardiovascular disease, stroke, hypertension, digestive disease, joint disorders and breathing problems (Votruba *et al,* 2000). In addition, overweight and obesity are established risk factors for cancer of the kidney, and it has been estimated that it may account for up to 30% of kidney cancers in both males and females (Bergstrom *et al,* 2001). Thomson *et al* (1998) reported that moderately obese individuals (aged 45-54 years) have a twofold greater risk of higher blood pressure, quarter higher risk of hypercholesterolemia and threefold greater risk of type 2 diabetes compared to normal non-obese individuals. When these disorders were included in the analysis, Segel *et al* (1994) estimated that 10% of deaths in 1989 were due to obesity related diseases. In turn this has a significant impact on the economy. Obesity accounts for between 2 and 7% of total health care costs in several developed countries (WHO, 2003). In 1995 the total cost, both medical and through loss of productivity attributed to obesity alone, was an estimated $99 billion in the USA (Wolf and Colditz, 1998). It has been estimated that the combined direct and indirect costs of obesity in England in 1998 was £2.6 billion (NAO, 2001), and it is reported that the complications associated with obesity account for 5-10% of all health costs in EU countries (Astrup, 2001). This trend is not only seen in Westernised countries. The development of obesity is increasingly associated with poverty even in developing countries (de Onis and Blössner, 2000; James *et al,* 2001).

As well as the physical disabilities, this disease is related to a number of psychological factors such as social stigmatisation, discrimination and low self esteem (Blackburn, 2001). Enzi (1994) investigated the psychological consequences related to obesity. It was concluded that obesity was associated with an increase in the risk of suffering from psychiatric disorders, reduced social, educational and employment status (despite there being no difference in intelligence between lean and obese). These factors relating to stigmatisation in the workplace, and society in general, result in a significant compromise in the quality of life.

The development of obesity is characterised by an imbalance (temporal) between energy intake and energy expenditure (Schrauwen and Westerterp, 2000). There is still uncertainty as to the aetiology of obesity. It has been reported that the primary cause must lie in the environment or behavioural changes (from epidemiological trends) since there are escalating rates of obesity occurring in a relatively constant gene pool (Prentice and Jebb, 1995). There has been a progressive reduction in the demands for physical activity with economic development. Along with this energy dense, high fat diets have become readily available and subject to aggressive promotion within society. The interaction between consumption of a high fat diet and the sedentary lifestyle is conducive to the development of obesity (James *et al,* 2001). Sonne-Holm and Sorensen (1977) reported that the increase in obesity observed between 1945 and 1975 in Danish men was paralleled by an increase in fat intake. However there is considerable inter-individual variability in body composition in individuals with similar diets. In the USA the prevalence of obesity is still increasing but intake of fat is reportedly decreasing (Kuczmarski *et al,* 1994). Therefore the relationship between fat intake and the development of obesity is still unclear. The total amount of dietary fat consumed remains a potent food related risk factor for weight gain, however the relationship does not constitute a biological certainty.

Obesity is a multifaceted problem. In order to gain an understanding of the mechanisms underlying its development, research must consider physiology, behaviour and environmental influences. This thesis will attempt to provide such a holistic approach in understanding the routes to obesity. Research of this kind is both beneficial on a human and economic level. This thesis will investigate the underlying causes and consequences of habitual food choice and attempt to gain an understanding of some of the important behavioural and psychological risk factors for obesity.

1.3 The concept of energy balance

' If energy intake of a subject equals energy output (expenditure) then he is said to be in energy balance and energy stores remain constant' (Garrow, 1974). A positive or negative energy balance can arise from changes in either energy intake (through modifications of the composition or energy density of the diet) or expenditure, both of which are controlled or influenced by complex psychological and physiological systems. This can be used to generate considerable energy imbalances in the short term (Blundell and Stubbs, 2002). In the long term humans defend against energy deficits regardless of body weight at the onset of the induced deficit (Garrow, 1988; Mela and Rogers, 1998). It has been proposed that evolution has selected our physiology and behaviour to favour overconsumption rather than under-consumption (Mela and Rogers, 1998). An asymmetrical system is observed- a system more responsive to deficits in energy and nutrient intakes than increments. Whether someone becomes obese under a given set of environmental and nutritional circumstances will be determined by an interaction between the behavioural response to the circumstances and the metabolic responses to the behaviour. This interaction determines how much and what type of energy enters the body and the fate of the energy within the body (Pagliassotti *et al,* 1997).

Both sides of the energy balance equation should be considered when trying to understand the development and maintenance of obesity. A positive energy balance can occur when energy intake exceeds energy expenditure. Prentice and Jebb (1995) argue that physical activity plays a key role in reducing energy needs. Being obese may therefore be a result of a largely 'normal' feeding response when exposed to a Western diet under modern sedentary conditions. Alternatively it may be brought about through maladaptive food choices and eating behaviours (Blundell and Stubbs, 2002).

1.4 Energy intake and the role of fat

The term 'energy intake' (that is fuel intake) concerns the quantitative aspects of consumption and the energetic value of food. In particular, importance is attached to the macronutrient composition of the food and its impact on energy balance (Stubbs, 1995; Blundell and Stubbs, 2002). This might be contrasted with the term 'feeding behaviour' (food intake), which is concerned with the qualitative aspects of eating such as food choice, habit, preferences and hedonic responses (which will be discussed in more detail later).

The total amount of energy ingested is directly influenced by the macronutrient composition of the diet. Epidemiological evidence supports the role of dietary fat in the aetiology of obesity, in that the prevalence of obesity is lower in countries characterised by a diet low in fat (Tataranni and Ravussin, 1997). Also cross sectional studies within a given population have shown that obesity is more prevalent among people whose fat intakes are high (Dreon *et al,* 1988; Romieu *et al,* 1988; Larson *et al,* 1995; Blundell and Macdiarmid, 1997). It should be noted here that this standpoint has been questioned. Willett (1998) argues that diets high in fat do not appear to be the primary cause for the high prevalence of excess body fat in society, stating that reported decreases in fat intake in the US are coupled with an increase in obesity. He also points out that in short term trials there appears to be compensatory mechanisms in operation because in trials lasting less than one year, fat consumption within the range of 18-40% of energy appears to have little effect on body fatness.

Seidell (1998) concluded that at present there is no conclusive evidence that dietary fat promotes the development of obesity independently of total energy intake. However it has been argued that the reason for this is not that dietary fat does not effect obesity, but that the absence of conclusive evidence might be explained due to the limitations of cross sectional studies, lack of controlled feeding trials and the implications of genetic variation in responses (West and York, 1998). It should also be pointed out at this point that if it is the average intake of the population which is taken into account, this may fail to indicate the behaviour of individuals in various states of energy balance and at different levels of body weight (Blundell and Cooling, 2000).

In response to the arguments put forward by Willett (1998), Bray and Popkin (1998) have stated that it is the total energy balance that matters most and the focus on dietary fat consumption must be seen through its effect on total energy balance. A major contributor to the frequency of obesity is a high energy intake brought about by an obesigenic environment (Egger and Swinburn, 1997). The prevalence of high fat foods is one characteristic of the food supply which has been identified as a likely promoter of increased energy intake and a positive energy balance (Blundell *et al,* 1992; Macdiarmid, 1996) either of the savoury (Cox *et al,* 1999; Westerterp-Plantenga, 1996) or the sugar type (Drewnowski *et al,* 1992). The processes whereby fat intake influences energy intake include the minimal appetite suppressant properties of dietary fat (limited satiating efficacy) and the high energy density, coupled with the high palatability associated with the ingestion of dietary fat, leading to passive overconsumption (Blundell, 1997).

1.4.1 Minimum appetite suppressant effects of fat (satiating efficacy)

Food varies in its capacity to effect appetite. This can be attributed to several properties of food, for example the energy content, taste sensation and physical properties of the food. Satiating power, or satiating efficacy, is the term applied to the capacity of any consumed food to suppress hunger and to inhibit the onset of a further period of eating (Kissileff, 1984). This is achieved through a number of mediating processes. The operation of these processes is generated by the impact of food on physiological and biochemical mechanisms collectively referred to as the satiety cascade (Blundell, 1991). The sensory effects relate to the experience of physical qualities of the food consumed. The cognitive effects relate to the beliefs held by the individual about the food. Post-ingestive (or pre-absorptive) are the effects prior to absorption across the gastrointestinal tract, and post absorptive are the effects brought about by the distribution of metabolites via the blood stream (see Figure 1.1).

Satiety and satiation act together to determine the pattern of eating behaviour and motivations. Satiation is the process that brings an eating episode to an end and satiety is defined as an inhibition of hunger and eating which maintains inhibition over further consumption. The conscious sensation of hunger is one index of motivation, and reflects the strength of satiation and satiety. The assessment of the impact of varying different food properties on satiation and satiety provides information that contributes to overconsumption. Identification and management of hunger appear to be important factors underlying the appetite function, and therefore should occupy an important position in the investigation and treatment of obesity.

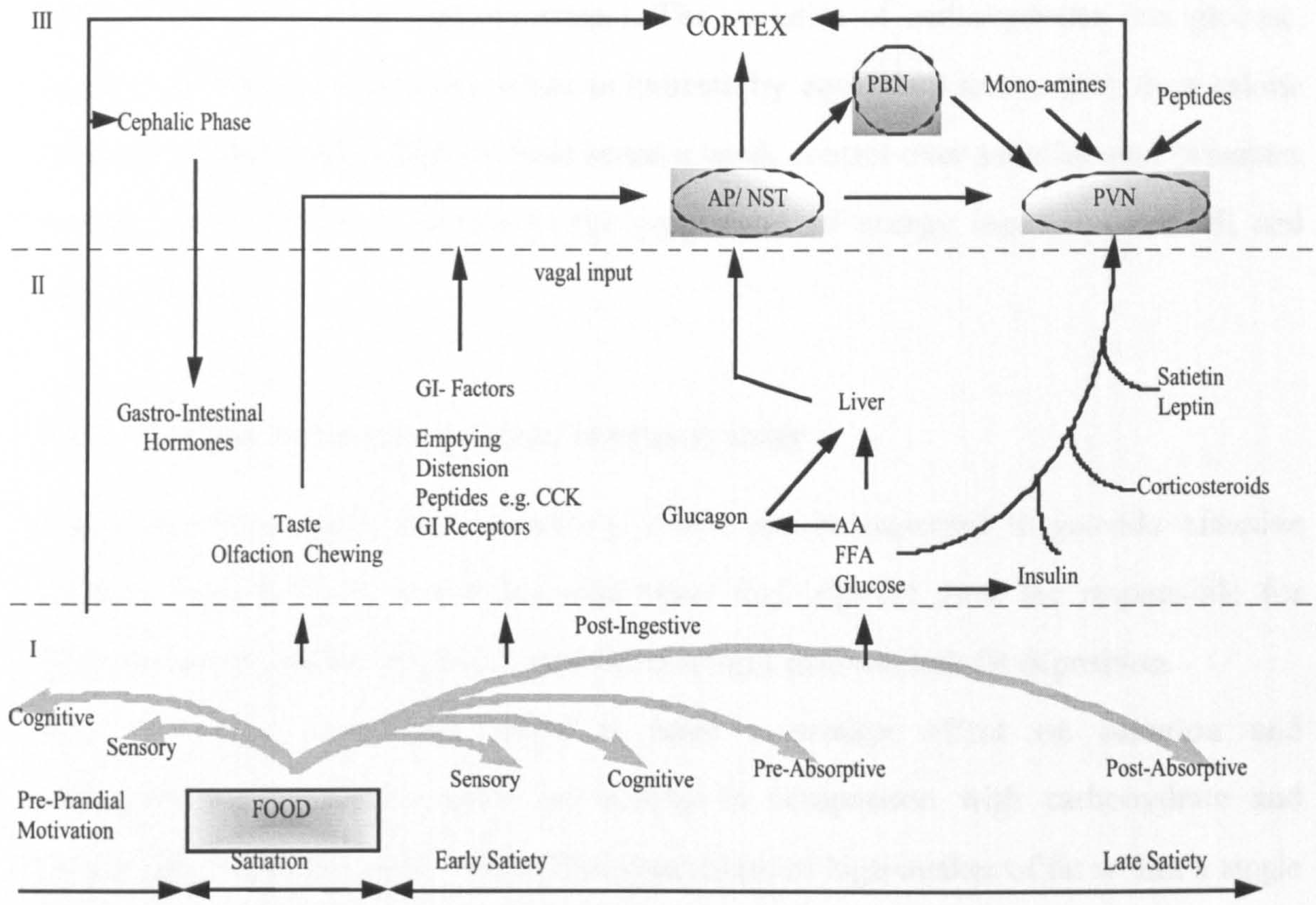

Figure 1.1 Conceptualisation of the appetite system revised from Blundell (1991)

The satiety cascade implies that food of varying nutritional composition will engage differently with the mediating processes. The dietary macronutrients have been shown to differ in their satiating power. Protein appears to exert the most potent control over appetite, suppressing hunger and food intake in excess of its contribution to total energy intake (de Castro, 1987). Carbohydrate also generates strong post ingestive satiety with the intensity and duration depending upon the particular structure of the carbohydrate. The mechanisms involved include glucoreceptors within the gastrointestinal tract, which send afferent information via the vagus nerve and splanchnic nerves, and glucosensitive cells in the liver, to the nucleus tractus solitarius and hypothalamic regions of the brain that monitor postabsorptive activity of glucose. These mechanisms contribute to the caloric control of satiety (or the energostatic control of feeding). Carbohydrates are known to be effective appetite suppressants due to their potent effects on satiety, and experimental evidence indicates that eating a high CHO snack and/or breakfast can significantly reduce daily fat intake, limit energy intake and in turn prevent weight gain (see Blundell and Le Noury, 2001 for review). It has also been identified that on a habitual basis, as carbohydrate intake increases, fat intake decreases (a reciprocal relationship between the macronutrients). The varieties of carbohydrates (i.e. glucose, fructose and sucrose) suppress intake in humans by equivalent amounts to their caloric values (Blundell, 1991). High fat food exerts a weak control over satiation and generates a weak satiety response relative to the proportion of energy ingested (Blundell and Green, 1994).

1.4.2 Passive overconsumption: energy density

Foods exerting a weak effect on satiety would not be expected to provide effective appetite control. There is a widespread belief that high fat diets are responsible for elevated energy intakes which in turn lead to weight gain through fat deposition.

High fat meals have been found to have a weaker effect on satiation and disproportionately weaker effect on satiety in comparison with carbohydrate and protein meals (Lawton *et al,* 1993). The observation of high intakes of fat within a single meal (eating episode) has been described as 'passive overconsumption' or high fat hyperphagia. This process is not observed with the other macronutrients. To help understand this the energy density of the macronutrients should be considered. Of the macronutrients, fat is the most energy dense (9.0 kcal/ g) compared to 3.75 kcal/g for carbohydrate and 4.0 kcal/g for protein. Blundell (1997) reported that subjects continue to eat similar amounts of food when presented with high fat, more energy dense diets; this being the reason for the elevated energy intake. Stubbs *et al* (2000) propose that energy density be defined in terms of the metabolizable energy per unit of weight of ready to eat food (foods which do not require any further preparation before ingestion). Protein and carbohydrate are shown to decrease the energy density of 'ready to eat' foods along with being more satiating. This can be contrasted with the effects of fat (and alcohol) which tend to be less satiating along with elevating energy density.

It should also be noted at this point that a growing amount of interest is observed in the development of a more sophisticated model in order to explain how dietary constituents effect appetite and energy balance. That is, to acknowledge that macronutrients *and* energy density effect energy intake, rather that substitute one over-simplistic model for another (Stubbs *et al,* 2000).

1.4.3 Passive overconsumption: palatability

The stimulation of overconsumption is further related to highly palatable foods. Yeomans (1996) showed how palatable foods influence subjective feelings of hunger and intake, entrained during the initial period of consumption. This is associated with faster eating rate and overall greater consumption within a single meal compared with less palatable food. Fat is responsible for texture, flavour and aroma therefore increasing palatability (Drewnowski, 1997).

In a subsequent study, Yeomans and Symes (1999) reported that foods which are more palatable increased overall food intake, and that subjective pleasantness ratings decreased across the duration of the eating episode. This decline in pleasantness between the start and end of the meal is consistent with the idea of negative gustatory alliesthesia (Cabanac, 1971) and could be interpreted as evidence that the decision to end a meal is hedonically driven (Cabanac, 1987) at least in normal subjects.

Mela and Rogers (1998) define palatability as a momentary subjective oro-sensory pleasantness of a food which indicates the sensory stimulation to eat. This may be influenced by the sensory attributes of the food (i.e. the fat content) but also the physiological state of the subject and the environment in which the food and subject interact (Cabanac, 1989). This highlights the importance of acknowledging individual differences. Preferences and response to energy density, for example, in foods may be effected by both the psychological and physiological dispositions of the subject (Stubbs *et al,* 2000). In the study by Mela and Sacchetti (1991) involving the investigation of taste preferences, the authors report a positive correlation between preference for high fat foods and percent body fat of the individuals. However, a causal relationship cannot be assumed. As yet it is unclear whether this taste preference leads to an increased risk of obesity or whether the development of obesity itself (the physiological state of being overweight) alters the initial taste preference. Although a recent study investigating taste preferences for dietary fat in monozygotic twins suggests that taste preference itself is a risk factor for obesity. Sets of twin, discordant for obesity, were asked questions concerning past and present preference for fat. It was found that obese twins reported a current preference for fatty foods three times more frequently than lean co-twins did. More importantly, both twins consistently recalled that obese twins had a greater preference for fatty foods in young adulthood compared to the leans. It was concluded from this study that independent of genetic background, acquired taste preferences for dietary fat was associated with obesity (Rissanen *et al,* 2002). That is, the acquisition of the taste preference must be environmentally driven putting an individual at risk of obesity. However it is still unclear what factors are involved in the initial development of this taste preference.

1.5 Appetite, food intake and food choice

The relationship between fat intake and the risk of obesity has previously been discussed. However it is also important to try to understand the determinants of food choice. Why do some individuals habitually choose a diet, particularly high in fat, in light of what is known in terms of the health risks?

Human appetite is controlled by a complex matrix of factors within a psycho-biological system that represents the interaction between physiological processes in the body and brain, and the social and physical environment (Blundell, 1991a; Blundell, 1991b). Biological influences include physiology, metabolism, reward mechanisms, nutritional deficits, hunger and genetics. Environmental influences include childhood experience (even the pre-natal environment), economic status, food availability, attitudes and learned preferences. Within the broad limits of biology, individual food choice and intake behaviour reflect aspects of food availability, existing habitual behaviours, learning mechanisms and individual beliefs and expectations (Mela, 1999).

These factors in effect provide an opportunity for individuals to establish and maintain a relatively stable set of culturally and biologically determined affective responses (likes) and habitual behaviours (Rozin, 1990). It is important to try to understand which of these influences and sub-factors are important in determining or predicting human food choice. This also illustrates the possibility of multi-factorial determinants of food choice whereby any one factor may be limited in overall effect (see Figure 1.2; adapted from Mela, 1999).

Food choice leads to food consumption. This behaviour will determine an individuals eating pattern and energy/macronutrient intake. This may be conscious or may have become so engrained that it is no longer under the conscious awareness of the individual; that is it has become a habit.

Investigating the underlying mechanisms (whether biological or environmental in origin) is of importance to help understand individual differences in food selection. Understanding why someone chooses a certain pattern of eating behaviour, which puts them at risk of obesity, will help in the development of more accurate prevention and intervention programs.

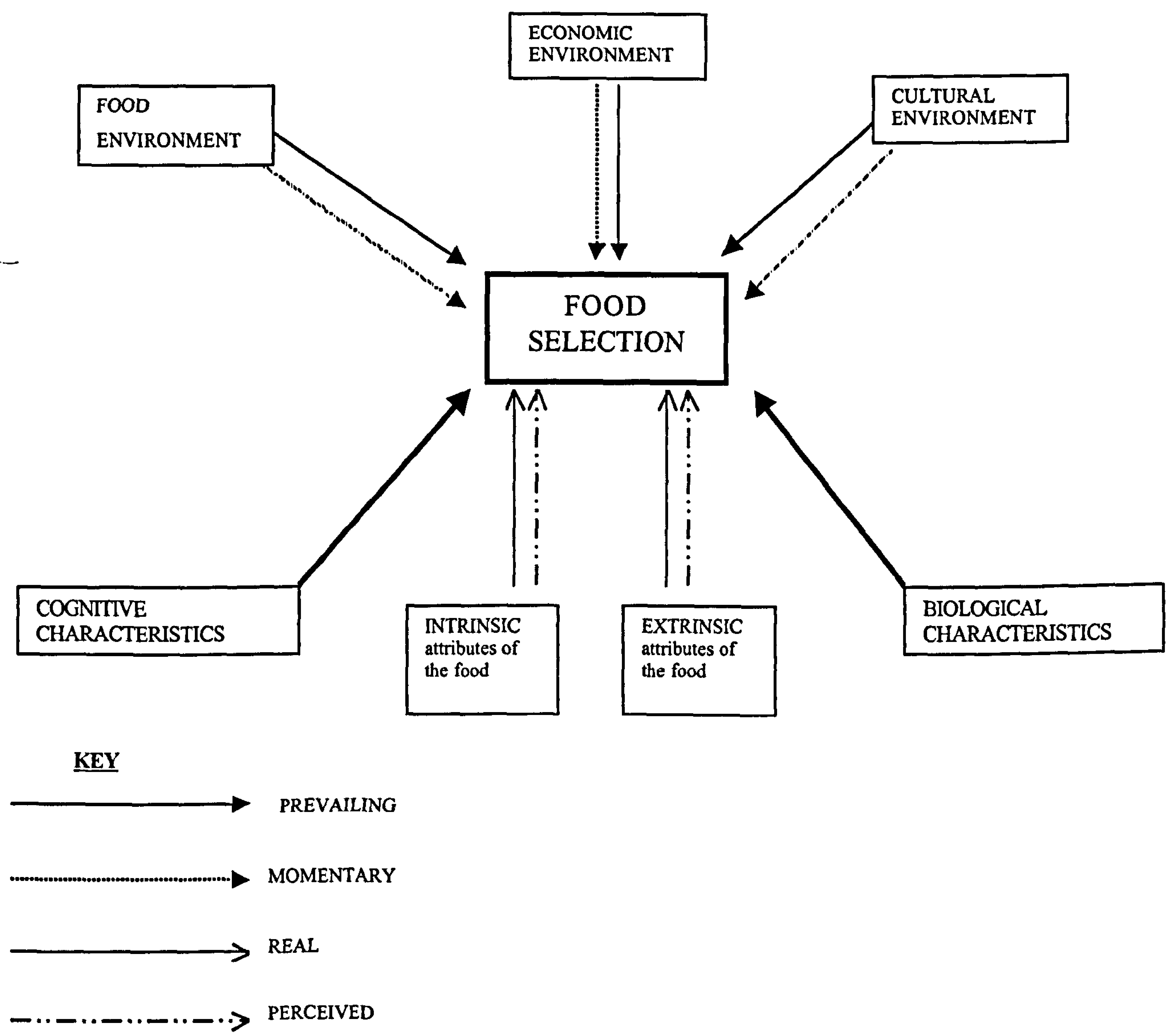

Figure 1.2 External and internal influences on human food selection

1.5.1 Hedonics

It can be argued that appetite (desire or liking) is the hedonic dimension of human eating behaviour. The hedonic response may be interpreted in two ways. First as a reward mechanistic response, that is more closely linked to biological neurotransmission systems such as dopamine and its receptors for example. Second as a taste preference, that may be directly learned from the environment.

Berridge (1996) proposed that food reward in itself consists of two components: psychological (liking) and functional (wanting). 'Liking' corresponds with the concept of pleasure and palatability (as previously discussed), and 'wanting' corresponds with incentive motivation and craving, both of which can be manipulated and measured separately. 'Liking' and 'wanting' are believed to have separate neural substrates. Liking is thought to be related to the neurotransmitter systems such as the opioid and GABA/benzodiazepine systems. It has been proposed that the primary role of the opioid peptide system is in mediating overeating that is associated with exposure to palatable (Mandenoff *et al,* 1982) or high fat foods (Romsos *et al,* 1987), therefore may be involved in this pleasure (liking) response to food (Drewnowski *et al,* 1992).

In contrast, the mediation of 'wanting' involves mesotelencephalic dopamine systems. Dopamine has been linked to the regulation of food intake (Balcioglu and Wurtman, 1998) by modulating food reward via the mesolimbic circuitry of the brain (Martel and Fantino, 1996; Wang *et al,* 2001). However, a direct link between dopamine and obesity is still poorly understood (for a detailed review see Berridge and Robinson, 1998).

Another important point highlighted by Berridge (1996) is the fact that liking and wanting can exist without subjective awareness. Conscious experience may distort the underlying reward process. Therefore when researching the reward response in human subjects it should be kept in mind that subjective reports may contain false assessments of the actual underlying processes.

The hedonic response to food (and in turn habit formation) may originate from learned preference conditioning. Sensory preference conditioning may be established by pairing specific qualities with positively rewarding physiological and psychological outcomes. This has been demonstrated relatively easily in a number of animal studies through flavour preference conditioning (see Sclafani 1990; 1997) and slightly fewer in humans (see Birch *et al,* 1990; Johnson *et al,* 1991).

Blundell and Stubbs (2002) propose that obesity may be brought about by hedonically mediated maladaptive food choice, and likes and dislikes may be a result of experience and/or associations of sensations with other food properties or eating contexts (Mela and Rogers, 1998); a process brought about through conditioning. So do we eat what we like or like what we eat? Increased exposure to food types may come to be liked and preferred over initially equivalent (or even initially preferred) alternatives (Pliner, 1982; Birch *et al,* 1987, 1998). So the influences of food availability, habit formation and individual differences are highlighted.

1.5.1.1 Habit

It might be proposed that food availability sets the stage for all other influences on food choice and intake (Mela, 1999). The acquisition and reinforcement of a stable set of preferences (likes and dislikes) along with habitual intake behaviours is provided by the food environment (Rozin, 1990). Habit might therefore be defined as a long established core dietary pattern, brought about through repeated exposure (Triandis, 1977), eventually leading to a behaviour that is automatic or out of awareness (Saba *et al,* 1999). As previously stated habitually consumed items can come to be preferred over equal alternatives. Food choice decisions, social situations, post-ingestive physiological consequences and other cues may all contribute to the increased likelihood of exposure to such food items.

Individual habits have important implications for the prevention and treatment of obesity. It has been proposed that changing someone's diet may be achieved through either changing their habits, beliefs or by changing the food availability (i.e. through competitive marketing for example). However the stability of food patterns highlights potential barriers to the introduction of novel concepts which are too far removed from the existing behaviour (Mela, 1999) particularly in adulthood.

1.5.1.2 Individual differences

As previously touched upon, taking into account individual differences when researching hedonic response is very important. The physiological state of the subjects and the environment in which the food and subject interact may have an important contributing effect (Cabanac, 1989). Addressing individual differences in nutritional status, that is lean versus obese for example, highlights this. Is obesity associated with greater pleasure from food? Saelens and Epstein (1996) found that in obese women food reward resulted in greater reinforcement value, suggesting a possible link between hedonic response and obesity.

Individual difference may be one of the reasons behind the lack of clear consensus in this area of research. Any kind of manipulation may have equal intensity effects but in opposite directions in particular subgroups. This therefore results in only a small (and often non-significant) overall mean population effect. By highlighting subgroups within the population from the outset this problem may be overcome.

Kosslyn *et al* (2002) argue that group data should be used in conjunction with individual differences research (not disregarded as 'noise') and by combining the two methods provide a powerful tool for linking psychology to biology. It should be acknowledged that individuals (of the same species) share the same fundamental and biological mechanisms which are often complex (as in the appetite control system). Therefore individuals may differ in how they use certain mechanisms as well as how often they use them. Therefore, by researching individual differences in eating behaviour (and other behaviours) it is possible to provide a much richer insight that will help in the understanding of such disorders and the development of more successful intervention and prevention programmes.

1.5.2 Attitudes

Genetic factors are seen to explain only a small part of family resemblance of overall food preferences (Rozin and Millman, 1987; Borah-Giddens and Falciglia, 1993). It has been proposed that social factors are more important than genetic factors for the development of individual differences in food preference (Rolls, 1988; Rozin, 1990). In order to understand why people eat too much fat, for example, Stafleu *et al* (1994) suggest looking at the relationship between social-psychological variables and food intake; this includes the influences of eating attitudes and beliefs.

The Theory of Reasoned Action proposed by Ajzen and Fishbein (1980) states that behaviour is predicted by the conscious decision to perform the action (behavioural intention), which in turn is predicted by a combination of people's attitude towards performing the behaviour, and their perception of the social pressure put upon them to perform the behaviour (subjective norm). One way in which to change people's habits (behaviour), therefore, is by changing their attitudes (Ajzen and Fishbein, 1980).

The fat content of the diet is just one of the many choices individuals are faced with on a day-to-day basis. Attitudes towards high fat and low fat foods may play an important role in making these choices. It might therefore be predicted that people with a positive attitude towards high fat foods would consume a high fat diet. However the relationship between attitudes and eating behaviour is still unclear.

Barker *et al* (1995) found that in women, fat phobic attitudes were inversely related to fat intake. However this was contrasted to the results found in men whereby a weak correlation between fat phobic attitudes and fat intake was found. Lloyd *et al* (1993) investigated attitudes and behaviour using an attitude questionnaire and a food frequency questionnaire. They divided the 665 respondents into tertiles for percent energy from fat (low, medium and high fat intakes) and found no consistent differences in eating attitudes and beliefs of the respondents. Story and Resmick (1986) found that US high school students were well informed about health and nutritional practices but did not translate this knowledge to their own food choice behaviours.

In contrast Shepherd (1990) proposed that information on peoples attitudes and beliefs is crucial in order to define food choice patterns and food consumption patterns. It has been concluded that attitudes are a good predictor of the consumption of foods with a high fat content (Shepherd and Stockley, 1985; 1987) and in a subsequent study Shepherd and Towler (1992) found a weak correlation between nutritional knowledge and behaviour but a strong correlation between attitude and behaviour.

From previous qualitative analyses examining the way people make food choices it was revealed that all participants used a personal food system, which consisted of a dynamic set of processes (values) constructed to enact food choices. For example, most frequently considered values were health, taste and convenience. It was proposed that events and experiences throughout the life course help to shape food choice values through the influence on ideals, beliefs, eating attitudes, social relationships and food contexts (Furst *et al,* 1996; Conners *et al,* 2001). Value negotiation was found to be important in the personal food system with categorization, prioritisation and balancing processes playing a dynamic role. Understanding which values are important (and under which set of circumstances) to which individuals and how these values are managed was proposed to be very important in the understanding (and prediction) of food choice behaviour (Conners *et al,* 2001). Therefore the investigation of the relationship between values, attitudes and behaviour is necessary in order to establish whether food choice is influenced primarily by socio-cognitive factors or whether the psychobiological stance is a better explanation.

As noted earlier, in adopting an energy balance model for the understanding of weight control it is impossible to consider food intake (eating patterns, food choice, hedonics and palatability) independently of energy expenditure. Individuals with particular eating patterns or food choices may have specific patterns of physical activity or physiological regulation of metabolism. Therefore it is necessary, wherever possible, to monitor the characteristics of energy expenditure alongside food intake. This is particularly important for the purpose of this thesis where the focus is upon the 'phenotype'.

1.6 Energy expenditure and energy balance

It is unclear whether chronic excess energy intake or a defect in energy expenditure, or a combination of both is responsible for the increase in body fatness. Therefore the role of energy expenditure must also be taken into account when considering the mechanisms of energy balance as a whole. Total energy expenditure can be broken down into three main components. First 'metabolic rate' which includes basal metabolic rate, sleeping metabolism and arousal metabolism. Second, the 'thermic effect of feeding' (or dietary induced thermogenesis) and lastly the 'thermic effect of activity' (Mcardle *et al,* 1991), which shall each be addressed in turn (see Figure 1.3). Defects can be observed in any of these components. Energy expenditure represents the oxidation of substrates in the body. Substrate oxidation is dictated by the body's need to generate energy (through ATP hydrolysis) which is used to perform metabolic functions, in maintaining body temperature and moving at different rates depending on the size and physical activity levels of the individual (Astrup *et al*, 1996).

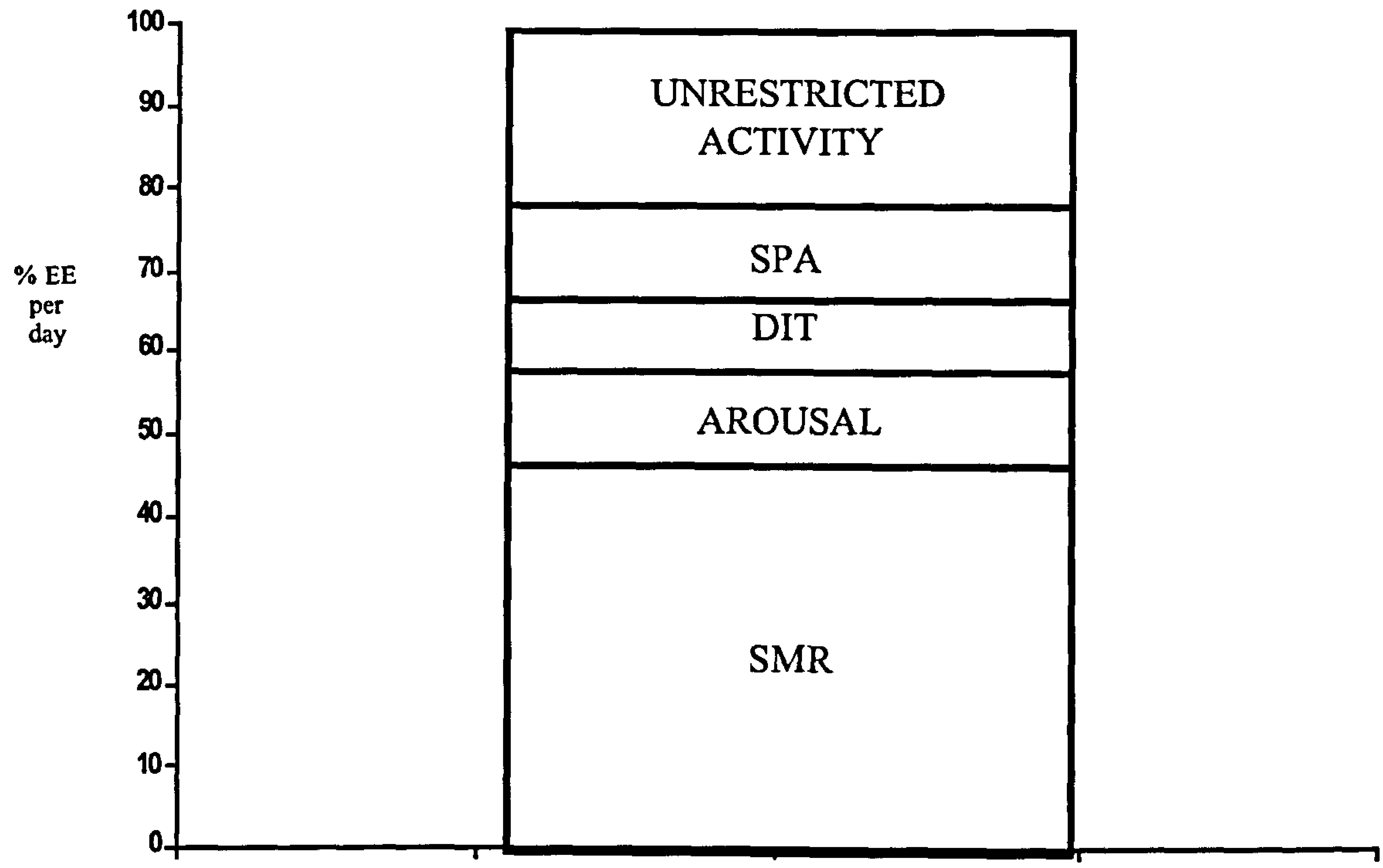

Figure 1.3: Components of total daily energy expenditure - y-axis shows % of daily energy expenditure (from Ravussin and Swinburn, 1992).

1.6.1 Metabolic rate

Basal metabolic rate (BMR) (or resting metabolic rate, RMR) can be defined as the energy necessary for the maintenance of normal physiological processes in an individual resting in a fasted state (Prentice *et al*, 1986; Hill, Rodgers and Blundell, 1995a). This varies with the amount and composition of total body tissue. Values are also slightly different depending on whether the individual is sleeping (SMR) or awake (AROUSAL). BMR is a combination of SMR and AROUSAL. Fat free mass is shown to correlate strongly with BMR, as it is metabolically active tissue (Ravussin *et al*, 1986). However only 60-80% of between subject variability in BMR can be explained by differences in fat free mass (Ravussin *et al*, 1986). BMR is also dependent on a number of factors such as age, gender, fat mass and genetic factors.

1.6.2 Thermic effect of feeding

Dietary induced thermogenesis (DIT) can be defined as the increase in energy expenditure that occurs after ingestion of food and represents the cost of absorption, digestion, metabolism and storage of ingested nutrients. This accounts for 10% of total energy expenditure. It has also been found to be sensitive to manipulations in the diet since the cost of metabolising protein, carbohydrate and fat differ (Hill *et al*, 1995a).

1.5.2.1 Storage capacity & oxidation rate of fat

In order to understand why there is so much interest in fat and weight regulation, the properties and metabolic fate of each macronutrient must be considered and compared. A positive balance of the macronutrients carbohydrate and protein leads to a rapid oxidation of these nutrients. A positive balance of fat, however, does not promote fat oxidation but leads to fat storage. It takes approximately 3-5 days for fat oxidation to sufficiently increase in order to cope with the excess fat consumed and in some studies even longer (Tataranni and Ravussin, 1997). Thomas *et al* (1992) observed that following a high fat diet, subjects tended to increase lipid oxidation rates after 7 days. However, this was only true for the lean volunteers. Obese subjects showed no relationship between fat intake and oxidation. Therefore it should be noted that Tataranni and Ravussin point out that although increased adiposity represents a common response to an increase in fat intake, there are inter-individual differences in lipid oxidation (probably genetically determined) protecting from or predisposing to obesity.

DIT comprises of two parts. First is obligatory thermogenesis which is related to the energy cost of digesting, absorbing, processing and storing nutrients. The second part represents the capacity to burn excess calories in a situation of excess energy intake, a mechanism thought to be due to the stimulation of the sympathetic nervous system (Saris, 1996). This process has been termed ' luxusconsumption'.

Westerterp, Wilson and Rolland (1999) found that the macronutrient composition of the diet had a direct impact on the magnitude of DIT, such that DIT was higher in all subjects while on a high protein/high CHO diet compared to a high fat diet. The dietary manipulation did not effect 24-hour energy expenditure but a trend was observed toward a higher energy expenditure on a high protein/high CHO diet. Therefore the macronutrient composition of the diet may contribute to the development of obesity.

The heritability of DIT is estimated to be at least 30% and impaired DIT response is implicated in the pathogenesis of obesity (Bouchard, 1996). However due to large coefficients of variation when measuring DIT, much data show conflicting evidence and it has been argued that the relatively small contribution to total energy expenditure means that it may not play a major role in the control of body weight.

1.6.3 Physical Activity

Total physical activity is the most likely source of individual differences in energy requirements. Hill *et al* (1995b) stated that exercise (i.e. frequency, intensity and duration) and individual characteristics (i.e. body weight, composition and fitness level) all influence the exact amount of energy expended during physical activity.

The energy cost of physical activity represents the total amount of external work performed by the body. This incorporates both spontaneous activity (SPA) and deliberate exercise (unrestricted activity). Physical activity is the most variable component of TEE and can account for a substantial portion of TEE in very active people, sometimes amounting to 5000-6000 kcal per day (Westerterp *et al*, 1986).

Levine *et al* (1999) propose that the best predictor of inter-individual differences in fat gain during overeating is, in fact, the amount of physical activity triggered by excess food. This physical activity, which is termed non-exercise activity thermogenesis (NEAT), encompasses the energy cost of activities of daily living, as well as all non-volitional activity (i.e. fidgeting).

Low physical activity levels have been identified as a greater risk factor for excess weight gain compared to the habitual diet (Rissanen *et al*, 1991) through significantly reducing energy requirements (Prentice and Jebb, 1995). The Allied Dunbar (1992) study found that 80% of men and 90% of women are employed in sedentary (inactive) occupations (i.e. office workers) in the UK. In addition to this, 30-35% of men and women had taken part in less then four 20min sessions of moderate exercise in the previous month vastly reducing their overall energy requirements, therefore putting themselves at risk.

1.7 Obesity, energy balance and food choice

The two major factors identified as important for inducing a positive energy balance and obesity are high levels of sedentary behaviour (low physical activity/energy expenditure) and a high intake of high fat foods (high energy intake). However both the amount of physical activity and the consumption of dietary fat show substantial individual variability. For example, it is possible to identify contrasting subgroups of the population defined in terms of their habitual fat intake (behavioural phenotypes). These individual differences will become the focus of research in this thesis. Inter-individual variability in habitual dietary patterns and food choices do confer different properties on behaviour, which has implications for body weight regulation. By identifying individuals who are at risk from obesity (high fat phenotypes) it is possible to investigate the important factors involved in the food selection process (antecedents to food choice) and the consequences of these food choice behaviours. Specifically, this can be achieved by highlighting those factors (whether psychological, environmental or physiological) that put an individual at risk or, in fact, protect against the weight inducing properties of such a diet. This strategy will help in the understanding of the aetiology, and more importantly, the prevention of obesity.

Chapter 2

THE HIGH FAT & LOW FAT PHENOTYPE

2.1 High fat & low fat phenotypes

Considerable evidence therefore indicates that the total amount of dietary fat consumed remains one of the most potent food related risk factors for weight gain. However, although a high fat intake is a strong behavioural risk factor for obesity, the relationship is not biologically inevitable. In order to understand this more fully it is proposed that the identification and understanding of the characteristics of certain subgroups of the population (phenotypes) who are at risk from weight gain (i.e. through their food choices), provides a very useful research tool.

Identification of the high fat (HF) and low fat (LF) phenotype allows a more in depth investigation of specific subgroups of the population and can be contrasted with the study of random samples of the population as a whole. The identification of phenotypes to study specific disorders is not a new concept. Baghurst *et al* (1994) investigated the attitudes, demographics and nutritional characteristics of habitual high fat and low fat consumers. Male HF (>38.6% energy from fat) compared to average fat consumers, were less likely to have altered their diet recently. They associated poor health with 'bad luck' rather than with factors that they had control over (such as eating habits, smoking and body weight). The reverse was true for LF consumers (<29.7% energy from fat).

Hulshof *et al* (1992) clustered dietary intakes and lifestyle variables in a Dutch study. Two groups of HF were identified; those with a high alcohol intake versus those with a low alcohol intake. HF/high alcohol were more likely to be male, middle aged and smokers and less likely to eat breakfast compared to the rest of the population. HF/low alcohol were more likely to be female, lower socio-economic status and obese.

2.1.1 Dietary and Nutritional Survey of British Adults

Macdiarmid (1997) conducted a series of studies investigating HF and LF consumers in a similar way to the comparison between the lean and obese. These studies were designed to explore the relationship between fat intake and obesity, and to investigate eating patterns and food choices made by HF and LF consumers. The Dietary and Nutritional Survey of British Adults (DNSBA) was conducted by Gregory *et al* (1990). It consisted of a database of nutritional information on 2197 adults in the UK aged 16-60 years between 1986-1987. A seven day weighed food diary, anthropometry, smoking habits, alcohol consumption and socio-economic variables were recorded. This database was reanalysed by Macdiarmid, Cade and Blundell (1996). The study aimed to explore different characteristics of HF and LF consumers in terms of their macronutrient intake and body mass index. In order to do this a dual system was used whereby HF and LF were classified in terms of their percentage fat intake as well as their absolute fat intakes. HF were classified as consuming >45% energy from fat and >138 g/d for males (>120 g/d for females). LF were classified as consuming <35% energy from fat and <85g/d for males (<70 g/d for females). From the re-analysis of the data, 1240 (57%) of the subjects were retained. Slimmers, the ill and those with an energy intake to BMR ratio of less than 1.2 were excluded (the main predictor of underreporting). 191 HF (93 male; 98 female) and 134 LF (76 male; 58 female) were then included in the analysis.

Total energy intake did not differ between consumers when defined by percentage fat. When defined as an absolute fat intake (in grams) HF had a higher total energy intake. The main sources of fat in the diet of HF were from meat and meat products. In LF, it came from cereal products (including cakes and biscuits for example).

This study showed that mean BMI was higher in HF and regardless of the classification, there were significantly more obese individuals in this group compared to LF. Many studies showing a positive relationship between dietary fat and BMI have also been reported (Lissner *et al,* 1987; Tucker and Kano, 1992). For example, Bolton-Smith and Woodward (1994) reported a large study that revealed a positive association between dietary fat (expressed as a percentage) and obesity but a negative relationship between obesity and sugar intake. The HF group in the study carried out by Macdiarmid *et al,* (1996), however, did contain a wide range of BMIs and included individuals with a very low BMI. The low fat group, on the other hand, had a smaller range of BMI and low prevalence of obesity. The distinction between the two groups of consumers was not as great as would be predicted on the basis of theories concerning dietary fat, fuel balance and adipose tissue storage. It could therefore not be concluded that a high fat diet inevitably induces obesity.

2.1.2 Leeds High Fat Study (LHFS)

The aim of a second study carried out by Macdiarmid (1997) was to identify a cohort of HF and LF in a random sample of the Leeds community who were potentially at risk from weight gain. HF and LF were defined in terms of their percent energy from fat, >45% and <35% respectively. In the study 87 male and 69 female HF, and 167 male and 201 female LF volunteers took part. It was found that BMI was positively associated with a high fat consumption but the relationship was weak. HF were more likely to be alcohol drinkers and smokers, more likely to skip breakfast, had lower reported levels of physical activity, lower dietary restraint and poorer nutritional knowledge. No significant differences were found in social class or level of education between consumers. HF liked high fat foods more and low fat foods less compared to LF. These findings were consistent with those of the DNSBA. HF displayed distinct eating and behaviour patterns compared to LF. These clusters of characteristics have now been termed 'behavioural phenotypes'. It was concluded that these findings supported the use of the HF and LF phenotype in order to address the relationship between fat intake and obesity. Macdiarmid (1997) also highlighted a possible methodological limitation associated with the use of the phenotypes. Bouchard (1994) stated that if the focus of a study is a phenotype that is only approximated instead of being directly measured, or if the phenotype is one which varies considerably over days, months or years in a person, then the value and power of the study may be greatly diminished. This highlights the necessity to identify such phenotypes, in terms of their dietary intake, with precision. However, the associated problem of under-reporting also needs to be acknowledged and addressed carefully. This will be discussed in more detail in Chapter 4.

2.1.3 Physiological Findings

The appetite control system has been investigated in lean HF and LF. Differences in hunger profiles in response to variable energy loads and macronutrient challenges (high fat and high CHO) have been displayed. The hunger response was found to be more sensitive in HF. A higher initial hunger level with a much sharper decline in hunger response to meals or nutrient loads was displayed in HF (Cooling and Blundell, 1998a). After eating, hunger was found to recover more rapidly in HF compared to LF. HF have also been found to display a greater level of hunger following a low energy lunch, greater range of hunger extremes and an increased capacity to overconsume fat compared to LF. When offered a range of high fat and high carbohydrate foods *ad libitum*, HF and LF differed in control over the meal size. HF consumed a similar weight of food for both food types, therefore consuming a greater amount of energy with the high fat (energy dense) foods. This can be contrasted to the LF group who consumed a smaller amount of high fat foods and consequently took a similar amount of energy regardless of the macronutrient composition. It was concluded from this study that the signalling systems for meal termination (satiation) and post meal inhibition of appetite (satiety) operate with differing strengths in HF and LF phenotypes (Cooling and Blundell, 1998a). Interestingly, a study of differences across an unrelated population would have failed to identify these individual differences, resulting in the occurrence of a type II error (Kosslyn *et al*, 2002). By studying individual differences in the context of general theories, an understanding of why some stimuli evoke different responses in different people might be exploited.

HF and LF showed no significant difference in pleasantness ratings for fat content and sugar. It was concluded from this study that factors other than taste were responsible for selection of the habitual diet. It was proposed that cognitive factors (such as learning experience, social desirability and appropriateness) combined with economic factors at least partly determined food choice (Cooling and Blundell, 2001).

A number of metabolic and physiological characteristics have been researched using the phenotypes as an investigative tool. HF have been showed to have significantly higher BMR and resting heart rates compared to lean LF, despite no significant difference in body weight and composition (Cooling and Blundell, 1998b). Heart rate was monitored continually for three 24 hour periods and minute by minute measures were converted to energy expended. This was achieved using the flex heart rate method, after calibrating heart rate against energy expenditure using indirect calorimetry during seven stages of activity from resting to vigorous running (Spur *et al*, 1988). During the waking hours HF showed three distinct peaks of heart rate, which appeared to correspond to mealtimes, and may indicate the dietary induced energy expenditure (thermogenesis) associated with large meals (Cooling and Blundell, 1998b). Physical activity was also measured using the factorial method (Bouchard *et al,* 1983). LF was found to be slightly more active but the differences were not found to be significant.

HF have been found to have significantly lower RQ (indicating a higher capacity for fat oxidation) as would be expected due to the habitual high intake of fat containing food. This indicates that HF are able to raise fat oxidation to match high fat intakes.

Cooling *et al* (1998) found that despite having very similar levels of body fat, HF had higher plasma leptin levels than LF. These mechanisms might partially offset the weight inducing properties associated with a high fat diet, by providing an increased energy expenditure. This indicates that HF and LF may prove to be a useful tool for the examination of the relationship between energy intake and energy utilisation.

Biological differences in appetite control may underlay in part the development of HF and LF. For example, de Castro (1993) found a correlation between fat intakes in genetically identical twins. Fisher and Birch (1995) found that high fat food preferences and fat intake in children correlated with parental body fat. An alternative explanation might lie in the physiological response to food ingested. This differs with different diets causing an adjustment of the operation of the appetite control system.

Protective physiological mechanisms have been observed that help HF deal with high fat/high energy intake and protect against weight gain. However, these findings are still restricted to lean young males. As yet, there is no evidence for the long-term effectiveness of this protection or whether these mechanisms apply to older phenotypes or women.

2.2 Different 'routes' to obesity

It has been shown that the habitual consumption of a high fat diet and its relationship to obesity does not constitute a biological certainty. A low fat diet does seem to protect against obesity but a high fat diet does not guarantee that the person will become obese. The idea of different routes to obesity has since been proposed (Blundell and Cooling, 2000). The question remains as to whether an environmentally driven diet selection leads to protective physiological adaptation, or a biologically driven energy expenditure leads to an appropriate diet selection.

There are two main routes to obesity that can be highlighted. The first is the 'metabolic' route to obesity. The tendency to gain weight can be associated with low BMR, low energy cost of physical activity, low capacity for fat oxidation (i.e. high RQ), low sympathetic nervous system activity, low plasma leptin concentration and high insulin sensitivity.

The second route to obesity can be termed as 'behavioural'. This includes preference for fatty foods, weakened satiation, relatively weak satiety, strong oro-sensory preference, a binge potential and a high food-induced pleasure response. These factors might have a direct influence on food choice and be regarded as biological dispositions that create vulnerability for weight gain, manifesting themselves through the behavioural acts themselves. It might be noted that these are unlikely to lead to a positive energy balance in a benign environment.

A positive energy balance can be achieved through a wide range of diets that result in energy intake exceeding energy expenditure. The type of diet that causes an individual to gain weight may depend on the individual's particular physiological profile. Some people may be better equipped to deal with high fat, high energy dense diets due to genetic determination, physiological adaptation or nutrient-gene interaction.

Taking these routes to obesity into account, HF and LF differ in terms of their metabolic and behavioural characteristics and are therefore at risk of weight gain from different means. HF consume a higher intake of fatty food and overall a higher energy intake (by definition). The cost of digesting and assimilating fat is lower than protein and carbohydrate, therefore requiring less energy. Furthermore, HF have overall lower physical activity energy expenditure which can be characterised by greater periods spent in sedentary behaviour. However, these risk factors appear to be compensated for by an increased BMR and heart rate, along with a decreased RQ (increased fat oxidation) and higher leptin levels.

LF, on the other hand, are protected from weight gain by their selection of a low fat diet and increased physical activity. However LF have a lower BMR, a higher RQ and higher insulin sensitivity, which are regarded as predictors for weight gain. LF are likely to resist weight gain as long as their eating and physical activity behaviour remains constant. It can therefore be said that HF are behaviourally at risk from weight gain and LF are metabolically at risk from weight gain.

Research strategy focusing on specific behavioural phenotypes can help our understanding of the factors leading to weight gain by drawing attention to the interaction between individual differences in physiological features and behaviour variables, and its relationship to energy balance (Blundell and Cooling, 1999). To understand the underlying mechanisms involved in food choice, individual differences need to be taken into account. The identification and comparison of individuals with contrasting habitual dietary habits has indicated how different combinations of behavioural and physiological profiles can produce apparent energy balance (at least in the short term) and weight stability. This suggests an example of the use of individual differences alongside group effects, to investigate underlying operating processes (Kosslyn *et al,* 2002).

This thesis aims to take this further and investigate in more depth the antecedents of food choice. What are the important factors influencing the development of such contrasting dietary habits? Measurement of different types of foods habitually selected poses the question of whether 'choices' are biologically driven (tissue needs, physiological requirements or neurosensory characteristics) or learned from the environment.

Secondly, through the identification of a third behavioural phenotype, underlying mechanisms rendering individuals vulnerable to obesity may be investigated further. Not all HF are protected from the weight inducing properties of a high fat diet. This was clearly seen from the results of the DNSBA whereby a larger proportion of HF were found to be overweight. It is still unclear what the key physiological and behavioural features are which make an individual vulnerable to weight gain. Identification of such traits will help diagnoses of susceptibility or resistance to weight gain and obesity on a high fat diet. By linking psychology and biology in a way that respects such individual differences, implications for treatment programmes could be profound (Kosslyn *et al,* 2002). That is, different treatment programmes may be more or less appropriate for different people. In the longer term, for example, by having the option to customise dietary interventions in a way that is appropriate to the individual, may result in higher weight loss success rates.

This research area offers the potential for biological and environmental explanations for food choice by identifying the causes underlying opposing types of food selection within the same cultural and economic group. In this area, food choice phenotypes may be useful tools to explore processes underlying the patterns of behaviour and to investigate the consequences of the habitual dietary intake.

Chapter 3

AIMS & OBJECTIVES

3.1 General aims of the thesis

The use of the 'Food Choice Phenotype' as a research tool is a method whereby individual differences may be studied within the framework of general theory of the population as a whole. It was stated by Underwood (1975) that individual differences provide a unique opportunity to test a wide range of psychological theories. Individual differences reveal the structure of the psychological function and may provide more robust insights than conventional group based methods offer. However, Kosslyn *et al* (2002) emphasise that in order to understand the connections between psychology and biology, individual differences should be considered within the context of general mechanisms (i.e. address individual variation *alongside* groups studies).

The 'food choice phenotype' (HF and LF) may be defined in two ways. Firstly as distinct separate categories or alternatively as behavioural traits at opposite ends of a continuous dimension (that is, fat intake). Given how dynamic eating behaviour is on a day-to-day basis, the latter maybe a better representation of this complex set of behaviours.

The primary aim of this thesis is to make use of the tool of behavioural phenotypes to help advance the understanding of the mechanisms that determine why a habitual high fat diet is preferentially selected by some individuals but not by others. By comparing lean HF and LF males the underlying factors effecting food choice may be investigated. If it is the case that one 'phenotype' relies predominantly on one 'strategy' (i.e. combination of processes) whereas the other habitually relies on an alternative 'strategy', then pooling data from both groups may be uninformative and even misleading. Therefore by highlighting these two subgroups, an understanding of not only the important mechanisms involved during the food choice process might be revealed, but also how these mechanisms interact. This work will help to improve the diagnosis of those at risk of obesity and improve the treatment and preventive measures currently available.

The second aim is to investigate the underlying mechanisms relating to the susceptibility and resistance to dietary induced obesity (DIO) by comparing lean and overweight male individuals both consuming habitual high fat intakes. People may not only differ in the type of specific mechanism used in their habitual eating behaviours but also in the *frequency* with which the mechanism is used. Both of these subgroups are eating a diet known to favour a positive energy balance, yet not all of them are susceptible to the weight inducing properties of such a diet. What mechanisms might be responsible which render an individual susceptible or vulnerable to dietary induced obesity? Important factors at play here may include portion size, meal frequency, a super-sensitive hedonic response or simply differences in physical activity levels. A greater understanding of the phenotypic variation in the population will help provide a better understanding of how to amplify resistance traits in individuals susceptible to dietary induced obesity. This requires an understanding of the deterministic basis of resistance and susceptibility in humans. As mentioned previously, by discovering and acknowledging characteristics of a given person or subgroup, it will be possible to customise interventions in order to achieve maximum benefit.

These individuals will be investigated in both their free-living environment and under laboratory conditions. This will combine the advantages of a naturalistic approach along with the accuracy of a control environment. The focus will be on assessing characteristics on a behavioural level (food choice, eating behaviour, physical activity, attitudes and intentions), including oro-sensory factors (taste and nutrient preference and hedonic response/reward). However the importance of physiological influences will not be overlooked.

To summarise, the main research questions proposed are as follows:

1. Why do some lean individuals choose such contrasting diets within the same cultural and economic environment? What are the antecedents of these food choices?
2. Why do some individuals become overweight on a high fat diet whilst others do not? What are the consequences of these food choices?

3.2 Specific objectives of the thesis

The main intermediate objectives proposed in order to achieve the aims for this thesis are stated below:

- To investigate further the achievement of energy balance in lean HF and LF in their free-living environment by characterising eating behaviour, dietary and sleeping patterns.

- To assess patterns of hunger and satiety in response to foods varying in macronutrient composition, in order to highlight possible physiological determinants of food choice in HF and LF.

- To identify the key features of resistance and susceptibility to obesity in free-living subjects. To investigate differences in eating behaviour and dietary patterns in the free-living environment in lean and obese HF males (further characterisation concerning resistance and susceptibility).

- To investigate individual differences in hunger and satiety following a high fat preload in lean and obese HF in order to disclose possible weaknesses in food intake regulation with potential weight-inducing foods. To investigate differences in oro-sensory/pleasure response to food in lean and obese HF.

- To investigate the role of attitudes, intentions and values in the food choice process in order to identify the antecedents to food choice. To explore the potential of a qualitative methodology to increase understanding alongside quantitative procedures.

- To investigate the importance of taste hedonics in the antecedents to food choice and its role in the resistance and vulnerability to obesity.

By addressing these objectives it is intended that a contribution will be made to the understanding of the role of food choice (in particular dietary fat consumption) to weight gain and obesity.

Chapter 4

GENERAL METHODOLOGY

In order to meet these stated objectives a number of behavioural and physiological methodologies were employed. An overview of the general measures used in this thesis is given here. Further details of specific measures utilised will also be provided in each experimental chapter.

4.1 Laboratory vs. free living environment

Ideally human behaviour should be examined in a context that offers precision along with naturalness. The measurement of behaviour should be carried out as accurately and precisely as possible. This often involves conducting experiments in a laboratory environment whereby conditions can be scientifically controlled in order to achieve quantitatively sound measurements. This type of experimental setting offers high internal validity, providing the capacity to establish good cause-effect relationships. However the power of generalisation of these types of studies is relatively poor; that is they have low external validity.

A more naturalistic approach would be to conduct experiments within a free-living environment (high ecological validity) whereby volunteers are not constrained by any experimental restrictions. The influences of real world constraints on eating behaviour are taken into account (i.e. situational, social, economic). With this type of method external validity is high, however precision and control is much lower and is subject to error. It is difficult to establish the effects of experimental manipulations, therefore making internal validity low (Hill *et al,* 1995). The best strategy, of course, is to maximise both types of validity. At present this is extremely difficult to achieve. Eating behaviour can be conceptualised as an intimate interaction between physiological regulation and adaptations to the nutritional environment (Blundell and King, 1996). Therefore, in this thesis, experimental, laboratory based studies along with free-living naturalistic studies were employed. Free-living and laboratory environments can be viewed as complementary methodologies rather than alternatives, thus giving a more complete picture of overall eating behaviour (Macdiarmid, 1997).

4.2 Ethical requirements

Prior to the start of each study ethical approval was obtained from the ethics committee of the School of Psychology, University of Leeds. Recruitment was carried out via advertisements in the University of Leeds student paper and through poster advertisements. Subjects were told of the general nature of the study and its requirements. Volunteers were then told that they were free to drop out of the study at any time and were not obliged to answer any questions that they did not feel comfortable with, although it was made clear that such a refusal may result in their exclusion from the rest of the investigation. They were also required to complete and sign a consent form (see Appendix i). A full explanation of the study objectives was given following completion during the debriefing session and volunteers were given an opportunity of ask any further questions. A small honorarium was given to each person in order to compensate them for any travel expenses and for their time. Subjects who took part in the studies were predominantly members of the staff and student (all disciplines) population at the University of Leeds.

4.3 Classification of lean and overweight HF and lean LF

Volunteers who came forward in response to advertisements were given three main screening questionnaires - a Food Frequency Questionnaire (Margetts *et al,* 1989), the Dietary Instrument for Nutrition Education (Roe, 1994) and the Short Fat Questionnaire (Dobson *et al,* 1993). These will be discussed in more detail below. Analysis of the FFQ was used to determine the habitual diet of each volunteer. The lean high fat (HF) phenotypes were defined as eating >120g/day and >43% energy from fat. The lean low fat phenotypes were defined as eating <70g/day and <33% energy from fat. The overweight volunteers were defined as eating approx 120g/d and approx >43%. The reason for classifying the overweight group on an approximation was due to the high probability of underreporting in an overweight/obese population, particularly with respect to fat intake (Goris *et al,* 2000; also see section 4.5). All lean volunteers recruited had a BMI of $\leq 25 kg/m^2$ and the overweight volunteers had a BMI of >27 kg/m^2. The scores obtained from the DINE (and the SFQ introduced as part of the screening process from Chapter 8) further supported the analysis of the FFQ. Any volunteer who did not score consistently on these questionnaires was excluded from the rest of the study. All volunteers were males aged between 18 and 30 years. They were all self reported non-smokers in order to control for any effects nicotine may have on metabolism and smoking related biases on eating patterns, food choices and taste preferences. This screening procedure was designed in order to obtained groups that were as distinct as possible.

4.4 Dietary assessment methods

4.4.1 Food Frequency Questionnaire (FFQ)

Food frequency questionnaires have been developed as a less time consuming method of measuring habitual dietary intake (Eck *et al,* 1996). The FFQ used in this thesis was a retrospective questionnaire designed to measure habitual dietary intake (Margetts *et al,* 1989), by recording the frequency of 63 commonly consumed food categories (see Appendix ii). Six levels for frequency of consumption are given: 'more than twice a day', 'every day', '3-5 times a week', '1-2 a week', '1-3 times a month' and 'rarely or never'. From this an estimate of energy and nutrient intake can be calculated. This method was used in the screening process for the identification of the HF (lean and overweight) and LF.

Advantages of using this questionnaire include the fact that it is inexpensive, quickly completed and it is non-invasive. The accuracy of this method is dependent on both the adequacy of the food list (i.e. appropriate for the correct target group-Western foods for example) along with the ability of the subject to accurately recall their dietary habits, which can be dependent on a number of factors such as their literacy, intelligence and memory. A number of validation studies have been carried out on the use of the FFQ. Martin *et al* (1997) concluded that the FFQ discriminated between low and high fat eaters significantly better than chance. Hu *et al* (1999) described reasonable reproducibility and validity of the major dietary patterns defined by factor analysis with data from an FFQ. However Schaefer *et al* (2000) found that the FFQ did not produce reliable estimates of absolute amounts of dietary fats or cholesterol. In their study it was found that percent energy from fat was significantly underestimated for high fat diets and significantly over estimated for very low fat diets. In spite of this, Block *et al* (1986) state that although it is acknowledged that the FFQ may overestimate absolute intake, its strength lies in its high reproducibility and that usual intake and diet composition (i.e. percent energy from fat, carbohydrate and protein) over a period of time are estimated with precision by FFQs. Another limitation of this method is the vagueness of the portion size categories, as it has been found that some volunteers have difficulty relating their own intakes to arbitrary categories (Briefel, 1994). In order to overcome these limitations the FFQ was used in conjunction with the DINE and SFQ in the screening process and these results were further confirmed using a 3-day food diary.

4.4.2 Dietary Instrument for Nutrition Education (DINE)

The DINE is a questionnaire specially designed to assess fat intake (Roe *et al,* 1994). The structure of this questionnaire is similar to the FFQ but specifically targets high fat foods (see Appendix iii). The initial calibration of the DINE proposed scores above 40 to correspond approximately to fat intakes of 122g/d and below 30 to approximately 83 g/d. This questionnaire was used along with the FFQ in the screening process to provide another measurement of fat intake when identifying the HF and LF phenotypes.

4.4.3 Short fat questionnaire (SFQ)

The short fat questionnaire is a brief questionnaire developed to measure behaviour related to fat intake and was designed by Dobson *et al* (1993). The questionnaire was designed for two purposes. Firstly the subjects themselves can use it to provide a rapid assessment, in order to quantify their own fat consumption. Secondly the authors proposed that it could be used to rank subjects broadly according to their fat intake behaviour. Version B of the SFQ was used in this thesis, which is a 17-item questionnaire (see Appendix iv). Example questions include '*How do you spread butter or margarine on your bread?' –Thickly (3), medium (2), thinly (1), don't use butter or margarine (0).* Or '*How often do you eat ice cream? – Six or more times a week (4), three to five times a week (3), once or twice a week (2), less than once a week (1), never (0).* The response categories are scored from either 4-0 or 3-0. A score is simply obtained by adding the scores from the individual questions. An estimation of the individual's total percent energy from fat intake can be obtained. From initial calibration of this questionnaire it was proposed that scores of $\leq$ 17 approximately relate to a percent fat intake of <30%, scores between 18 and 22 relate to 30 – 34.5% energy from fat, scores between 23 –27 relate to 34.5 – 37.5% energy from fat and scores $\geq$ 28 relate to a percent fat intake of $\geq$ 37.5%. It was concluded by the authors that this measure was sufficiently accurate and reliable (it has high intrasubject reproducibility, r=0.85; criterion validity, r=0.55) to classify individuals or groups into ordinal categories according to their behaviour related to their fat consumption, although it was acknowledged that the main aim of this questionnaire was not to measure the actual amount of fat consumed. The questionnaire was strongly associated with other scales measuring attitudes, behaviour and knowledge related to low fat diets.

This questionnaire was used in conjunction with the FFQ and DINE in order to give a more accurate assessment of an individual's fat intake in a relatively quick and convenient way.

4.4.4 Three day food diaries

Following identification of those individuals who met the initial screening criteria, a three-day food diary data was obtained in order to provide confirmation of group membership. Food diaries are a prospective method of assessing dietary intake. This involved volunteers estimating as accurately as possible all the foods and drinks consumed over a certain period of time (usually 3 to 7 days). Subjects were required to record the time of consumption, the quantity (weight/size) consumed, method of preparation and a detailed description of everything consumed, including brand names and/or recipes (see Appendix v).

One advantage of using food diaries is that, unlike the FFQ, it does not rely on good memory. Also an accurate food diary can provide an estimate of energy and macronutrient intake along with details of meal patterns, reflecting time of consumption, size and frequency of meals and snacks. Provided the volunteers are highly motivated when completing food diaries, they can be a reliable and valid method of assessing dietary intake (de Castro, 1994). However the completion of the food diary can be demanding to the volunteer and relies on the individual's literacy and motivation. Problems also arise when subjects try to accurately record their food intake when the meal is consumed outside the home. The major limitation of this method is its invasive nature, making it very susceptible to underreporting and/or alterations in the normal eating patterns (i.e. under-eating).

4.5 Under-reporting and under-eating

The issue of misreporting is a major problem in human appetite studies. Beaton (1994) commented that 'dietary intake cannot be estimated without error and probably never will be'. However, as it is unlikely that all limitations associated with nutritional research will be eliminated, it is important that they be acknowledged and understood. Systematic errors arise from the mis-reporting of food intake. In a series of studies carried out by O'Reilly (2001) it was concluded that the commonly used term 'mis-reporting' consists of two separate phenomena. Firstly she described the 'observation effect', which was defined as a change in feeding behaviour observed when an individual is asked to record their intake. This effect was found to be macronutrient specific, in that females showed a reduction in fat intake and males showed a reduction in alcohol intake, leading to a 5% reduction in overall energy intake. The second term described was the 'mis-reporting effect', which was defined as the tendency to misreport altered feeding behaviour when asked to self-report food intake. This effect was not found to be macronutrient specific and its effects were reported to be variable depending on the method of dietary assessment administered (between 5-20%). It was concluded from this work that future studies should ensure that data is of a sufficient standard when investigating dietary intake, even if this means collecting smaller amounts of high quality data as opposed to large amounts of unreliable data (O'Reilly, 2001).

Knowledge of habitual foods consumed is necessary in order to obtain values for energy consumed and macronutrient intake. To achieve this outcome it is necessary for volunteers to use a form of self-report and self-monitoring of their food intake. It has been repeatedly found that certain groups of individuals fail to do this accurately. In a study by Goris *et al* (2000) a group of obese men were asked to keep a record of food consumed for a seven day period. It was found that obese men then reduced their habitual food intake by 26% and failed to record 12% of what they actually ate. The typical characteristics of an underreporter are found to be those individuals who are overweight and obese. Gender differences have also been found. De Vries *et al* (1994) found that 12% of women compared with only 8% of men underreported their intake. This could be due to social pressure and greater concern about body weight and food compared to men.

However, underreporting can be detected. Physiological measures can be used as a reference against which reported intake can be compared. For example, the doubly labelled water measurement of energy expenditure provides an external biomarker for evaluating the validity of dietary reports (Black *et al,* 1985, 1995; Schoeller, 1990, 1995; Sawayer *et al,* 1996; Black, 1997, 1999; Champagne *et al,* 1998; Ambler *et al,* 1998). A study by Martin *et al* (1996) compared self reported energy intake with total energy expenditure using the DLW method in middle-aged women, during the second year of a dietary intervention study. These non-obese women underreported energy intake by 20%, which raises further concern about the general accuracy of the intake questionnaires.

However the use of the DLW method is not always applicable. In many studies the ratio of energy intake to basal metabolic rate (EI:BMR) is used instead (Goldberg *et al,* 1991). BMR can be calculated from standard Schofield equations or accurately measured using indirect calorimetry (Schofield, 1985). EI:BMR is based on the assumption that total energy expenditure (TEE) is equal to energy intake (EI), where TEE = BMR x PAL (physical activity level). The minimum EI:BMR value for 'survival' is 1.27. It has been shown that it is virtually impossible to survive on an EI:BMR of <1.2 (Goldberg *et al,* 1991). The use of the EI:BMR ratio has been developed in a number of publications producing guidelines for cut-off values to identify underreporters (Black, 1999; Goldberg *et al,* 1991). For the purpose of this thesis volunteers selected will be male and any found to be underreporting using a cut off EI:BMR value of <1.2 will be excluded from the analysis. However it should also be noted that the EI:BMR cut-offs has its limitations and has also been subject to criticism (see O'Reilly, 2001).

4.6 Measurement of food intake and appetite in the laboratory

4.6.1 Test Meals

A number of methods can be used in order to assess food intake in a laboratory setting and the use of the test meals cuts out any external factors influencing eating behaviour. Those that were employed in this thesis included the pre-load paradigm (Kissleff, 1984). Following the consumption of a fixed quantity of food (pre-load) the subject is then allowed to consume a test meal (typically 4 hours later) and eats until a comfortable fullness is reached. By varying the characteristics of the preload, the effects of particular food attributes (e.g. energy, macronutrient composite or volume) on subsequent intake or on any number of physiological indices (e.g. metabolic, hormonal) can be assessed.

Alternatively an *ad libitum* test meal (concurrent evaluation) can be provided to the volunteer, that contains an attribute of interest (e.g. energy, fat). This method can investigate the effects of the attribute on satiation.

Such test meals require the foods to be weighed before and after their consumption to assess the amount of intake and were weighed using the Melle PJ400- precision instruments (UK) to the nearest 0.1g.

Outside of the laboratory setting (following consumption of the test meal for example), the use of snack boxes was employed in order to maintain control over further intake. Volunteers were instructed to consume freely from the snacks provided (typically during the evening). The advantage of using such a method include limiting choices in the free-living environment by providing a fixed amount and range of food and providing an indirect measure of intake without the need for weighed recordings and food diaries during that particular test day.

All studies requiring the use of test meals were carried out in the Human Appetite and Nutrition Unit (HARU) in the School of Psychology, University of Leeds. Energy intake from the test meals was calculated using the following conversion factors: 3.75 kcal/g for carbohydrate, 4.0 kcal/g for protein and 9.0 kcal/g for fat.

Before beginning a test meal study each volunteer was required to complete a food preference questionnaire in order to establish a liking for the foods which made up the particular test meal. On occasions where the volunteer expressed a particular dislike for any of the foods an alternative food (with the same macronutrient composition) was provided. Where this was not possible the volunteer was excluded from the study.

4.6.2 Subjective measurement of appetite and mood (VAS)

Visual analogue scales (VAS) are one of the most widely used psychological tools to probe subjective sensations (Hill *et al,* 1995) and have been used extensively in clinical and research settings. The use of VAS can provide a very valuable source of information on the effects of nutritional manipulations and habitual appetite regulation. The scale consists of a 100mm horizontal line, anchored at each end with the most negative (e.g. 'not at all...') and positive (e.g. 'extremely....') sensations. Traditionally this requires the subject to place a vertical line at the point which corresponds to the strength of that sensation they are experiencing (i.e. *'How hungry do you feel?'*), using paper and a pen. However a new computerised method of administering VAS has been developed which automatically records the subject's responses (the exact time and intensity of the rating). This is known as the electronic appetite rating system (EARS) and makes use of a hand held personal computer (Psion) that is designed to be portable and easily handled (see Figure 4.1)

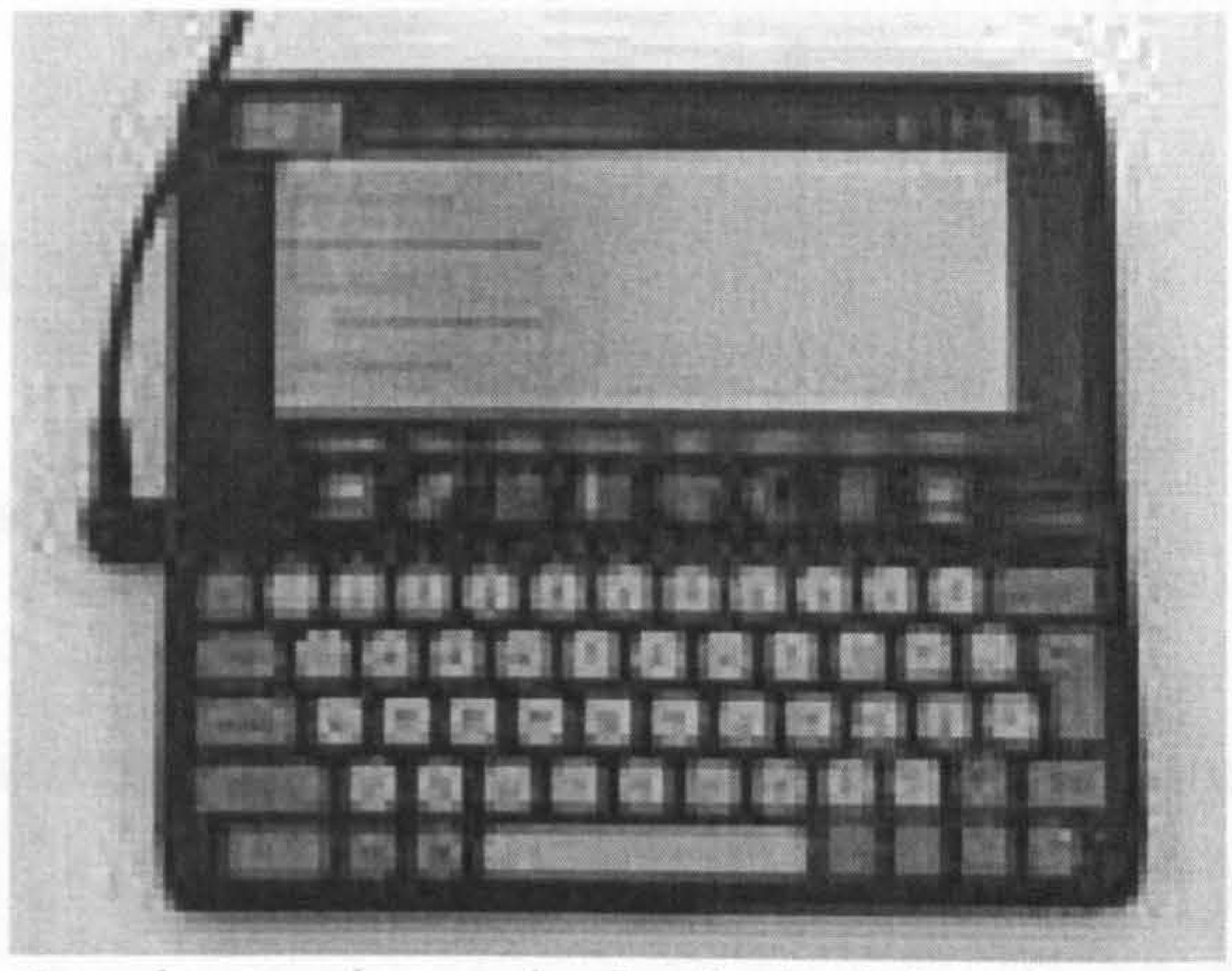

Figure 4.1- The Psion: An electronic method of administering visual analogue scales

This method was originally used to track mood ratings and reaction time in field studies on shift workers (Totterdell and Folkard, 1992). VAS are typically given to volunteers periodically throughout the test day, particularly pre- and post- each meal consumed during that day. The EARS can be programmed to alert the volunteer (via an auditory signal) when they are required to enter their response. The VAS appears on the screen in an identical format to the paper and pen method. The EARS has also been compared against the traditional method in a free-living study in which subjects carried a Psion or paper booklets. There was a significant reduction in the time needed for data analysis and the subjects preferred using the personal computer (Delargy *et al,* 1996).

When using VAS the researcher must be aware that subjective sensations of hunger, satiety and other appetite variables on any particular test day can be influenced by a number of different internal (physiological and psychological) and external (temperature, physical activity, weather etc.) factors. Therefore the question of reproducibility and validity of this method has been questioned. Validity refers to the ability of a method to measure what it intends to measure. A number of studies in the literature show that VAS ratings of 'hunger', 'desire to eat' and 'appetite for a meal' before a test meal can be related, to a certain degree, to the subsequent food intake (Hill *et al,* 1987; Porrini *et al,* 1995; Barkeling *et al,* 1995; Hulshof *et al,* 1993). A number of studies also report good test-retest results between identical or almost identical trials, using paired rank-sum tests or correlation (Robinson *et al,* 1975; Lappalainen *et al,* 1993; Porrini *et al,* 1995). Flint *et al* (2000) concluded from their investigation into the reproducibility and validity of VAS, that appetite scores done by VAS can be reproduced and therefore used in studies using single test meals. However they did warn that the use of VAS requires that some consideration should be given to specific parameters being measured and sensitivity in order to avoid type 2 errors.

4.7 Psychological measures

4.7.1 The Leeds Sleep Questionnaire

The Leeds Sleep Questionnaire (LSQ) is a retrospective questionnaire adapted from a version used in many clinical trials (Parrot and Hindmarch, 1980). It can be used to assess habitual and prospective quality of sleep (see Appendix vi). Self-assessment of sleep involves the use of eight variables that are administered via 100mm visual analogue self-rating scales. The visual analogue scale consists of a 100 mm horizontal line with two extreme states defined at the ends of the line (e.g. alert/ not alert). The volunteer is required to respond by placing a vertical mark on the line to indicate their self-evaluation. Factors include *'getting to sleep'* (GTS), *'quality of sleep'* (QOS), *'awake from sleep'* (AFS), *'alertness on waking'* (AOW) and *'alertness 1hr after waking'* (AAW). The higher the score obtained on the questionnaire, the more problematic the sleep is reported to be. An overall (composite) sleep score can be calculated or, alternatively, these variables can be broken down and quality of sleep can be assessed on a number of different variables. The LSQ is quick and easy to complete and has been found to be sensitive in many psychopharmacological studies. It has been used to monitor possible effects upon sleep associated with the administration of antihistamine, antidepressant agents and hypnotic agents (Hindmarch and Parrott, 1979). In a review by Parrott and Hindmarch (1980) the LSQ was compared to a number of physiological measures. It was concluded that the subjective sleep evaluations frequently produced results that were consistent with results obtained with more objective (ECG) measures. The self-evaluations of sleep, as obtained from the LSQ, can therefore provide consistent and meaningful findings in psychological and psychopharmacological investigations. Although the LSQ does not provide any objective indication of sleep and sleep changes, it can provide useful information on subjectively perceived quality of habitual sleep and perceived changes in sleep along with early morning behaviour, with a reasonable degree of reliability and validity (Parrot and Hindmarch, 1980).

4.7.2 Measures of restraint and eating behaviour

The Three Factor Eating Questionnaire (Stunkard and Messick, 1985) and the Dutch Eating and Behaviour Questionnaire (van Strien, *et al,* 1986) were used in order to obtain a measure of cognitive restraint and other eating variables. The TFEQ is a widely used tool in eating behaviour research. It is a 51-item questionnaire measuring cognitive restraint (21 items), disinhibition of control (16 items) and susceptibility to hunger (14 items). It contains statements requiring either true or false responses or answers (items 1-36) followed by a set of multiple-choice scales, with four possible responses, such as *'rarely', 'sometimes', 'usually' or 'always'* (items 37 –51). A score of 11 on the restraint scale is considered the cut off point for serious dieting (see Appendix vii).

The DEBQ is a 33-item questionnaire that measures three factors of eating behaviour. These are restraint, which includes restriction of the intake of food and dieting behaviour; external eating, which is concerned with disinhibition of eating when in sight or smell of food; and emotional eating, where items are concerned with eating when upset or in a negative mood (see Appendix viii). Scores from this questionnaire range from 1-5 and a higher score indicates higher restraint, greater sensitivity to emotional conditions and sensitivity to external cues. The scale has been found to have advantages over similar methods (see Wardle, 1986) and has been shown to be robust in the UK population (Wardle, 1987).

4.7.3 Food Choice Questionnaire (FCQ)

The Food Choice Questionnaire (Steptoe *et al,* 1995) provides an opportunity to assess a broad range of factors perceived as relevant to food selection within the Western population. Specifically the FCQ can be used to investigate the motives related to food choice and has been verified using factor analysis and test-re-test reliability over a 2 to 3 week period. The 68-item questionnaire was developed as a multidimensional measure of motives relating to food choice and includes nine factors: health, mood, convenience, sensory appeal, natural content, price, weight concern, familiarity and ethical concern. Four responses are provided: *'not at all important', 'a little important',* *'moderately important'* and *'very important'*. These are scored 1 to 4 respectively and an overall score can be calculated for each factor (see Appendix ix).

4.7.4 Forced Choice Method of assessing food preference

The forced choice method of assessing food preference measures food choice along two dimensions – nutrient (high fat and low fat) and taste (sweet and savoury). Colour photographs of 20 foods are used, that can be classified into four groups; high fat savoury, high fat sweet, low fat savoury and low fat sweet. Five different foods from each of the four food categories are paired against a food from each of the remaining categories (see Appendix x for example). Each individual food item appears in the measure three times. Thirty food comparisons (pairs) in total are presented in a photograph album labelled either 'A' or 'B'. The foods are not named and no nutritional information is provided. Subjects are instructed to indicate the food item from the pair they would choose to eat on the response sheet. The subject is required to make the response, in this way they are 'forced' to make a directional choice (Block, 1999).

The instrument is scored by counting how many responses are made in each of the four categories. Responses can be interpreted in two ways. Firstly the data can be presented as scores ranging from '0' (never preferred) to '15' (most preferred) by considering the response as separate CATEGORIES (high fat savoury, high fat sweet, low fat savoury and low fat sweet). Alternatively the responses can be considered as FOOD TYPES (i.e. high fat, low fat, sweet and savoury). In this case there is a minimum of '5' (due to random selection or forced selection) and a maximum of '25' (as 5 out of the possible combination would be presented as the alternative response only). Subjects may be asked to indicate their food preference as trait food choices (i.e. asking subjects what they would habitually choose out of each pair in a non-hungry, non-full state). Also pre- and post-meal food preferences can be measured to test the effects of hunger level on food choices.

One advantage of using this method is that the effects of impression management on the part of the participant are minimised. As the volunteer is *forced* to respond there is less opportunity for denial and underreporting, or for making choices that the participant believes are favourable. With traditional food preference checklists, the choices made by the respondent have depended on the mental representation of that food. The method used in this thesis, however, used photographs of foods. The respondent is forced to choose one food over the other therefore eliminating the factor of mental imagery, portion sizes and method of preparation. Also the forced choice format has the capacity to unambiguously elicit decisions about food preferences.

4.7.5 Eating attitude measures

A number of questionnaires were administered in order to assess specific eating attitudes and intention. The shortened version of the Eating Attitude Survey (EAT-40, Garner and Garfinkel, 1979) was used, known as EAT-26 (Garner *et al,* 1982). This questionnaire was originally designed in order to measure symptoms of anorexia nervosa. However, in this context the scores on the EAT-26 are merely associated with a pattern of behaviour and attitudes similar to those of a sample of diagnosed eating disordered patients and are not necessarily sufficient for diagnosis (Garner *et al,* 1983). Factors measured using the EAT-26 include dieting, food preoccupation and oral control (see Appendix xi). However for the purpose of this thesis an overall score was calculated and used in the analysis.

Additionally an attitude survey was used in order to give a measure of attitudes, intentions, subjective norm, self-identity and ambivalence (Armitage and Conner, 1999). This tool was based on the Theory of Planned Behaviour (Ajzen, 1991). These variables were used to investigate which are the best predictors of intention and behaviour to eat a low fat diet. This instrument was included to determine whether or not the habitual consumption of a high or low fat diet was dependent upon (and determined by) the presence of specific attitudes and intentions (see Appendix xiii).

4.8 Measurement of energy expenditure

4.8.1 Heart rate monitoring

Heart rate was measured using POLAR heart rate monitors (PE400, Finland). The monitors consist of two pieces, a transmitter which contains two electrodes that detect electrical signals from the heart by recording the voltage differential on the skin during each heartbeat. A continuous electromagnetic signal is then sent to the second piece of equipment - the wrist receiver. The transmitter is attached to the chest with an elastic belt and the wrist receiver is worn like a watch on either of the volunteer's wrists. The receiver stores the data, which can then be downloaded for analysis into a computer via the POLAR interface.

The heart rate readings can be used to estimate energy expenditure (EE) over a 24-hour period. The use of heart rate monitoring has become an increasingly popular method of assessing EE, as it is relatively cheap and reliable. When this method is combined with measurements of BMR using indirect calorimetry an estimate of EE can be established. This FLEX method is defined as the mean of the highest heart rate during rest (lying, sitting and standing) and lowest heart rate during the highest imposed exercise during the calibration procedure (Stubbs *et al,* 2002) and should be determined separately for each subject (Wareham *et al,* 1997).

FLEXHR = ([highest heart rate at rest + lowest heart rate during exercise]/2+10).

An average value of resting energy expenditure (calculated from indirect calorimetry) from the three levels of resting can be calculated for each subject (REST). A regression equation of energy expenditure (calculated from indirect calorimetry) and heart rate during the four levels of exercise can be calculated for each subject.

Daily energy expenditure can then be calculated for each subject from 24h heart rate (beats per minute converted to kcal per minute) by substituting any heart rate <FLEXHR with the subject's average resting value of energy expenditure (REST). The regression equation is applied to heart rates >FLEXHR in order to convert these heart rates to energy expenditure. Cases where more than 10% of the 24h heart rate data is missing were excluded from the analysis. Any missing heart rate values (e.g. due to momentary loss of heart rate telemetry signal or interference from electrical signals) were replaced by mean values taken from 5min either side of the missing value. Spuriously high (>200bpm) and low (<30bpm) heart rates are also replaced by mean values taken from 5min either side of the missing value. This formulation leads to 1440 values (i.e. minutes per 24h) of energy expenditure, the sum of which equals 24h energy expenditure. Sedentary activity is defined as the percentage of total daily energy expenditure accounted for by REST values (also see Stubbs *et al,* 2002). Flex heart rate has previously been validated against whole-body calorimetry (Spurr *et al,* 1988; Ceesay *et al,* 1989) and against doubly labelled water (Livingstone *et al,* 1990; Lovelady *et al,* 1993). This method provides an objective and accurate estimate of EE as well as providing a means of describing the pattern of physical activity (Wareham *et al,* 1997).

Although this method is useful it is also subject to some limitations. For example, it is not possible to differentiate between increases in heart rate due to physical activity and increases due to stress (Haskell *et al,* 1993). Also the transmitter belt can be subject to interference from machines, microwave and cars (Gretebeck *et al,* 1991). The operation of the heart rate monitor also requires a clear and detailed explanation to the volunteer in order to ensure the data is properly collected.

4.8.2. Indirect calorimetry

Direct calorimetry involves the measurement of energy expended over a given period of time by measuring heat emitted from the body. Room size chambers are used to detect heat loss. However the construction of these chambers are technically difficult and expensive. They are also only suitable for long periods of measurement.

In this thesis energy expenditure and respiratory quotient (RQ) was measured using indirect calorimetry. Indirect calorimetry can be used during periods of rest to measure resting metabolic rate and also in response to food to measure dietary thermogenesis. This technique is based on the fact that oxygen consumption and carbon dioxide output are directly proportional to the heat generated by the body. By measuring oxygen consumption the heat production can be calculated using a simple equation.

All methods of measurement work on the principle of measuring the volume of expired air and the concentration of oxygen and carbon dioxide in expired and ambient air to calculate oxygen and carbon dioxide production using the Weir (1949) equation (see below).

$$\text{Energy expenditure (kcal/min)} = [(VO_2 * 3.941) + (VCO_2 * 1.11)]$$

In the studies involved in measuring basal metabolic rate (BMR) included in this thesis the ventilated hood system was used. This works by securing a transparent perspex hood over the volunteer's head and making it airtight. A stream of air is then forced across the face that mixes with expired air. This is then collected and analysed by the relevant instrument (e.g. Sensor Medics Vmax29). The rate of EE is calculated by determining the volume of air flowing through the hood and by measuring the oxygen and carbon dioxide concentrations in the incoming and outgoing air. A measure of EE is then averaged and reported for every 20-second interval.

4.8.3 Respiratory Quotient (RQ)

Respiratory quotient is defined as the ratio of carbon dioxide production to oxygen consumption. It provides information on the disposal of carbohydrate and fat at a given time, as the quantity of carbon dioxide produced in relation to oxygen consumed varies depending on the substrate metabolised. When subjects are tested after an overnight fast the nutrients utilised for oxidation are derived from the body stores rather than from dietary intake, therefore nutrient oxidation (RQ) in the fasted subject gives some indication of the rate of utilisation of body nutrient stores. A lower RQ indicates a higher rate of fat oxidation.

4.8.4 Antropometry & body composition

Height was measured using a wall mounted stadiometer (Ke We, Germany) and measurement was recorded to the nearest centimetre. Weight was measured in the morning following an overnight fast to the nearest 0.1kg using a digital balance (Adam Equipment, MSP-200). From this the body mass index (BMI) was calculated by dividing the subjects weight (in kg) by the height (in m^2):

$$\text{BMI} = \text{weight (kg)} / \text{height } (m^2)$$

The measurement of body composition was carried out using the InBody 3.0 Body Composition Analyzer (Biospace Co. Ltd, 1999). The subject is required to grip the hand electrodes firmly and step onto the foot electrodes. Fat tissue does not conduct an electrical current due to its low water content, whereas lean tissue is conductive. If height and weight are controlled for, then the higher the resistance to conduct an electrical current, the higher the percent body fat. The instrument operates by sending a low level (harmless) electrical current through the body. This measures the resistance the body has to the current and uses this to calculate the percent body fat. The body composition is automatically measured and a detailed analysis is immediately printed out. The analysis given includes measurements of lean body mass (LBM), body fat, percent body fat, total body water, fat distribution (waist-hip ratio), muscle type (sarcopenic, muscular), a fitness score, estimated BMR and BMI.

4.9 Statistical analysis

The Statistical Package for the Social Sciences (SPSS) for Windows (versions 6.1 & 9.0) was utilised for the analysis of data in this thesis (SPSS Inc. Chicago, IL). Microsoft Excel version 5.0c (Microsoft Corporation, 1993) was also used along with Diet 5 for Windows (Univation), which is a computer software package for dietary analysis based on McCance and Widdowson's food tables (Holland *et al,* 1991). Detailed information regarding the application of statistical tests is given in each individual experimental chapter.

Chapter 5

INTERACTIONS AMONG THE HABITUAL DIET, EATING PATTERNS AND SLEEPING: comparison between (lean) high fat and low fat phenotypes

5.1 Introduction

Feeding and sleeping are behaviours that are frequently investigated separately even though there is plenty of evidence to suggest they are linked (Wells *et al,* 1995; 1997). Sleep itself is associated with a reduction in metabolic rate, heat loss and body cooling. Eating an evening meal with a high energy content would be expected to alter metabolism and body temperature through normal post-prandial thermogenic effects related to satiety (e.g. Westerterp-Plantenga *et al,* 1998), and consequently these changes would be expected to influence sleep. As well as the energy and macronutrient content of the meal, the latency between the evening meal and the onset of sleep is likely to effect sleep, as the composition and timing of a meal is known to influence the concentrations of fuel metabolites, substrate utilisation, and associated hormones (Stubbs *et al,* 1995).

Proximity of the meal to bedtime thereby altering the circadian temperature profile is likely to be relevant and it has been reported that going to bed at different phases of circadian temperature profile alters sleep latency and duration (Glotzbach and Heller, 1994). However Driver *et al* (1999) reported no differences in sleep composition and subjective assessments of sleep quality in relation to an evening meal differing in energy content. It was concluded that short-term variations in energy intake and macronutrient composition altered body temperature but not sleep. However the authors proposed that if the men in their study had consumed the meal closer to bedtime, sleep would have been significantly effected, thus illustrating the importance of taking meal patterns into account as well as meal composition.

The interaction between eating patterns and sleeping can be investigated using behavioural phenotypes differing in their habitual macronutrient consumption. Two subgroups of the population have previously been identified in terms of their habitual fat and carbohydrate intake, now termed high fat (HF) and low fat (LF) phenotypes. However both groups are found to be lean despite the association between a high fat intake and obesity. Thus a high fat intake may be considered a strong behavioural risk factor for obesity, but the relationship is not inevitable. To investigate the mechanisms involved in the achievement of energy balance in these phenotypes, characterisation of both physiology and behaviour is necessary in these individuals. It is already know that the phenotypes differ in their physiological response to food. HF phenotypes have been previously found to display quite different physiological responses. Cooling and Blundell (1998b) have found that HF had lower RQ than LF, confirming that fat oxidation was higher in HF, and also found to have significantly higher BMR than LF, together with different profiles of 'thermogenic' responses to high-fat and high-carbohydrate loads (Blundell, Cooling and King, 2002). Another important finding was that HF had higher plasma leptin levels than LF, despite having similar levels of body fat (Cooling *et al*, 1998). These factors all contribute to an increase in energy expenditure in the HF. It may be possible that differences in eating behaviour, particularly during the evening and in turn sleeping patterns, may also contribute to an increase in energy expenditure. The metabolic and physiological requirements needed to deal with different diets may change the physiological response to food, as well as adjusting the operation of the appetite control system. However, it is still unclear whether these phenotypes have a biological basis or simply constitute patterns entrained by a particular environment or self imposed interventions (Green et al, 1994; Cooling and Blundell, 1998a).

The habitual diet reflects a complex interaction between the individual (motivation, eating/sleeping patterns, physiology, hunger profiles) and the environmental (choice and food availability) characteristics. Macronutrient intake (particularly fat intake) is related to aspects of physiology and behaviour patterns of eating and sleeping. Since it is known that diets varying in macronutrient content influence the control and expression of appetite (Cooling and Blundell, 1998b), then it can be proposed that habitual consumption of a large amount of dietary fat will in turn effect the pattern of eating and the profile of sleeping behaviour. This may in turn have implications for performance and mood states.

5.2 Objective

This study was designed to investigate the achievement of energy balance in lean HF and LF in their free-living environment by further characterisation in terms of dietary patterns and eating behaviour. More specifically this study addresses some of the consequences of macronutrient intake, namely the physiological (i.e. sleep) and behavioural (i.e. eating patterns) effects of the habitual diet.

5.3 Method

5.3.1 Subjects

Eighteen lean healthy males were recruited from the staff-student population of the University of Leeds: 9 HF and 9 LF. All subjects were aged between 18 and 30 years (HF: 20.7+/- 1.4; LF: 21.9 +/- 3.1) and had a body mass index (BMI) of ≤25 kg/m^2. Each subject was required to read and sign a participant information sheet and consent form as required by the School Psychology, University of Leeds Ethical Committee, following ethical approval of this study.

5.3.1.1 Recruitment Process

All volunteers who responded to advertisements were required to complete a set of questionnaires (see chapter 4 for further details of these questionnaires), which comprised:

1. Food Frequency Questionnaire (FFQ)
2. Dietary Instrument for Nutrition Education (DINE)
3. The Leeds Sleep Questionnaire (LSQ)

Analysis of the FFQ was used to determine the habitual diets of each volunteer and the DINE score confirmed this. Fifty-four subjects were recruited of which 9 high fat phenotypes and 9 low fat phenotypes who met the criteria were identified. The high fat (HF) phenotypes were defined as eating >120g/day and >43% energy from fat and the low fat (LF) phenotypes as eating <70g/day and <33% energy from fat. At recruitment, those volunteers meeting the criteria were asked to complete the Baecke questionnaire which was used to assess habitual activity levels (work activity, sport and leisure activities). Scores from these three factors were used to calculate an overall activity score (Baecke *et al,* 1982).

5.3.2 Experimental Design

The purpose of the investigation was to compare eating and sleeping patterns in habitual HF and LF phenotypes in their free-living environment. The study took an independent groups design.

5.3.3 Procedure

Volunteers arrived in the Human Appetite Research Unit (HARU) on three separate mornings (between 08:00 and 10:00) in a fasted state. Height was measured on the first visit using a stadiometer. Weight was measured on each visit using a digital balance (Adam Equipment, MSP-200) prior to measuring basal metabolic rate and fat oxidation (measured via respiratory quotient, RQ). The resting oxygen consumption and carbon dioxide production (used to calculate resting metabolism) was measured by using a ventilated hood indirect calorimetry system (SensorMedics Vmax 29); the principal of the ventilated hood system has previously been described (see Chapter 4 and also Westrate (1993) for review). The method required the subject to lie flat on a bed in a thermoneutral environment and remain at bed rest throughout the measurement period of approximately 25 minutes. These measurements were repeated on three separate days.

Participants were then thoroughly briefed on how to use the equipment required for the three profile days, which was designed to assess habitual eating patterns, and profiles of appetite, mood and heart rate. These profile days were carried out on two week days and one weekend day (not necessarily consecutive). During each profile day volunteers were instructed to wear a heart rate monitor (POLAR Sports Tester PE 4000, Finland), which was to be worn for the full 24 hours of the study day including the time spent bathing, showering and sleeping. Subjects were required to fit and start the monitor immediately after rising on each study day. Heart rate readings were taken every 60 seconds. This was used to measure physical activity patterns and arousal during sleep and non-sleep. Food diaries were provided with which volunteers were asked to keep a detailed and accurate record of everything they ate and drank during the study day. Subjects recorded the time of consumption, whether the eating episode was considered a meal or a snack, amount eaten and a brief but accurate description of what was consumed. This was used to assess total energy and macronutrient intakes, and the meal/snack profiles. Each subject was also instructed on how to use EARS - an electronic means of administering visual analogue scales to assess subjective states of mood and appetite. Eight scales were administered; hunger, fullness, desire to eat, alertness, tiredness, irritability, contentedness and depression. This set of ratings was carried out immediately before and after each meal, plus 1-hour and 2 hours post meal. This was done in order to assess the acute effects of food consumption on the expression of appetite and psychological mood states. Subjects were instructed not to alter their normal routine or eating patterns and were not restricted on exercise or sleep. If an individual did not routinely consume (for example) breakfast they were not required to complete that set of ratings. VAS (100mm) have been used previously in many studies and are known to be sensitive and valid subjective markers of the motivation to eat in both nutritional and pharmacological studies (Hill and Blundell, 1990; de Graaf, 1993; Flint *et al*, 2000).

5.3.4 Statistical Analysis

Food diaries were analysed using Diet5 for Windows (The Robert Gordon University, Aberdeen). In order to minimise the inaccuracy of fat free mass measurement by the impedance procedure, BMR (kcal/day) was recalculated using a regression equation between BMR and fat free mass for both high fat and low fat phenotypes. This equation assumes a linear relationship between BMR and fat free mass (see Ravussin and Bogardus, 1989).

Analysis of the data was conducted using SPSS for Windows (version 6.1) statistical software package (SPSS Inc. Chicago, IL). Independent groups *t*-tests (parametric) were used in the comparison of high and low fat phenotypes for dietary variables, metabolic variables and sleep characteristics. Heart rates were averaged over 30min periods (i.e. 48 periods per day) and analysed using repeated measures ANOVA with time as the within subjects factor and high or low fat phenotypes as the between subjects factor. In all statistical tests performed p-values < 0.05 were considered significant and the data are presented as means +/- SDs.

5.4 Results

Subject characteristics are shown in Table 5.1. Age, macronutrient variables and energy intake were obtained from the screening questionnaires (the FFQ and DINE). Accurate height and weight measurements were used to calculate BMI. HF and LF were of similar ages and did not significantly differ on weight (t=0.767, df=16, p=0.454), height (t=0.578, df=16, p=0.571) or BMI (t=0.361, df=16, p=0.723).

Table 5.1: Characteristics of high fat and low fat groups on key variables (mean +/- S.D.)

	HF	LF
Age (y)	20.7 +/- 1.4	21.9 +/- 3.1
Height (m)	1.77 +/- 0.06	1.79 +/- 0.07
Weight (kg)	73.82 +/- 7.9	76.76 +/- 8.33
BMI (kg/m^2)	23.6 +/- 0.8	24.0 +/- 0.8
DINE fat score	35.3 +/- 7.8	23.4 +/- 7.6*
Energy intake (kJ/d)	11501.3 +/- 3369.5	9256.2 +/- 2679.8
Energy intake (kcal/d)	2748.8 +/- 805.3	2212.2 +/- 640.5
Fat intake (g/d)	130.0 +/- 44.0	66.9 +/- 20.6*
Fat intake (% kcal)	45.1 +/- 2.0	28.7 +/- 4.5**
CHO intake (g/d)	284.4 +/- 74.1	322.6 +/- 108.7
CHO intake (% kcal)	41.8 +/- 3.1	57.0 +/- 6.4**
Protein intake (g/d)	96.2 +/- 38.1	80.4 +/- 27.7
Protein intake (% kcal)	14.7 +/- 1.7	15.3 +/- 3.0

* $p<0.05$; ** $p<0.001$

Independent groups *t*-tests were carried out on each variable and significant differences were found between the two groups on the DINE score (t=3.08, df= 16, p<0.05), fat intake in grams (t= 3.92, df=16, p< 0.001), % fat intake (t= 10.08, df=16, p< 0.001) and % CHO intake (t=-6.40, df=16, p< 0.001). The high fat and low fat phenotypes met the criteria for inclusion in the groups. HF habitually reported consuming significantly greater absolute amounts of fat (in grams) and greater % energy from fat but a smaller % energy from CHO than LF.

5.4.1 Physiological Responses

HF and LF responses to the physiological measures can be seen in Table 5.2.

Table 5.2: Summary of physiological data (mean +/- S.D.)

	HF	LF
BMR (kcal/d)	1844 +/- 156.9	1816 +/- 240.7
BMR correct for lean mass (kcal/kg/d)	29.7 +/- 2.16	28.0 +/- 1.76*
Oxygen consumption at rest -VO_2 (mlO_2/kg/min)	3.7 +/- 0.5	3.4 +/- 0.30
Respiratory Quotient	0.78+/- 0.04	0.80+/- 0.03
Heart rate (bpm)	75.7+/- 0.55	72.6+/- 0.55**
Sleeping heart rate (bpm)	59.9+/- 11.9	50.5+/-10.1*

* $p < 0.05$, ** $p < 0.0001$

HF had slightly higher BMR and lower RQ but unlike previous studies (Cooling and Blundell, 1998; Cooling and Blundell, 2000) these differences did not reach significance (BMR: t=0.290, df=16, p=0.776; RQ: t=-1.017, df=16, p=0.324). However, HF did have significantly higher BMR when corrected for lean body mass (t=-2.051, df=16, p<0.05). No significant difference in oxygen consumption was found (t=1.381, df=16, p=0.186).

Differences were also found in 24-hour heart rate readings between HF and LF. Figure 5.1 shows the mean heart rate readings from 12 noon onwards for 24 hours. Three peaks in the heart rate readings can be observed particularly in the HF group. A repeated measures ANOVA revealed a main effect of group for the whole day period ($F_{[1,37]}$ = 4.099, p<0.005) and average heart rate was significantly higher in HF (75.7+/- 0.55 bpm) than LF (72.6+/- 0.55 bpm) (p<0.05). For heart rate readings between from 3 am and 5.30 am (when all volunteers were definitely asleep, as indicated in the activity section of the food diary) when analysed separately, a significant difference of nearly 10 bpm ($F_{[1,37]}$ = 724.5, p<0.001) was observed.

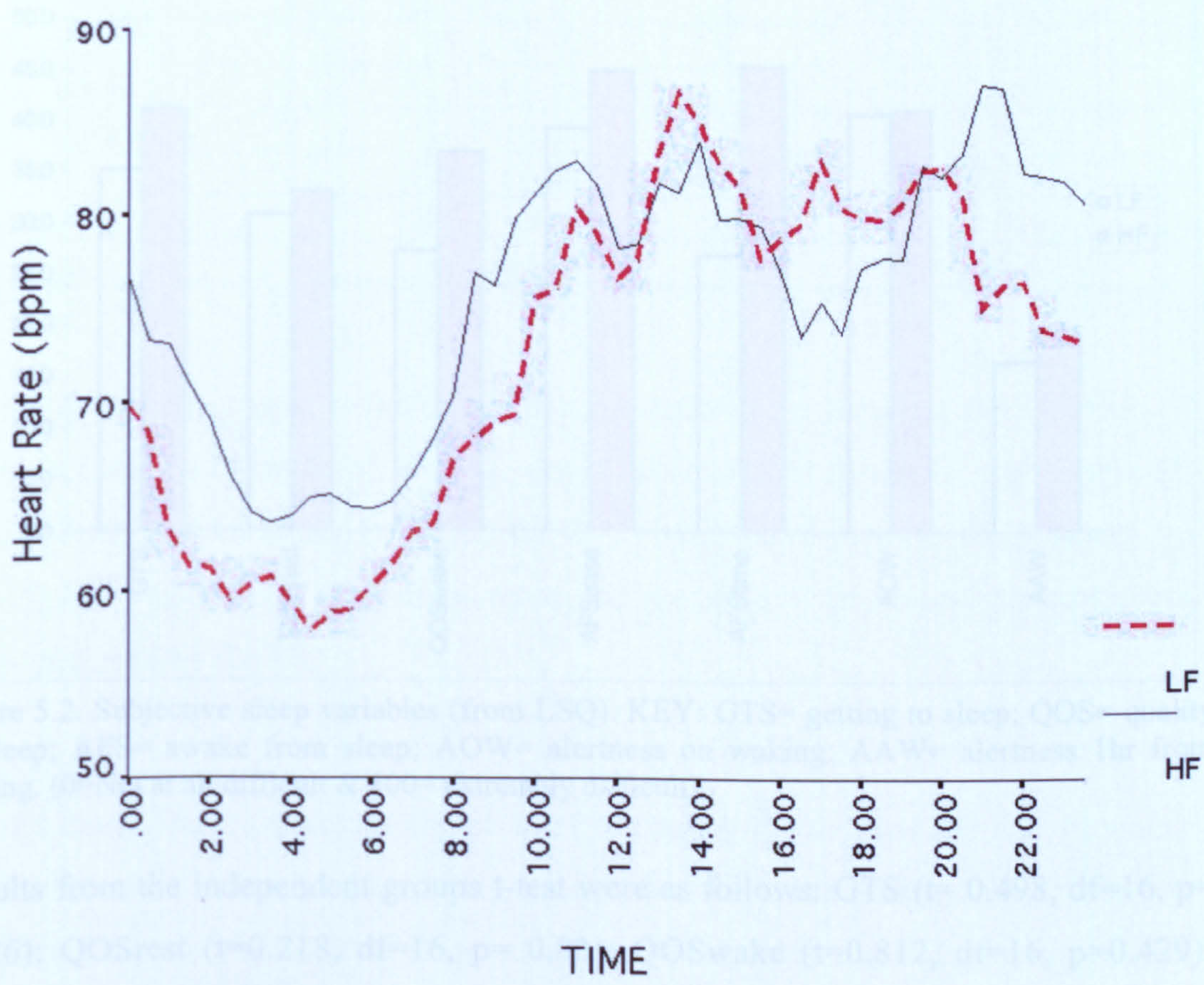

Figure 5.1 Mean 24-hour heart rate profiles (midnight to midnight) across the experimental day.

Results from the Baecke physical activity questionnaire are shown in Table 5.3. HF scored slightly higher for activity at work whereas LF scored slightly higher sporting and leisure activity levels, this being reflected in the overall Baecke scores. However none of the differences was found to be statistically significant.

Table 5.3 Baecke physical activity score (mean +/- sd)

BAECKE VARIABLE	HF	LF
Work	2.36 (0.47)	2.28 (0.40)
Sport	3.03 (0.67)	3.56 (0.83)
Leisure	3.17 (0.41)	3.28 (0.72)
Baecke score	8.56 (0.97)	9.11 (1.21)

5.4.2 Sleep Variables

In addition to the recording of the heart rate during sleep, subjects were required to complete a retrospective sleep questionnaire (LSQ). Results from the questionnaire are displayed in Figure 5.2.

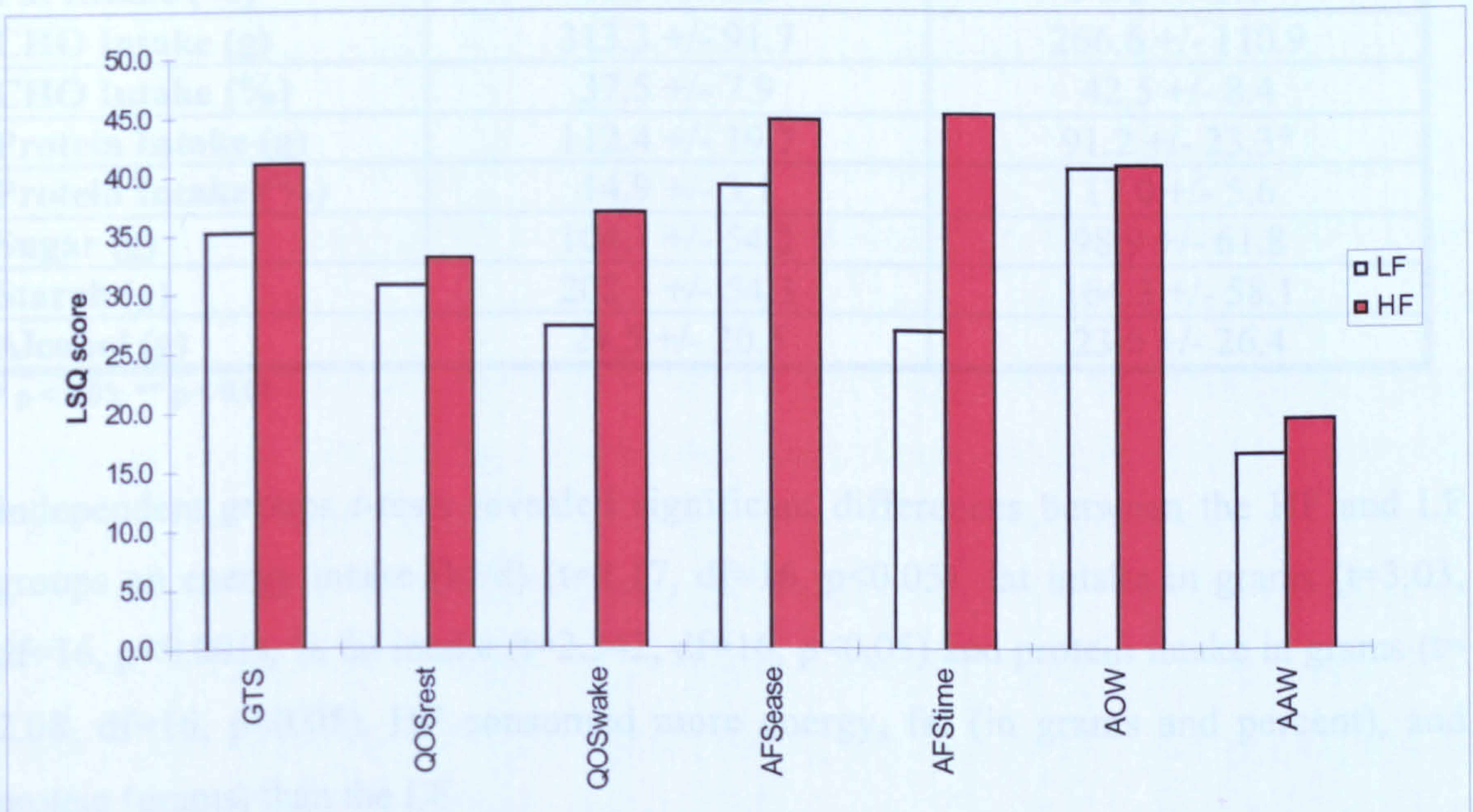

Figure 5.2. Subjective sleep variables (from LSQ). KEY: GTS= getting to sleep; QOS= quality of sleep; AFS= awake from sleep; AOW= alertness on waking; AAW= alertness 1hr from waking. (0=Not at all difficult & 100= extremely difficult).

Results from the independent groups t-test were as follows: GTS (t= 0.498, df=16, p= 0.626); QOSrest (t=0.218, df=16, p= 0.83); QOSwake (t=0.812, df=16, p=0.429); AFSease (t=0.403, df= 16, p= 0.692); AFStime (t= 1.741, df= 16, p=0.101); AOW (t= 0.035, df=16, p= 0.972); AAW (t=0.510, df= 16, p=0.617). Although none of these results was significant it might be worth noting that the HF scored higher than LF on all seven sleep variables. A composite sleep score was computed (overall quality of sleep) for each group. Again HF scored higher (37.6 +/- 17.5) compared to the LF (31.1 +/- 15.9) but did not reach significance (t=0.828, df=16, p=0.42). However this score was positively correlated with sleeping heart rate for the period surrounding the nadir (r=0.85, p<0.001).

5.4.3 Dietary Analysis

Each volunteer completed a three day food diary during the time of heart rate monitoring. The mean daily energy and macronutrient intake over the three experimental days is given in Table 5.4.

Table 5.4: Overall food diary analysis (mean +/- S.D.)

	HF	LF
Energy Intake (kJ/d)	12859 +/- 2264	9791 +/- 3594*
Energy Intake (kcal/d)	3073 +/- 541	2340 +/- 859*
Fat Intake (g)	140.7 +/- 32.4	89.3 +/- 39.4**
Fat Intake (%)	41.5 +/- 7.2	34.1 +/- 6.1*
CHO Intake (g)	313.3 +/- 91.7	266.6 +/- 110.9
CHO Intake (%)	37.5 +/- 7.9	42.5 +/- 8.4
Protein Intake (g)	112.4 +/- 19.7	91.2 +/- 23.3*
Protein Intake (%)	14.9 +/- 3.1	17.0 +/- 5.6
Sugar (g)	104.1 +/- 54.2	98.9 +/- 61.8
Starch (g)	202.3 +/- 54.3	164.3 +/- 58.1
Alcohol (g)	24.5 +/- 20.5	23.0 +/- 26.4

* p < 0.05; ** p < 0.01

Independent groups *t*-tests revealed significant differences between the HF and LF groups on energy intake (kJ/d) (t=2.17, df=16, p<0.05), fat intake in grams (t=3.03, df=16, p<0.001), % fat intake (t=2.342, df=16, p<0.05) and protein intake in grams (t= 2.08, df=16, p<0.05). HF consumed more energy, fat (in grams and percent), and protein (grams) than the LF.

5.4.3.1 Eating patterns

The food diary data were also analysed so as to display the number and size of eating episodes and the pattern of eating. Figure 5.3 shows the energy intake and % macronutrient intake for each meal and snack. LF consumers ate slightly more food at breakfast than HF but this was not significant. Eight out of nine LF and all HF consumed breakfast at least once during the 3 day period and all volunteers consumed lunch and evening meals. A significant difference in food consumption was found for the evening meal, with HF consuming significantly more energy (t=2.60, df= 16, p <0.05) and a greater amount of fat (g) (t=2.14, df= 16, p<0.05) than the LF.

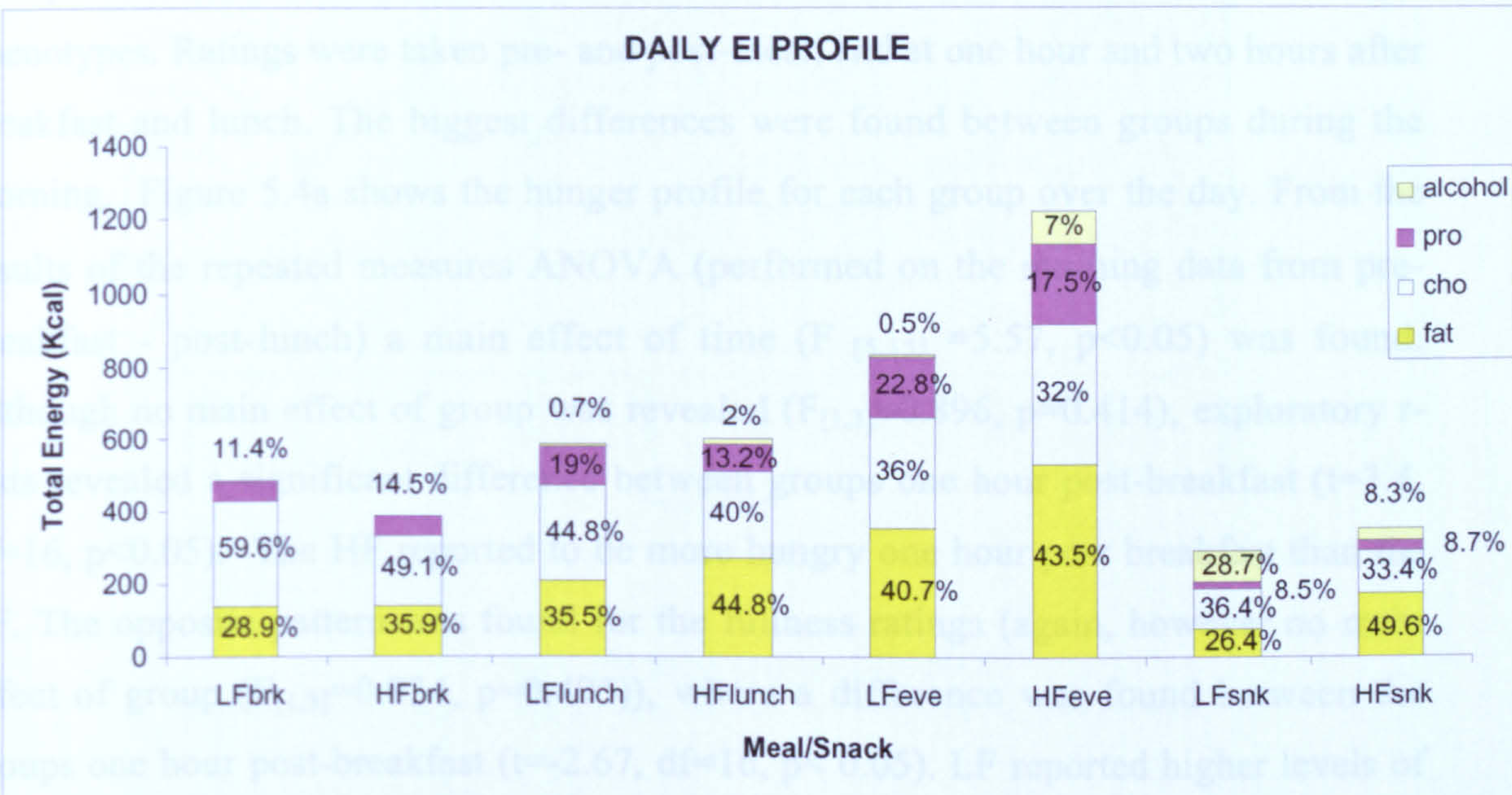

Figure 5.3: Food Diary breakdown, daily energy intake and macronutrient profiles [Key: LFbrk/HFbrk= LF/HF consumption at breakfast; LFlunch/HFlunch= LF/HF consumption at lunch; LFeve/HFeve= LF/HF consumption at evening meal; LFsnk/HFsnk= LF/HF consumption from snacks during evening]

<u>Evening Snacks</u>: During the evening (post evening meal) all 9 of the HF and 6 LF consumed an evening snack; average % energy from fat was approximately 50% for HF and 26% for LF. Typical examples of snacks selected by HF include spring rolls, battered sausage, custard and muffins, kebabs and chips, cereal and whole milk. Typical evening snack selected by LF included toast, digestive biscuits and carrot cake. Independent groups *t*-tests revealed that HF consumed significantly more energy (t=2.14, df= 13, p< 0.05), fat in grams (t=2.14, df= 13, p<0.05), fat % (t= 4.68, df=13, p< 0.001), CHO % (t=4.87, df=13, p< 0.001), protein in grams (t=3.87, df=13, p< 0.05) and protein % (t=2.20, df=13, p < 0.05) during the latter part of the day following the main evening meal.

Seven HF and seven LF consumed caffeine containing drinks (tea, coffee, Pepsi/cola) during the study days. Mean daily caffeine intake was slightly higher in HF (188.5 +/- 135.6 mg/d) than LF (106.5 +/- 65.5 mg/d). Three individuals from each group consumed caffeine containing drinks after 8.30 pm during the study period. Again mean intake was slightly higher for HF (57.88 +/- 39.01 mg/d) than LF (34.24 +/- 4.21 mg/d). However, none of these differences were found to reach significance.

5.4.4 Subjective Appetite & Mood Responses (EARS)

Analysis of the PSION data revealed further differences between HF and LF phenotypes. Ratings were taken pre- and post-meal, and at one hour and two hours after breakfast and lunch. The biggest differences were found between groups during the morning. Figure 5.4a shows the hunger profile for each group over the day. From the results of the repeated measures ANOVA (performed on the morning data from pre-breakfast - post-lunch) a main effect of time ($F_{[5,15]}=5.57$, $p<0.05$) was found. Although no main effect of group was revealed ($F_{[1,3]}=0.896$, $p=0.414$), exploratory *t*-tests revealed a significant difference between groups one hour post-breakfast ($t=3.4$, $df=16$, $p<0.05$). The HF reported to be more hungry one hour post breakfast than the LF. The opposite pattern was found for the fullness ratings (again, however no main effect of group ($F_{[1,3]}=0.934$, $p=0.405$)), where a difference was found between the groups one hour post-breakfast ($t=-2.67$, $df=16$, $p< 0.05$). LF reported higher levels of fullness than HF. Difference were also found one hour post-breakfast on the variables alertness ($t=2.55$, $df=16$, $p<0.05$), tiredness ($t= -3.23$, $df=16$, $p<0.005$) (see Figure 5.4b), and for the depression ratings ($t= -2.78$, $df=16$, $p<0.05$). HF reported feeling slightly more depressed than LF around breakfast time and less so 1 hour post-breakfast (see Figure 5.4c), although both groups displayed low ratings for this variable on the 100mm VAS scale. Although interesting, however, it should be reiterated that the above post hoc tests were carried out for exploratory reasons.

5.5 Discussion

This study was designed to examine the relationship between sleeping and eating in a free living environment using HF and LF phenotypes as an investigative tool. Previous studies have shown that the behaviour of the HF phenotype increases the potential to promote a positive energy balance and weight gain (Cooling and Blundell, 1998a; Macdiarmid *et al,* 1996b). The consumption of a diet dominated by a high fat intake has been shown to be associated with changes in appetite control and also increased sedentariness (Cooling and Blundell, 2000). These factors are both considered risk factors for weight gain. However the HF phenotype (young male adult), in this and previous studies, is indistinguishable from the LF phenotype in terms of body mass. These young male HF phenotypes appear to be protected from the risk of weight gain. This study aimed to further characterise the phenotypes in order to help the understanding of how energy balance is achieved in these groups of males.

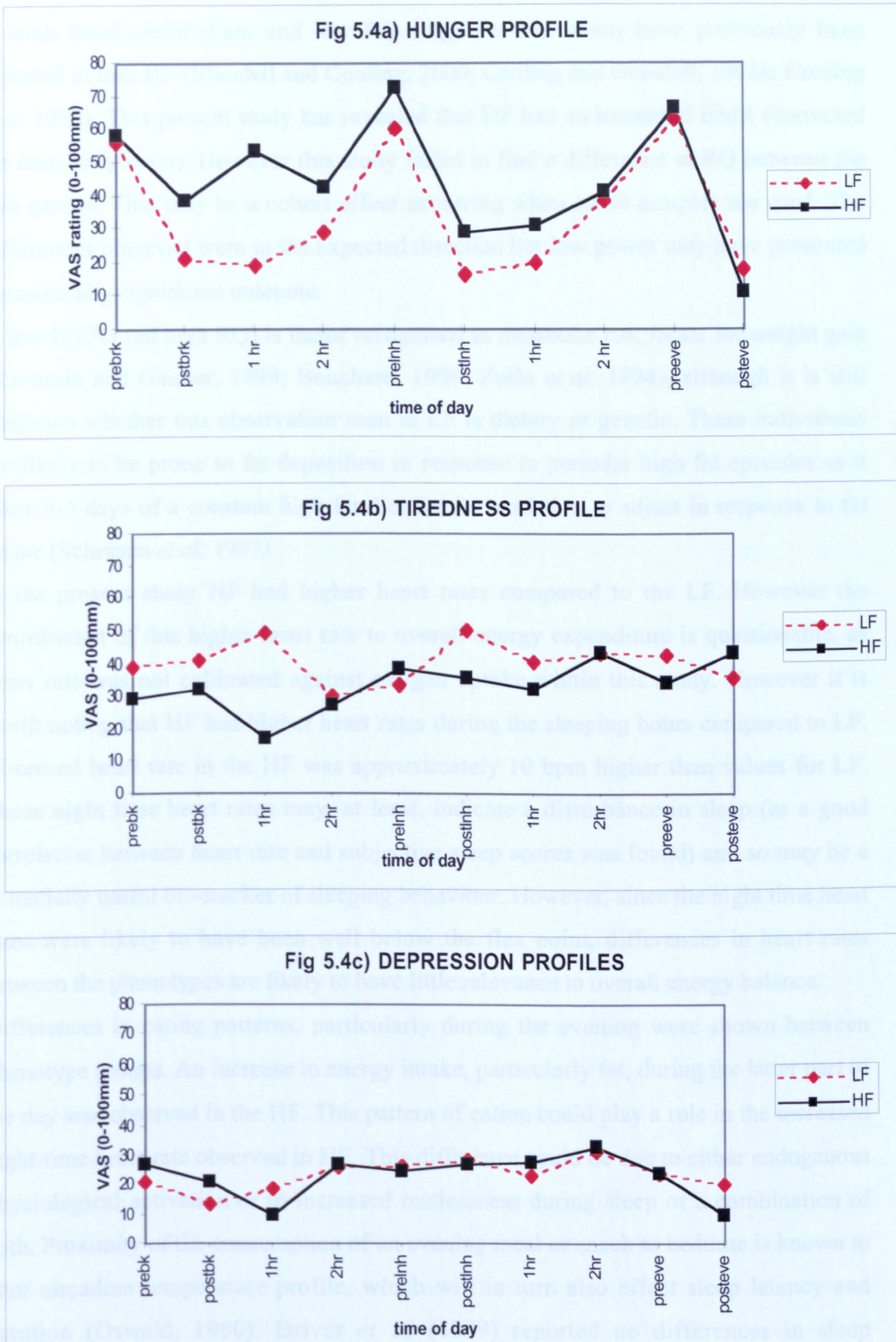

Figure 5.4 Profiles of VAS ratings of hunger (5.4a), tiredness (5.4b) and depression (5.4c) across the experimental day.

A high basal metabolism and low RQ (high fat oxidation) have previously been reported in lean HF (Blundell and Cooling, 2000; Cooling and Blundell, 1998b; Cooling *et al* 1998). This present study has revealed that HF had an increased BMR (corrected for lean body mass). However this study failed to find a difference in RQ between the two groups. This may be a cohort effect occurring when small samples are used. The differences observed were in the expected direction but low power may have prevented a statistically significant outcome.

A low BMR (and high RQ) is factor recognised as metabolic risk factor for weight gain (Ravussin and Gautier, 1999; Bouchard, 1996; Zurlo *et al,* 1994), although it is still unknown whether this observation seen in LF is dietary or genetic. These individuals are likely to be prone to fat deposition in response to periodic high fat episodes as it takes 3-5 days of a constant high fat diet for fat oxidation to adjust in response to fat intake (Schrauen *et al,* 1997*).*

In the present study HF had higher heart rates compared to the LF. However the contribution of this higher heart rate to overall energy expenditure is questionable, as heart rate was not calibrated against oxygen uptake within this study. However it is worth noting that HF had higher heart rates during the sleeping hours compared to LF. Observed heart rate in the HF was approximately 10 bpm higher than values for LF. These night time heart rates may, at least, indicate a disturbance in sleep (as a good correlation between heart rate and subjective sleep scores was found) and so may be a potentially useful bio-marker of sleeping behaviour. However, since the night time heart rates were likely to have been well below the flex point, differences in heart rates between the phenotypes are likely to have little relevance to overall energy balance.

Differences in eating patterns, particularly during the evening were shown between phenotype groups. An increase in energy intake, particularly fat, during the latter part of the day was observed in the HF. This pattern of eating could play a role in the increased night-time heart rate observed in HF. This difference could be due to either endogenous physiological activation or to increased restlessness during sleep or a combination of both. Proximity of the consumption of an evening meal or snack to bedtime is known to alter circadian temperature profile, which will in turn also effect sleep latency and duration (Oswald, 1980). Driver *et al* (1999) reported no differences in sleep composition and subjective assessments of sleep quality in relation to an evening meal differing in energy content and concluded that short term variations in energy intake and macronutrient composition altered body temperature but not sleep. However it was proposed in this study that it is the investigation of the maintained effect of eating patterns, duration, energy and macronutrient intake, that may be of greater significance than a single dietary manipulation – as is the case with habitual consumers of contrasting diets. In this study HF reported slightly higher subjective increases in sleep disturbance. However this was not found to be significant, which may indeed indicate that the disturbance in sleep may not be great enough for the individual to consciously perceive as problematic.

Male HF were seen to have a slightly (although n/s) smaller breakfast compared to LF but reported greater hunger levels post-breakfast. Hunger is known to be a distracter, one consequence of which is interference with cognitive performance. Paradoxically HF reported themselves to be less tired than LF following breakfast; a feature that could raise performance. HF reported feeling less tired during the morning (despite the increased heart rate during the night assumed to be associated with a degree of sleep disturbance). Previously it has been reported that the amount of fatty food in the diet was positively associated with faster reaction times (Health and Lifestyle Survey, 1987). Reaction time is clearly related to alertness and performance. In the Health and Lifestyle study differences in reaction time between those eating high and low levels of fatty foods was as much as 150ms, with those consuming higher levels of fat achieving quicker reaction times on a task. Benton (1997) questioned whether it is reasonable to suggest that dietary fat influences neural functioning. Animal literature indicates that fatty acids alter cerebral metabolism of glucose, which leads to the elevation of electroconvulsive threshold (Appleton and DeVino, 1974). Therefore it is possible that long term (chronic) intake of high doses of dietary fat lead to changes in neural functioning which in turn effect levels tiredness and performance in humans. Cognitive performance could be further investigated in the phenotypes (i.e. memory tests, reaction times), however this is not within the scope of this thesis.

This investigation has extended knowledge about HF and LF phenotypes. It has been confirmed that individuals characterised by different profiles of nutrient intake (by definition) show differences in night-time sleep behaviour, subjective states and daily rhythm of eating. This suggests an interesting relationship between habitual diet, sleep and behaviour patterns, which could throw further light on the potential for body weight control.

5.6 Summary

This study has shown that the amount of fat habitually consumed (phenotype) is associated with:

- Differences in the profile of energy intake with HF consuming more food and much more fat during the second half of the day.

- Differences in night time heart rate, indicating a higher level of disturbed sleep in the HF group.

- Differences in metabolic activity (shown here and previously demonstrated). Although this effect may be of variable size and could differ between cohorts.

- Differences in the quality of sleep. A habitual high fat intake is associated with more perceived sleep problems (but does not reach significance).

- Differences in perceived hunger and tiredness during the early part of the day.

Chapter 6

HUNGER & SATIETY RESPONSES TO HIGH FAT AND HIGH CARBOHYDRATE MEALS IN LEAN HIGH FAT AND LOW FAT PHENOTYPES

6.1 Introduction

Food varies in its capacity to effect appetite. This can be attributed to several properties of the particular foods, for example the energy content, taste sensation and physical properties. Satiating power, or satiating efficacy, is the term applied to the capacity of any consumed food to suppress hunger and to inhibit the onset of a further period of eating (Kissileff, 1984). Satiety and satiation act together to determine the pattern of eating behaviour and motivations. Satiation is the process that brings an eating episode to an end and satiety is defined as an inhibition of hunger and eating which maintains inhibition over further consumption.

The conscious sensation of hunger is one index of motivation and reflects the strength of satiation and satiety. The assessment of the impact of varying different food properties on satiation and satiety provides information about features of food that contribute to overall appetite control and factors which contribute to overconsumption. Identification and management of hunger appear to be important factors underlying the appetite function, and therefore should occupy an important position in the investigation and treatment of obesity (see Blundell & Gillett, 2001).

The satiety cascade implies that food varying in nutritional composition will engage differently with the mediating process. The dietary macronutrients have been shown to differ in their satiating power. Protein is found to be the most satiating (de Castro, 1987), followed by carbohydrate then dietary fat, which has a relatively weak effect on satiety (Blundell *et al,* 1993; Stubbs, 1998, 1999; Stubbs *et al,* 2000). It has been reported that protein suppresses hunger and food intake in excess of its contribution to total energy intake, carbohydrate suppressed hunger and energy intake roughly proportion to its contribution to energy intake and fat produced less than caloric compensation (de Castro, 1998). Using a preload strategy and related procedures (i.e. VAS) it is possible to assess the satiating power of a wide variety of foods differing in macronutrient composition. Foods exerting a weak effect on satiety would not be expected to provide effective appetite control. As previously discussed, there is a widespread belief that high fat diets are responsible for elevated energy intakes, which in turn lead to weight gain through fat deposition. Tremblay *et al* (1989) found that high levels of fat in the diet can overcome appetite control mechanisms and lead to overconsumption. However, there is a body of evidence which suggests that different types of subjects behave differently in relation to various nutritional challenges (Macdiarmid *et al,* 1996; Cooling and Blundell, 1998). A subgroup of individuals has been found who consume a habitual high fat diet yet maintain a normal weight and has been termed the high fat phenotype (Blundell and Macdiarmid, 1997; Blundell and Cooling, 1999).

It is proposed that high fat and low fat phenotypes differ in their physiological and behavioural response to foods varying in macronutrient composition. HF and LF differ in the types of food they consume, the amount of macronutrients and their food preferences (Macdiarmid *et al,* 1996b). It has been suggested that biological differences concerning the control of appetite may underlay their development. de Castro (1993) has found correlations between fat intakes in genetically identical twins, for example. Alternatively habitual consumption of a high fat or low fat diet may entrain different patterns of physiological satiety signals (pre- and post-absorptive), which will mediate the expression of appetite and the pattern of eating. Physiological differences have already been found between the two groups (i.e. higher BMR, lower RQ and higher heart rate in the HF) which are believed to be among the mediating factors preventing excess weight gain in the high fat phenotype, and could be involved in the expression of appetite.

6.1.1 Calculations of satiating power of food

A number of methods make different uses of the relationship between food consumed, changes in hunger or fullness and changes in subsequent intake. The ways of assessing 'satiating power' and the underlying principles have to be taken into account in interpreting the outcome measures.

Subjective ratings of the motivation to eat usually show positive correlations with the amount of food consumed (e.g. Mattes, 1990) and can be considered a valid indicator of the strength of appetite. Blundell and Rogers (1991), for example, found that measures of appetite before a test meal generally correlated well with energy intake at the test meal. The Satiety Quotient (SQ) is dependent on this assumption. SQ is a measure of the extent to which the food eaten during the eating episode reduces subjective appetite per unit (e.g. per kJ).

SQ is a method that calculates the satiating power by measuring change in motivation to eat (i.e. suppression of hunger or elevation of fullness) relative to the amount (energy or weight) of food consumed. SQ is a method that uses the differential between pre- and post-food ratings. Subjective ratings of appetite represent a way to easily and reliably measure motivation to eat at numerous time points following a preload/meal. Hence relating intake at a preload/meal to motivation to eat at these points will give an indication of the effects of the preload over time. If the rating used is hunger, the greater the quotient value the greater the hunger rating would be reduced per unit of intake.

Since both weight (g) and energy (kJ/ kcal) values of food consumption are important in the regulation of food intake both of these values (for the amount of food consumed) can be used to calculate the SQs.

$$\text{SQ: } \frac{\text{ratings of motivation to eat pre-eating episode} - \text{rating post-eating episode}}{\text{intake of eating episode}}$$

The quotient allows a comparison of the effects of food or fluid on satiety over time by relating intake to subsequent subjective ratings of appetite. Much information about the satiating capacity of food may be lost by failing to consider the satiating effects of food over time. This information may not by immediately apparent on examination of the rating of motivation to eat.

6.2 Objective

This study was designed to explore the impact of (and short term changes to) the habitual diet on hunger and satiety signals in high fat and low fat phenotypes by testing the hypothesis that the two groups will differ in their appetite responses to meals varying in fat and carbohydrate content.

6.3 Methods

6.3.1 Subjects

Sixteen lean healthy males were recruited from the staff-student population of the University of Leeds: 8 HF and 8 LF. All subjects were aged between 18 and 30 years (HF: 21.4+/- 2.7; LF: 20.8 +/- 1.8), had a body mass index (BMI) of $\leq$25 kg/m^2, and were self reported non-smokers. Each subject was required to read and sign a participant information sheet and consent form as required by the School of Psychology, University of Leeds Ethical Committee, following ethical approval of this study.

6.3.1.1 Recruitment Process

All volunteers who responded to advertisements were asked to complete an initial screening pack of questionnaires (see chapter 4 for further details of these questionnaires), which comprised:

1. Food Frequency Questionnaire (FFQ)
2. Dietary Instrument for Nutrition Education (DINE)
3. The Three Factor Eating Questionnaire (TFEQ)

Analysis of the FFQ was used to determine the habitual diets of each volunteer and the DINE score confirmed this. The 8 high fat (HF) phenotypes were defined as eating >120g/day and >43% energy from fat and the low fat phenotypes as eating <70g/day and <33% energy from fat. Additionally, analysis of the TFEQ was used to determine the degree of dietary restraint and disinhibition of eating. A score of 11 on the restraint scale was used as a cut off point for serious dieting. Any individual scoring higher than this was excluded from the study at recruitment.

6.3.2 Experimental Design

The purpose of the study was to assess the subjective response of the high and low fat phenotype, in terms of hunger, fullness and desire to eat over time, following either a high fat or high carbohydrate preload. The study was a 2 x 2 fully repeated measures design with both HF and LF participating in two experimental conditions:

A: LOW FAT CONDITION

- FIXED low fat breakfast, snack and lunch
- AD LIB evening meal

B: HIGH FAT CONDITION

- FIXED high fat breakfast, snack and lunch
- AD LIB evening meal

The two conditions were presented in a counterbalanced order, one week apart. Both fixed test conditions were of equal weight and energy content, only differing in macronutrient composition.

6.3.3 Procedure

Volunteers operated under the experimental protocol from immediately after rising in the morning until the same time the following morning. Subjects were instructed not to eat anything until arrival at the HARU at approximately 08:00. Height was measured using a stadiometer and weight was measured on a digital balance (Adam Equipment, MSP-200). A fixed breakfast was provided. Volunteers were then free to leave the lab and instructed not to eat or drink anything other than the fixed snack (to be consumed two hours post breakfast) until arrival back in the HARU four hours post breakfast. Immediately prior to consumption of the fixed lunch, pre-lunch visual analogue scales (VAS) were administered using EARS. The scales used were *'hunger'*, *'fullness'* and *'desire to eat'*. VAS have been used previously in many studies and are both known to be sensitive and valid subjective markers of the motivation to eat both in nutritional and pharmacological studies (see chapter 4). Following the fixed lunch, an immediate post lunch VAS was completed along with a palatability questionnaire. This questionnaire consisted of seven VAS requiring the subjects to report how pleasant, salty, tasty, bland, filling, satisfying and healthy they found the meal. Volunteers were again free to leave the lab and instructed not to eat or drink anything except water until arrival back 4 hours post lunch for the *ad libitum* evening meal. During the afternoon VAS were administered +1/2hr, +3/4hr, +1hr, +1 1/2 hr, +2hr and +3hr-post lunch, pre- and post-evening meal and 10pm. Four hours post-lunch volunteers were asked to come back to the HARU to take part in the next part of this experimental protocol (see Chapter 7 for procedure and analysis).

6.3.3.1 Test meals

Two fixed conditions were used. Both required the consumption of a fixed breakfast, fixed mid-morning snack and fixed lunch. Both conditions consisted of cornflakes, milk, toast with margarine and jam for breakfast. A sweet roll made with white bread, margarine, cream cheese and jam was consumed for the mid-morning snack. A chicken and tomato pasta meal with French bread and a chocolate mousse was provided for lunch. Table 6.1 shows the total energy and macronutrient composition for each condition. The energy and weight of these conditions was kept constant (overall and for each meal separately) with only the fat and carbohydrate content varying (see Table 6.2- condition A and Table 6.3- condition B for recipes and nutritional breakdown).

Table 6.1 - Total amount of energy, weight and macronutrients consumed during each condition (breakfast, snack plus lunch).

	CONDITION A (LOW FAT)	CONDITION B (HIGH FAT)
Weight (g)	893.6g	893.8g
Energy (kcal)	1458.5	1465.1
Fat (g)	40.6 g	81.4 g
CHO (g)	238.0 g	143.1 g
Protein (g)	50.2 g	49.0 g
Fat (%)	25.0 %	50.0 %
CHO (%)	61.2 %	36.6 %
Protein (%)	13.8 %	13.4 %

6.3.4 Data Analysis

Independent groups *t*-tests were used to analyse the screening questionnaires (FFQ, TFEQ and DINE). 2 by 2 repeated measures ANOVA was used to analyse the subjective ratings across the test days. Hunger (and SQ), fullness, desire to eat and sensory ratings were the dependant variables. Low fat/ high CHO (condition A) and high fat/ low CHO (condition B) were included as within subjects factors and high and low fat phenotypes (GROUP) were used as between subject factors. Post hoc Bonferroni tests were applied where a significant difference was found.

Table 6.2. - Test meal composition: condition A - *low fat (high carbohydrate)*

a) Breakfast

g per 100g of food, % energy

FOOD ITEM	PROVISION	FAT	CHO	PROTEIN
Kellogg's cornflakes	35g	0.7g, 1.7%	82g, 86.1%	8g, 8.6%
Skimmed milk	118g	0.1g, 2.7%	5g, 56.4%	3.4g, 40.9%
White bread (med, toasted)	25g	1.6g, 5.4%	57.1g, 80.6%	9.3g, 14.0%
Flora light	11g	38g, 96.0%	3.7g, 3.9%	0.1g, 0.1%
Jam (strawberry)	15g	0.1g, 0.4%	64.6g, 99.1%	0.3g, 0.5%

b) Mid-morning snack

g per 100g of food, % energy

FOOD ITEM	PROVISION	FAT	CHO	PROTEIN
White bread roll	57g	1.9g, 7.5%	46.4g, 76.5%	9.1g, 16.0%
Flora Light	5g	38g, 96.0%	3.7g, 3.9%	0.1g, 0.1%
Low fat cream cheese	22g	6g, 42.5%	3.5g, 10.3%	15g, 47.2%
Jam (strawberry)	10g	0.1g, 0.4%	64.6g, 99.1%	0.3g, 0.5%

c) Lunch

g per 100g of food, % energy

FOOD ITEM	PROVISION	FAT	CHO	PROTEIN
Spaghetti pasta	161.6g	0.7g, 6.1%	22.2g, 80.0%	3.6g, 13.8%
Tinned tomatoes with peppers	116g	0g, 0.0%	4.2g, 75.0%	1.3g, 24.8%
Olive oil	8.8g	100g, 100%	0g, 0.0%	0g, 0.0%
Tomato puree	3.2g	0.4g, 4.6%	14.9g, 71.4%	4.7g, 24.0%
Chicken	32g	4g, 25.4%	0g, 0.0%	26.5g, 74.6%
Cheddar cheese	4g	34.4g, 75.5%	0.1g, 0.1%	25g, 24.4%
Low fat cheddar cheese	8g	17g, 55.6%	0.1g, 0.1%	30.5g, 44.3%
French bread	64g	2.7g, 9.0%	55.4g, 76.8%	9.6g, 14.2%
Flora light	8g	38g, 96.0%	3.7g, 3.9%	0.1g, 0.1%
Choc angel delight	39.5g	17g, 35.7%	69.5g, 60.8%	3.7g, 3.5%
Condensed milk	50.5g	0.2g, 0.7%	59.2g, 83.5%	10.5g, 15.8%
Sugar	10g	0g, 0.0%	105g, 100%	0g, 0.0%
Double cream	12g	48g, 96.3%	2.6g, 2.2%	1.7g, 1.5%
Water	78g	0g, 0.0%	0g, 0.0%	0g, 0.0%

Table 6.3 - Test meal composition - *condition B - High fat*

a) Breakfast g per 100g of food, % energy

FOOD ITEM	PROVISION	FAT	CHO	PROTEIN
Kellogg's cornflakes	25g	0.7g, 1.7%	82g, 86.1%	8g, 8.6%
Whole milk	150g	4g, 54.2%	4.7g, 26.5%	3.2g, 19.3%
White bread (med, toasted)	20g	1.6g, 5.4%	57.1g, 80.6%	9.3g, 14.0%
Flora	7g	70g, 99.9%	0.1g, 0.1%	0.1g, 0.1%
Reduced sugar jam (strawberry)	4g	0g, 0.0%	28.4g, 99.3%	0.2g, 0.7%

b) Mid-morning snack g per 100g of food, % energy

FOOD ITEM	PROVISION	FAT	CHO	PROTEIN
White bread roll	40g	1.9g, 7.5%	46.4g, 76.5%	9.1g, 16.0%
Flora	7g	70g, 99.9%	0.1g, 0.1%	0.1g, 0.1%
Cream cheese	19g	15g, 69.5%	3g, 5.8%	12g, 24.7%
Low fat cream cheese	12g	6g, 42.5%	3.5g, 10.3%	15g, 47.2%
Reduced sugar jam (strawb'ry)	10g	0g, 0.0%	28.4g, 99.3%	0.2g, 0.7%

c) Lunch g per 100g of food, % energy

FOOD ITEM	PROVISION	FAT	CHO	PROTEIN
Spaghetti pasta	80	0.7g, 6.1%	22.2g, 80.0%	3.6g, 13.8%
Tinned tomatoes with peppers	192	0g, 0.0%	4.2g, 75.0%	1.3g, 24.8%
Olive oil	17.6	100g, 100%	0g, 0.0%	0g, 0.0%
Tomato puree	6.4	0.4g, 4.6%	14.9g, 71.4%	4.7g, 24.0%
Chicken	51	4g, 25.4%	0g, 0.0%	26.5g, 74.6%
Cheddar cheese	13	34.4g, 75.5%	0.1g, 0.1%	25g, 24.4%
French bread	40	2.7g, 9.0%	55.4g, 76.8%	9.6g, 14.2%
Flora	9.6	70g, 99.9%	0.1g, 0.1%	0.1g, 0.1%
Choc angel delight	39	17g, 35.7%	69.5g, 60.8%	3.7g, 3.5%
Cocoa	1.5	20.8g, 58.7%	10.5g, 12.3%	23.1g, 29.0%
Gelatine	2	0g, 0.0%	0g, 0.0%	87g, 100%
Whole Milk	66.5	3.9g, 54.2%	4.8g, 26.5%	3.2g, 19.3%
Candarel	0.2	0g, 0.0%	75g, 100%	0g, 0.0%
Double cream	39	48g, 96.3%	2.6g, 2.2%	1.7g, 1.5%
Water	42	0g, 0.0%	0g, 0.0%	0g, 0.0%

6.4 Results

6.4.1 Screening

Details of the 16 recruited subjects (8 HF and 8 LF phenotypes) can be seen in Table 6.4. The energy intake and macronutrient variables were calculated from the analysis of the FFQ. Significant differences were found between the two groups on fat intake %, fat intake g, CHO intake %, and the DINE. HF and LF subjects met the criteria for inclusion in the groups. HF reported consuming significantly more fat in grams ($t= -3.97$, $df= 14$, $p<0.001$), % energy from fat ($t= -13.07$, $df=14$, $p<0.0001$) according to the FFQ and also significantly more fat according to the DINE ($t= -3.63$, $df= 14$, $p<0.01$) but less % energy from CHO ($t=-4.66$, $df= 14$, $p<0.0001$) than the LF. These differences in macronutrient intake between phenotypes are consistent with previous findings (see Cooling and Blundell, 1998a; Macdiarmid *et al,* 1996).

Table 6.4: Characteristics of HF and LF on key variables (mean +/- sd)

SCREENING VARIABLE	LF	HF
Age (years)	20.8 +/- 1.8	21.4 +/-2.7
TFEQ- restraint	6.0 +- 2.9	4.5 +/- 2.8
BMI (kg/m^2)	24.0 +/- 2.9	23.9 +/-2.6
DINE	18.6 +/- 6.8	33.6 +/-8.9*
Energy Intake (kJ/day)	8572.7 +/- 1169.5	9785.5 +/- 2080.1
Energy Intake (kcal/day)	2050.9 +/- 279.8	2341.0 +/-497.6
Fat intake (g/day)	67.4 +/- 8.7	120.3 +/-23.4**
Fat intake (%/day)	30.5 +/- 2.7	43.7 +/-1.1***
CHO intake (g/day)	281.1 +/- 58.5	231.5 +/-51.0
CHO intake (%/day)	52.4 +/- 6.1	41.4 +/-2.6***
Protein intake (g/day)	88.9 +/- 18.9	98.4 +/-22.7
Protein intake (%/day)	17.3 +/- 4.2	17.4 +/-2.4

*p<0.01; **p<0.001; ***p<0.0001 (independent t-test)

6.4.2 Subjective Ratings

The macronutrient manipulations gave rise to some interesting responses in the subjective reports of hunger. Figure 6.1 shows the hunger profiles pre-lunch and for the rest of the day.

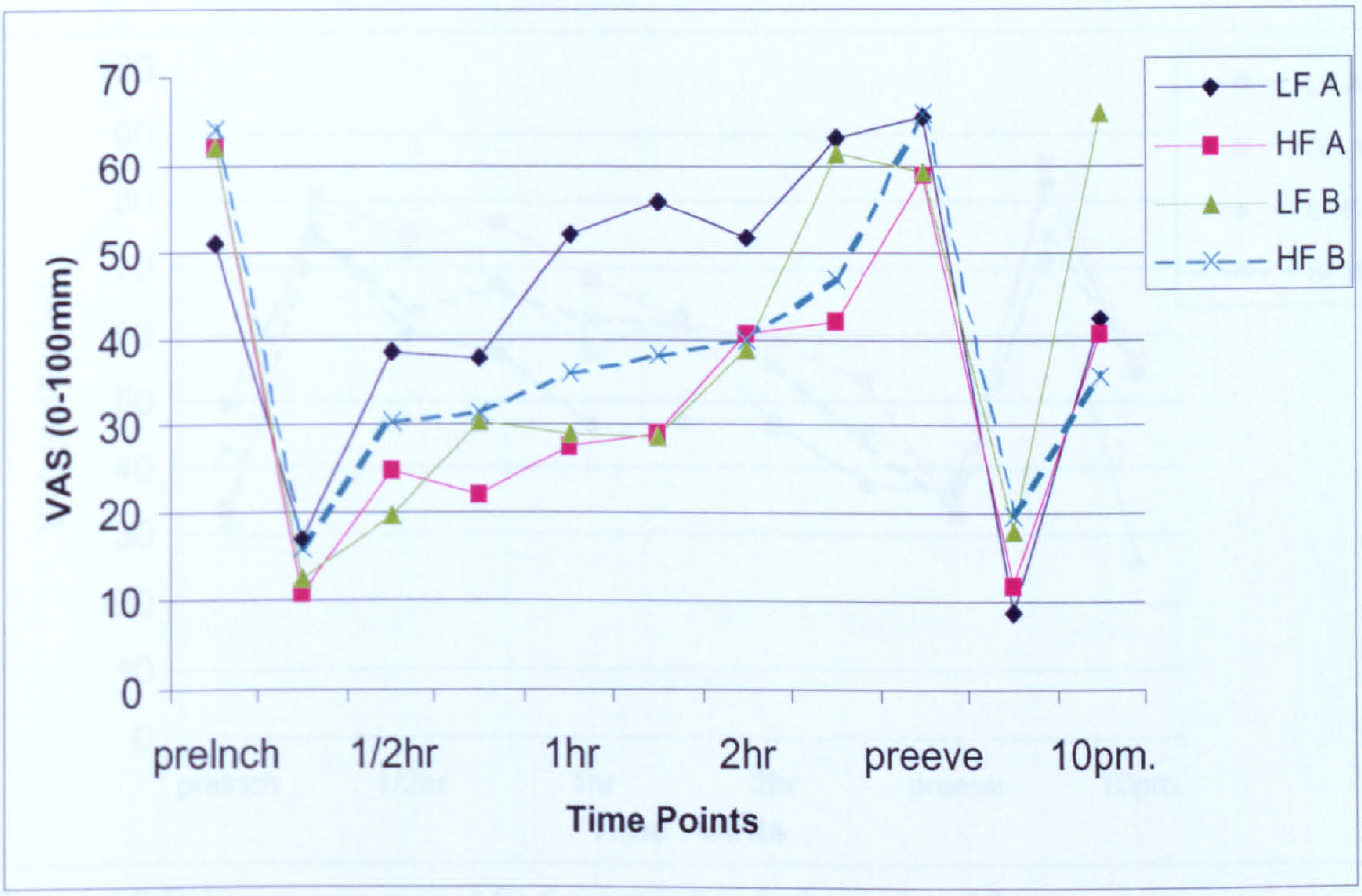

Figure 6.1 Hunger ratings (VAS) from pre-lunch through to 10pm

A 2 by 2 repeated measures ANOVA revealed that there was a significant main effect of GROUP for ratings of hunger ($F_{[1,7]}$= 14.206, p<0.01). Bonferroni post hoc tests revealed that, independent of condition, LF reported significantly higher hunger levels (mean: 42.4; SE:1.25) compared to HF (mean: 36.1; SE:1.12) (p<0.01).

No significant main effect for CONDITION was found ($F_{[1,7]}$=0.07, p=0.804). That is, independent of phenotype group, no differences in hunger ratings were found between the high and low fat conditions. However, there was a significant CONDITION by GROUP interaction ($F_{[1,7]}$ =14.557, p<0.01). This shows that the LF (mean:45.3) reported greater levels of hunger following the low fat condition (A) compared to HF (mean:33.6) (p<0.01) and similar overall hunger following the high fat condition (B) (LF mean: 39.6; HF mean: 38.6) (p=0.803). Looking at the within subject effects LF reported higher levels of hunger following condition A than condition B (p<0.05) and HF reported higher hunger levels following condition B compared to condition A (p<0.01).

Similar patterns were found for fullness (see Figure 6.2) and desire to eat (see Figure 6.3). No significant main effect of CONDITION was found for ratings of fullness ($F_{[1,7]}$= 0.01, p=0.993). However, a significant main effect of GROUP ($F_{[1,7]}$= 10.334, $p<0.05$) was found. Independent of condition HF reported to be more full overall (mean: 59.6; SE:1.15) compared to LF (mean: 54.0; SE:1.29).

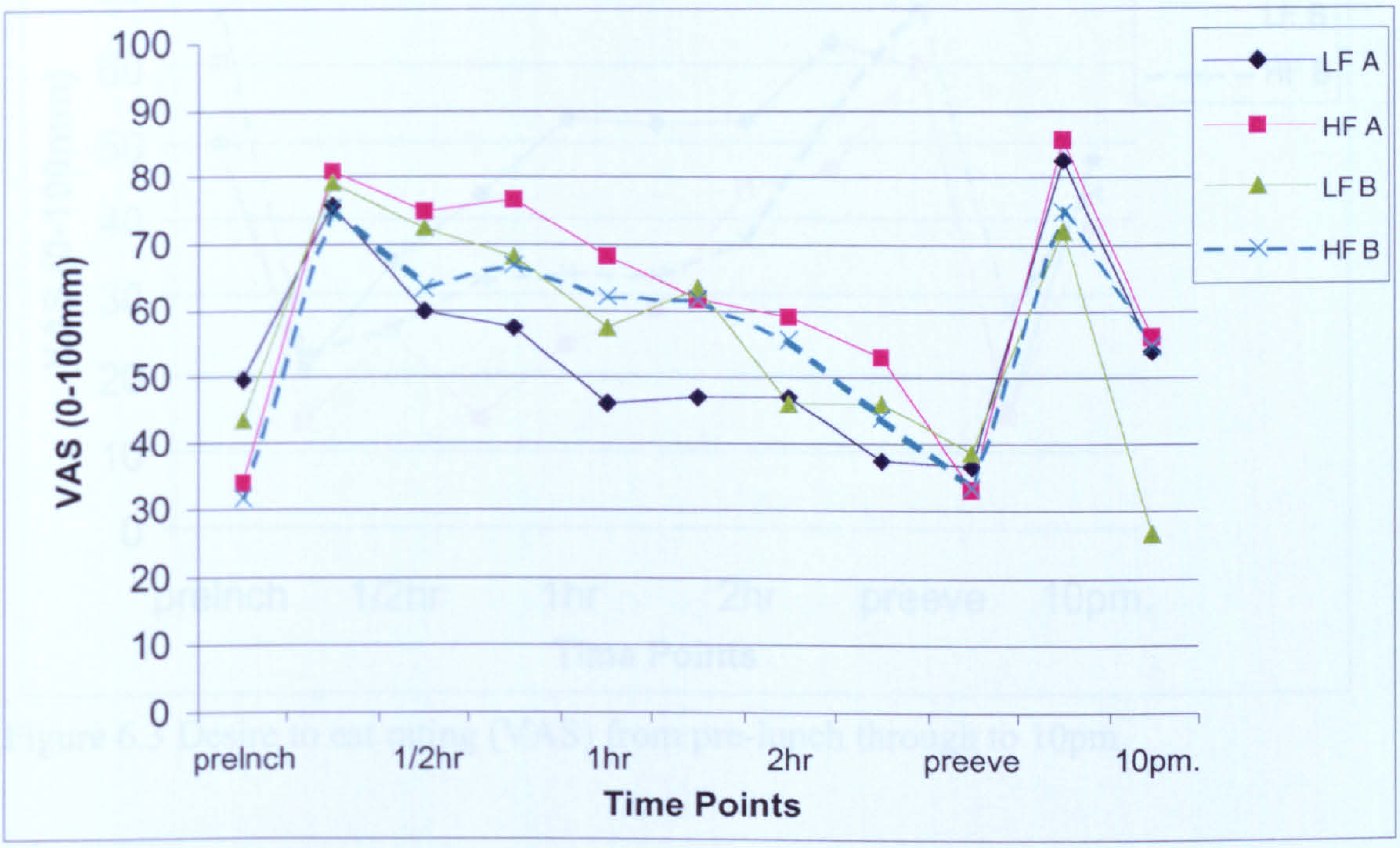

Figure 6.2 Fullness ratings (VAS) from pre-lunch through to 10pm

A significant GROUP by CONDITION interaction was found for ratings of fullness ($F_{[1,7]}$= 27.59, $p<0.001$). HF reported feeling more full after the low fat condition (mean:62.2; SE:0.61) compared to the high fat condition (mean: 57.0; SE:0.50) despite the condition being equal in weight and energy ($p<0.01$). The reverse was true for the LF who reported feeling less full after the low fat condition (mean: 51.4; SE:2.82) and more full after the high fat condition (mean 56.6; SE:1.13) ($p<0.05$).

Figure 6.3 shows the desire to eat profiles across the day. There was no significant main effect of CONDITION ($F_{[1,7]}$= 3.445, p=0.106). However a significant main effect of GROUP ($F_{[1,7]}$= 10.48, $p<0.01$) was found. Independent of high or low fat condition LF reported a significantly higher desire to eat (mean:45.2; SE:2.10) compared to the HF (mean:36.0; SE:1.9) ($p<0.05$). Also a GROUP by CONDITION interaction was found ($F_{[1,7]}$=21.81, $p<0.01$). Post hoc tests showed that LF had a greater desire to eat than HF during the low fat (high CHO) condition ($p<0.05$). Additionally, LF reported a stronger desire to eat following the low fat condition compared to the high fat condition, although this was not significant (p=0.254) whereas HF had a stronger desire to eat following the high fat condition (p<0.001).

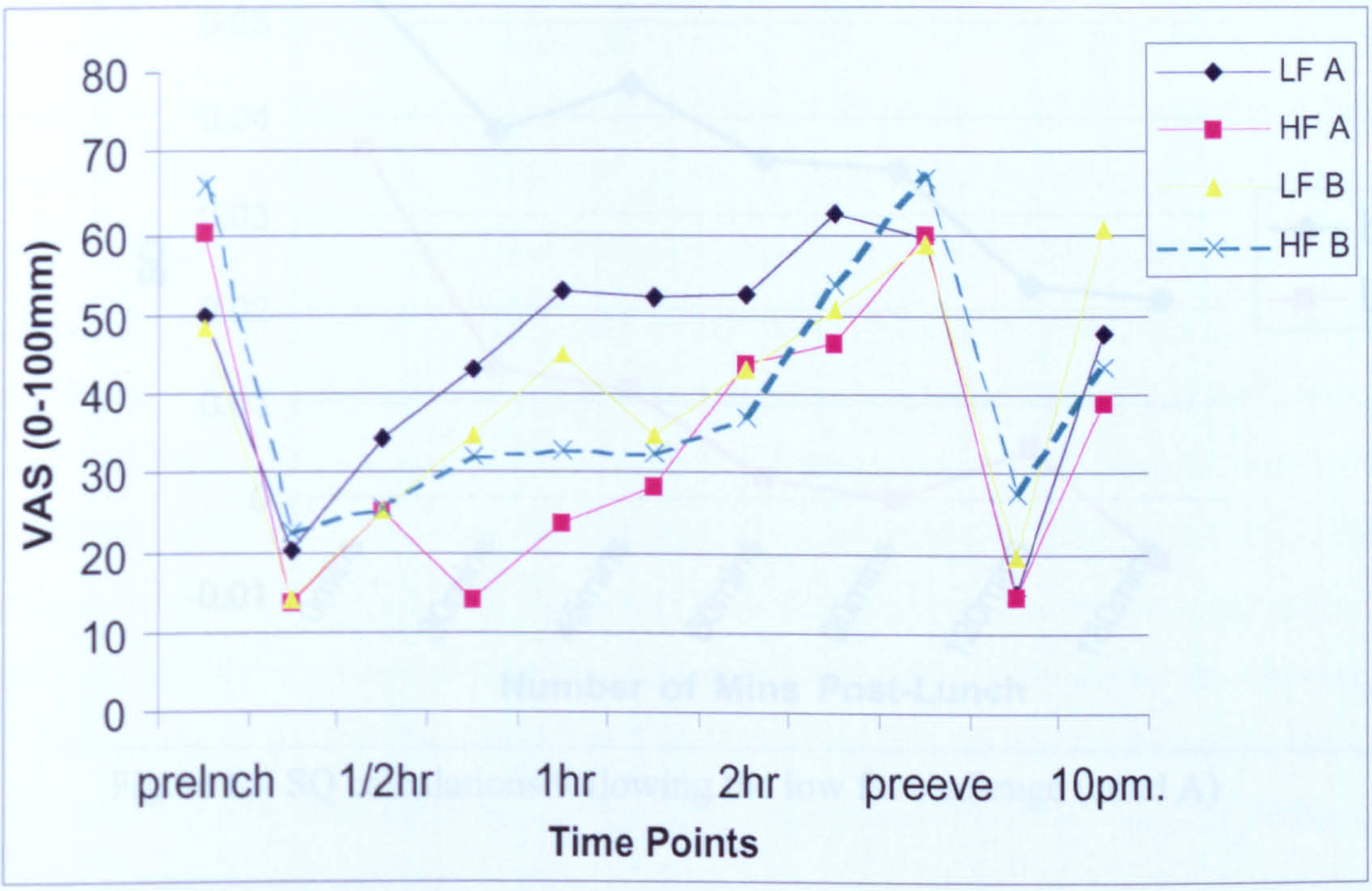

Figure 6.3 Desire to eat rating (VAS) from pre-lunch through to 10pm.

6.4.3 Satiety Quotients

Figure 6.4 shows SQ calculations following the low fat challenge. It can be seen that HF showed a greater level of satiety following this meal compared to the LF. LF reached pre-lunch hunger levels at approximately 90 minutes post-lunch. However HF were still yet to reach pre-lunch hunger levels 3 hours post lunch. Figure 6.5 shows the SQ calculations following the high fat challenge. It can be seen that both LF and HF reported similar levels of satiety following this lunch. LF reached pre-lunch hunger levels 3 hours post-lunch and again HF were yet to reach their reported pre-lunch hunger.

Figure 6.4 SQ calculations following the low fat challenge (cond A)

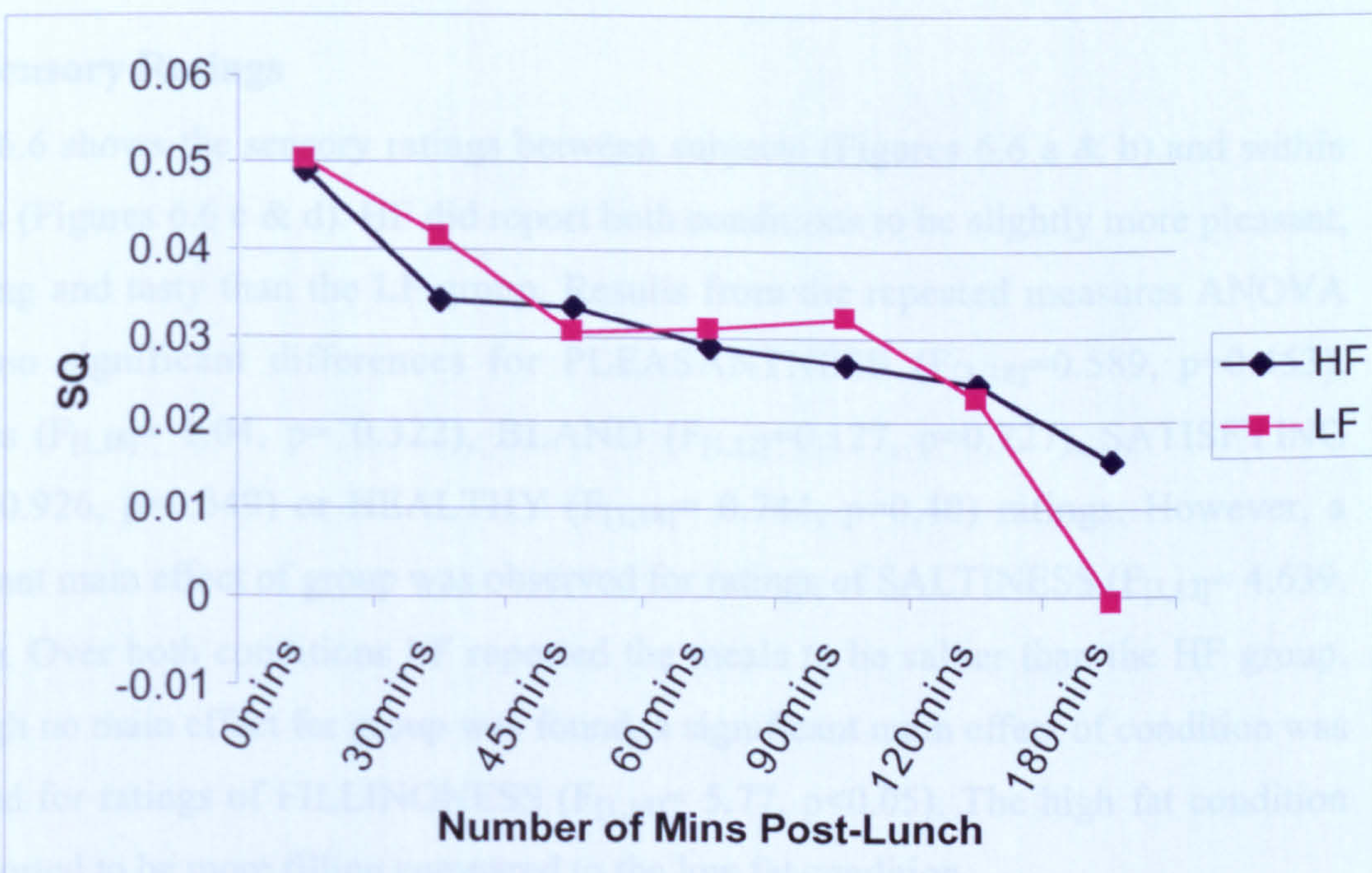

Figure 6.5 SQ calculations following the high fat challenge (cond B)

A 2 by 2 repeated measures ANOVA was carried out on the data. A significant main effect of TIME was found ($F_{[6, 42]}$ =136.88, p<0.001), indicating that the lunches became less satiating per unit energy as time post-lunch increased. Also a significant TIME by

GROUP interaction was observed ($F_{[6,42]}$ =5.967, $p<0.001$). Overall LF reported the lunches as becoming less satiating per unit energy as time post-lunch increased compared to the HF.

There was a significant main effect of GROUP ($F_{[1,7]}$ =40.139, $p<0.001$), with LF reporting to be less satiated by the lunches overall compared to HF. A significant main effect of CONDITION was found ($F_{[1,7]}$ = 11.573, $p<0.05$). Overall the high fat condition was found to be more satiating than the low fat (high CHO) condition. Also a significant CONDITION by GROUP interaction was observed ($F_{[1,7]}$ =40.142, $p<0.001$). LF found the low fat condition less satiating than the HF and both groups found the high fat condition to be similarly satiating, this result contributing to the significant difference between conditions. A significant CONDITION by TIME interaction was found ($F_{[6, 42]}$ =2.744, p=0.024). The high fat lunch was reported to be more satiating per unit energy over time compared to the low fat lunch by all subjects.

HF were more satiated following a low fat (high CHO) challenge compared to the LF. There were no significant difference in satiety response between HF and LF following the high fat challenge.

6.4.4 Sensory Ratings

Figure 6.6 shows the sensory ratings between subjects (Figures 6.6 a & b) and within subjects (Figures 6.6 c & d). HF did report both conditions to be slightly more pleasant, satisfying and tasty than the LF group. Results from the repeated measures ANOVA found no significant differences for PLEASANTNESS ($F_{[1,18]}$=0.589, p=0.453), tastiness ($F_{[1,18]}$= 1.04, p= 0.322), BLAND ($F_{[1,12]}$=0.127, p=0.727), SATISFYING ($F_{[1,18]}$=0.926, p=0.349) or HEALTHY ($F_{[1,18]}$= 0.744, p=0.40) ratings. However, a significant main effect of group was observed for ratings of SALTINESS ($F_{[1,12]}$= 4.639, $p<0.05$). Over both conditions LF reported the meals to be saltier than the HF group. Although no main effect for group was found, a significant main effect of condition was observed for ratings of FILLINGNESS ($F_{[1,18]}$= 5.77, $p<0.05$). The high fat condition was reported to be more filling compared to the low fat condition.

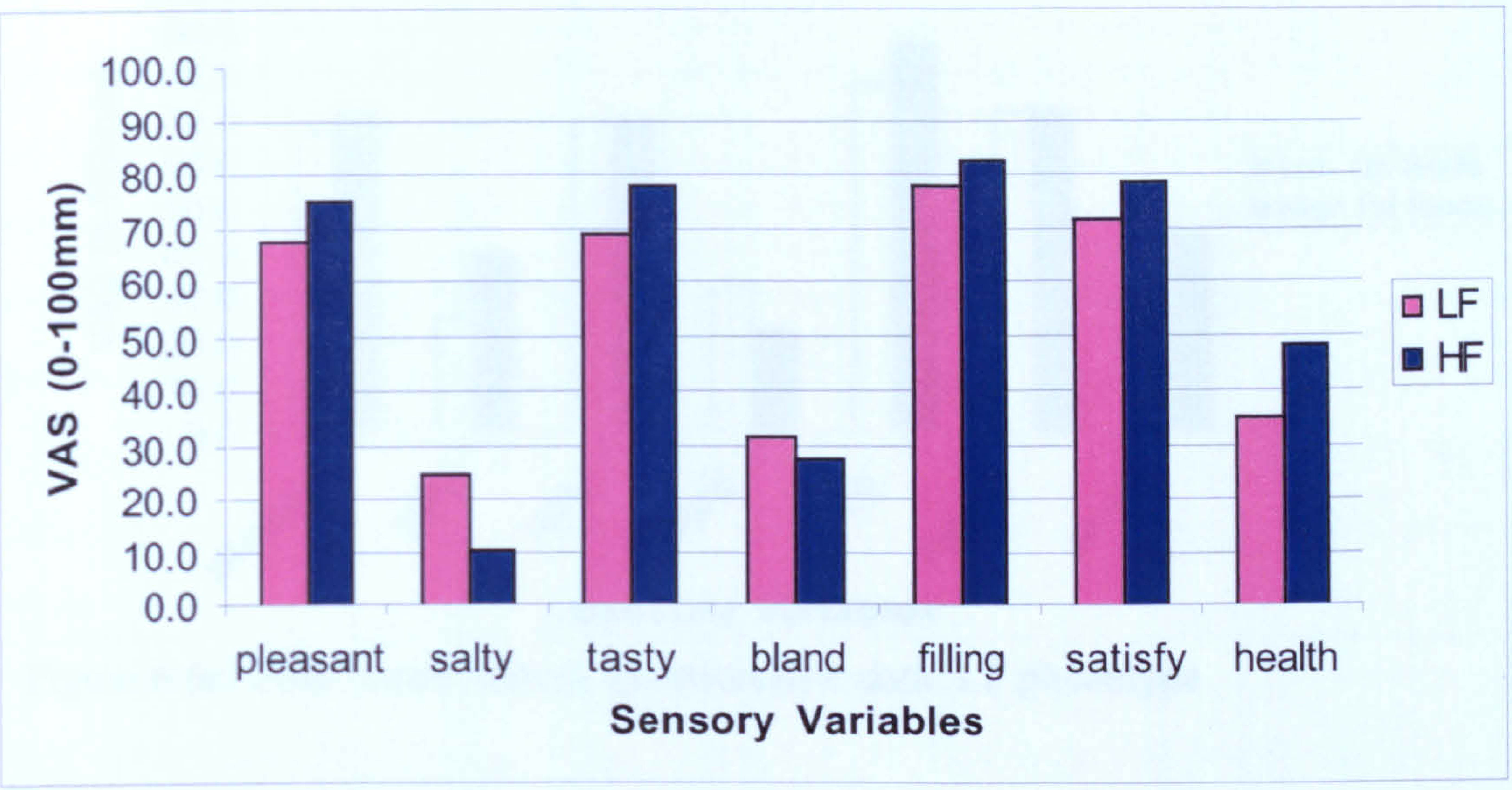

Figure 6.6a- Post-lunch sensory questionnaire data: low fat condition (A)

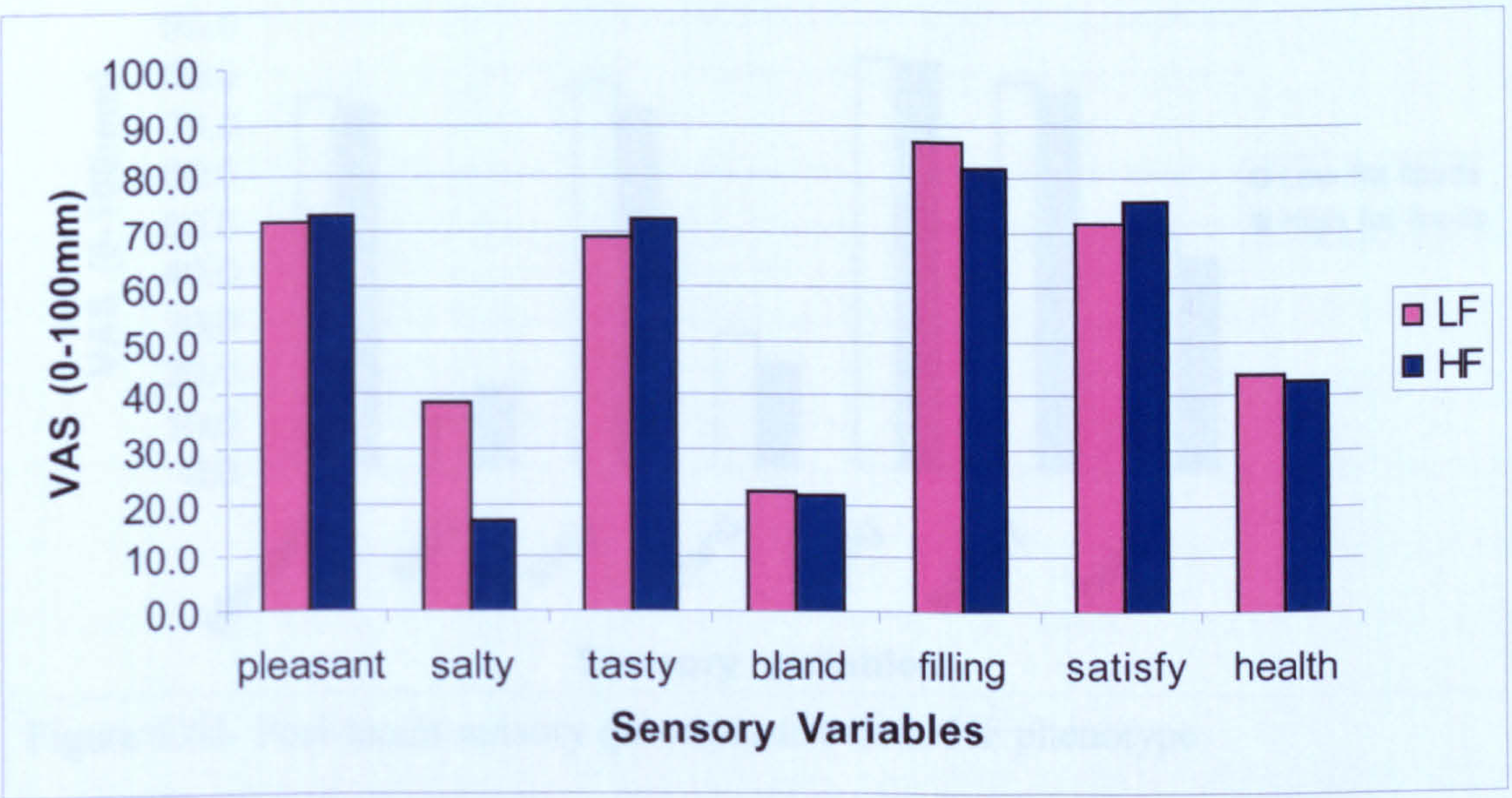

Figure 6.6b- Post-lunch sensory questionnaire data: high fat condition (B)

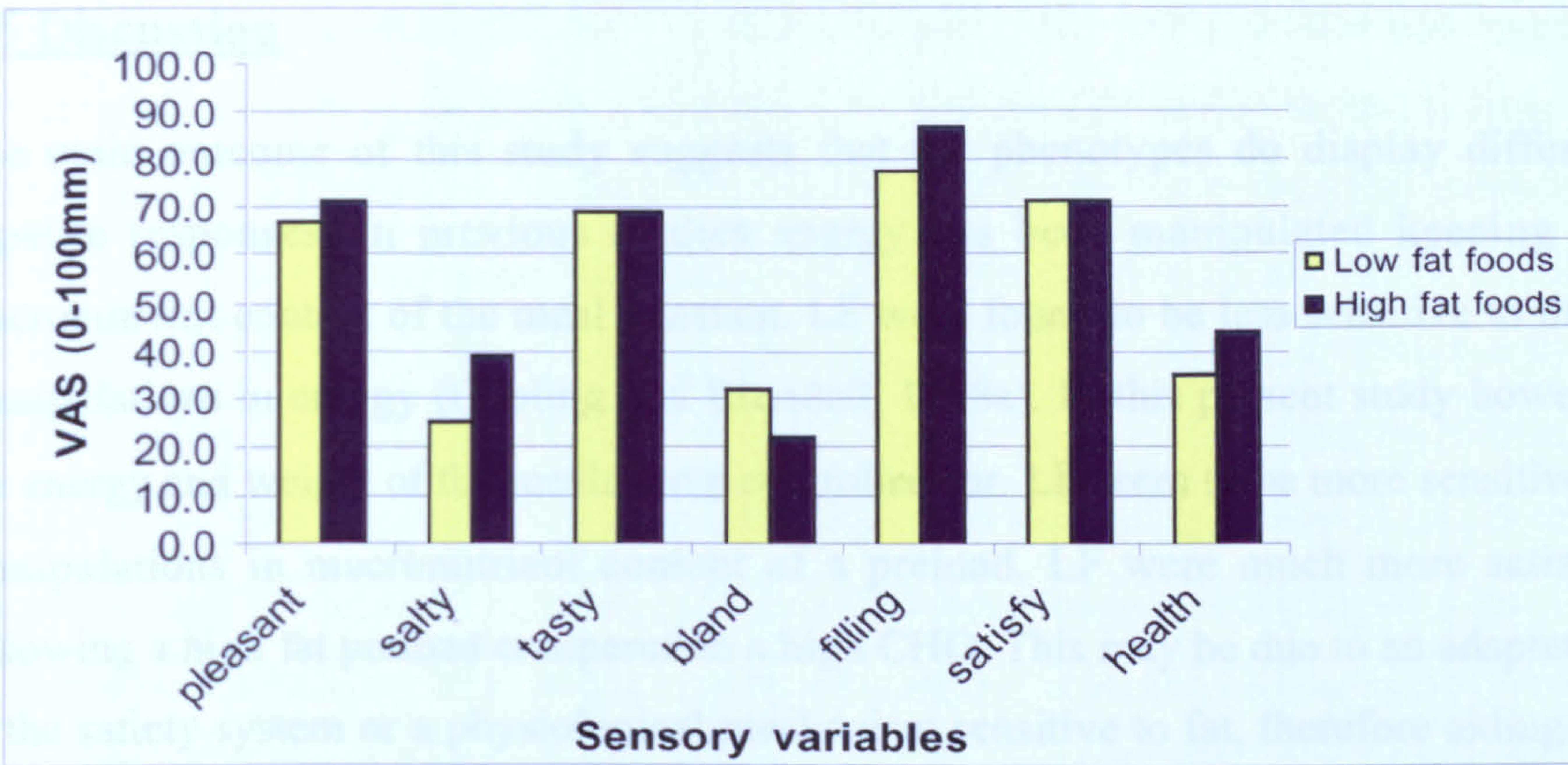

Figure 6.6c- Post- lunch sensory questionnaire data: LF phenotype

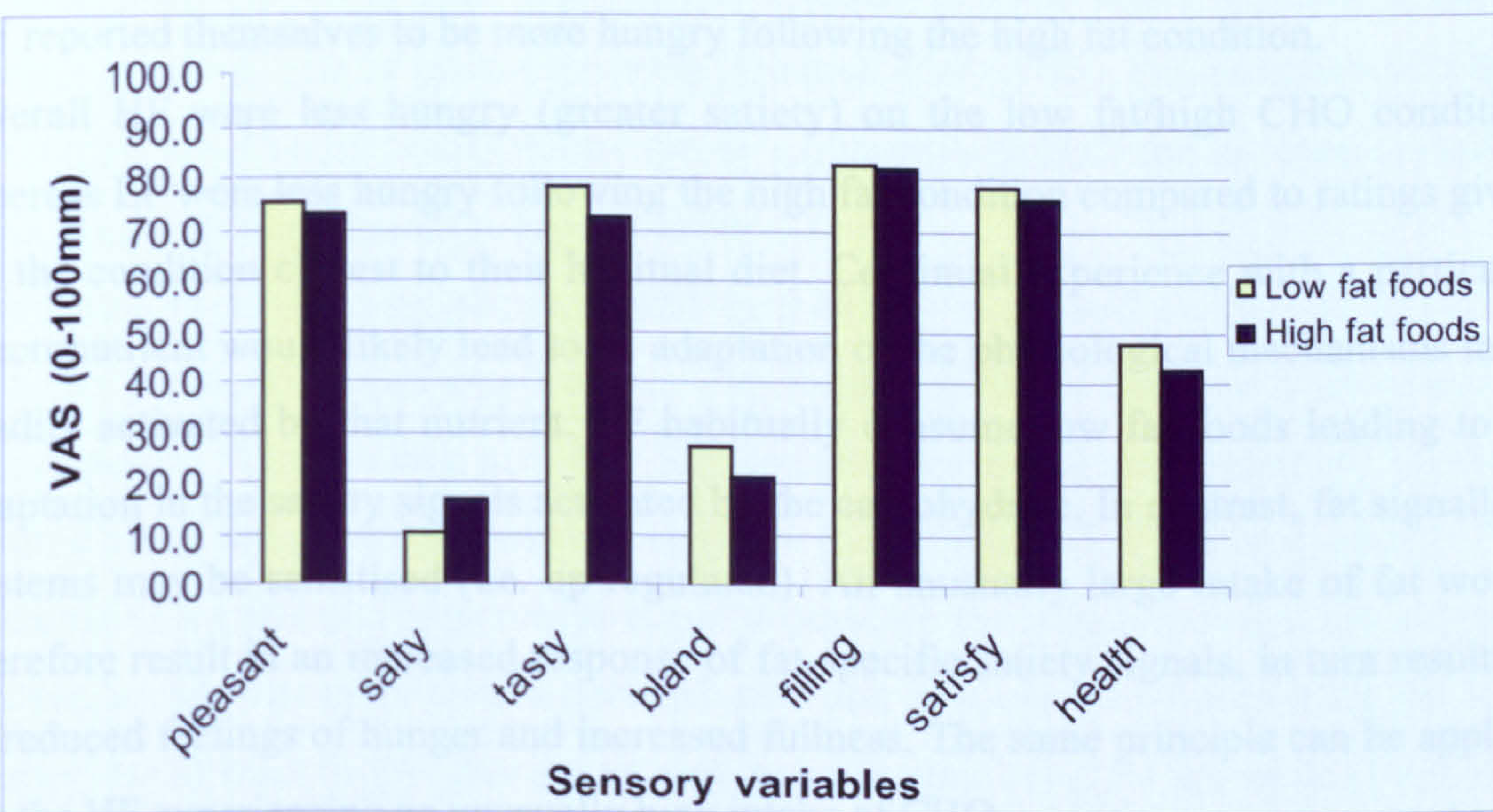

Figure 6.6d- Post-lunch sensory questionnaire data: HF phenotype

6.5 Discussion

The main outcome of this study suggests that the phenotypes do display different appetite responses. In previous studies energy has been manipulated keeping the macronutrient content of the meal constant. LF were found to be less sensitive to these manipulations in energy (Cooling and Blundell, 1998a). In this present study however the energy and weight of the meals were controlled for. LF seem to be more sensitive to manipulations in macronutrient content of a preload. LF were much more satiated following a high fat preload compared to a high CHO. This may be due to an adaptation of the satiety system or a physiological mechanism sensitive to fat, therefore aiding the prevention of passive overconsumption in this group of individuals. HF on the other hand were sensitive to the energy content in the Cooling & Blundell study. A low energy meal showed a rapid recovery in hunger compared to a high energy meal. In this present study however, where energy was kept constant, the hunger profiles showed that HF reported themselves to be more hungry following the high fat condition.

Overall HF were less hungry (greater satiety) on the low fat/high CHO condition whereas LF were less hungry following the high fat condition compared to ratings given on the condition closest to their habitual diet. Continual experience with a particular macronutrient would likely lead to an adaptation of the physiological mechanisms most readily activated by that nutrient. LF habitually consume low fat foods leading to an adaptation in the satiety signals activated by the carbohydrate. In contrast, fat signalling systems may be sensitised (i.e. up regulated). An unusually large intake of fat would therefore result in an increased response of fat-specific satiety signals, in turn resulting in reduced feelings of hunger and increased fullness. The same principle can be applied for the HF experiencing an unusually high intake of CHO.

At first glance, the results of the present study appear to be not consistent with the earlier studies of Cooling and Blundell. However the experimental procedures were different and this must be taken into account in drawing conclusions. In a previous study carried out by Cooling and Blundell (1998a) HF and LF were provided with either a high fat or high CHO *ad lib* meal on two separate occasions. LF were found to consume a uniform amount of energy from both, therefore eating more CHO and a greater amount in weight compared to the amount consumed from the high fat meal. The smaller amount of food consumed in the high fat *ad lib* meal raises the possibility that some early detection of the fat content of these foods (by mouth, stomach and upper intestine) generated signals which inhibited eating and was the basis for judgements of fullness (Cooling and Blundell, 1998a). However when the meal provided was fixed, as in this present study, it might be expected then that the LF would report feeling less hungry (more full) following a high fat meal compared to a low fat meal when both energy and weight were kept constant. Therefore the results of the previous study (Cooling and Blundell, 1998a) and the present study are consistent. Due to the lower energy density of CHO food LF normally eat a greater mass of food (for equal energy) compared to HF, therefore their physiological response to ingestion is likely to be adapted to deal with larger stomach volumes (and faster gastric emptying) but less able to deal with fatty foods. This might explain why the LF reported feeling more full after consumption of the high fat challenge compared to the low fat (high CHO) condition and also compared to the ratings of hunger given by HF. From the results it can be seen that the HF were less hungry following the high CHO challenge. Due to the higher energy density of their habitual diet it is proposed that HF have an adapted physiological system to deal with smaller volumes of food intake and due to the fat content, a slower rate of gastric emptying (French *et al,* 1995). Consumption of a high CHO meal would result in a different satiety response, which HF are not used to dealing with, resulting in increased feelings of fullness.

The operation of different physiological mechanisms is in itself an interesting finding and has methodological implications for future research that involves a dietary manipulation. The finding also has implications for the interpretation of previous studies using unselected samples of subjects (i.e. a mix of LF, HF and others). The outcome of a particular experiment could depend on the habitual diet of the subjects. Failure to take an individual's habitual diet into account when recruiting for such studies could lead to the absence of any positive results if the group is mixed (the average of two distinct patterns) or in the case of inadvertent selective recruitment could result in a misleadingly extreme response. This has previously been highlighted along with the idea that a common system of appetite control operating similarly in all individuals may have to be revised and possibly replaced by a conceptualisation which reflects a system modulated by intrinsic or acquired biases (Cooling and Blundell, 1998a).

These results might also be explained in terms of a change in normal eating patterns for HF. It has previously been established that HF and LF have quite different eating patterns with HF on average usually found to skip breakfast (Macdiarmid *et al,* 1996b) and consuming much of their energy intake during the late afternoon and throughout the evening (Le Noury *et al*, 2000; see Chapter 5). In this study HF were asked to consume a large amount of energy in the beginning of the day, a pattern of eating quite different to their habitual routine. This might explain why the HF reported themselves to be more satiated during this period compared to the LF, particularly following the high CHO. Lastly, the findings from the sensory questionnaire are of interest. It might be first postulated that hedonic value and an increased reward response to food are involved in the development of the habitual diet. For example, HF select high fat foods because they find them more rewarding (i.e. satisfying, tasty and pleasant) than lower fat foods and more rewarding compared to their LF counterparts. However the findings from this study do not suggest this. No significant differences were found for ratings of pleasantness, tastiness and satisfaction between groups or within groups. That is, all volunteers, despite their habitual diet, appear to enjoy all the foods equally. This could be linked to how energy balance is maintained in HF. Although selecting a diet that puts them at risk, they are less prone to over eating if they do not have an enhanced hedonic response to the food consumed. This hypothesis will be further investigated later in this thesis by comparing lean and overweight HF (resistant and vulnerable individuals).

6.6 Summary

This study has established that there are differences in hunger and satiety responses to macronutrient challenges (high CHO and high fat) in habitual high fat and low fat phenotypes, when energy and weight of food are kept constant.

- LF show a decrease in hunger following a high fat challenge and HF show a decrease in hunger following a high CHO challenge. This indicates an increased sensitivity of satiety signals following consumption of a novel nutrient.

- No significant differences in ratings of pleasantness, tastiness and satisfaction were found between lean HF and LF.

- Fat and CHO foods differ in their post-ingestive actions independently of weight, energy value and taste characteristics. However, these macronutrients do not exert similar effects in all volunteers (i.e. habitual HF phenotypes experience different effects compared to LF).

- Interestingly, high fat foods were found to have a greater satiating capacity than high carbohydrate foods. This may have arisen, in part, because of the specific experimental procedures.

- Methodological implications for (past and) future research involving dietary manipulations have been highlighted. In a non-selected group these differences would cancel out therefore giving the impression that fat and CHO do not differ in their actions. Failure to take into account the habitual diet when recruiting could lead to the absence of positive results or misleading extreme responses.

These results show that HF and LF phenotypes (habitual diet) respond quite differently to prior fat and CHO loading. These findings validate the identities of the phenotypes and promote the view that these groups are physiologically different. However, it should be kept in mind that this study has examined only the subjective experiences arising from an imposed pattern of consumption. This experimental strategy is different from a free feeding situation and has not measured the actual behavioural response.

Chapter 7

SUBSEQUENT MACRONUTRIENT COMPENSATION AND CHANGES IN SLEEP PATTERNS FOLLOWING A HIGH CARBOHYDRATE AND HIGH FAT CHALLENGE

7.1 Introduction

As previously discussed, it has been found that food varies in its capacity to effect appetite. The previous part of this study looked at the immediate post-ingestive and post-absorptive effects of fat and carbohydrate on the hunger response and satiety. This part aims to look at the acute effect of changing the diet on subsequent food and energy intake. Metabolic and physiological requirements to deal with different diets may change the physiological response to food and adjust the operation of the appetite control system (Cooling, 1998). It has been shown from the previous study that LF show decreases in hunger and increases in satiety following a high fat challenge compared to a high carbohydrate challenge. Is it the case that these changes in the physiological response to the food therefore influence subsequent energy intake, that is, do LF compensate for the increased amount of fat previously consumed? A subsequent compensatory underconsumption following a high fat meal has been shown in some studies (Foltin *et al,* 1990) but not in others (Stubbs *et al,* 1993). Romon *et al* (1999) investigated subsequent energy intake in response to a carbohydrate or fat meal in male and female volunteers. It was found that subsequent energy intake was not different after CHO or fat intake. It has also been concluded that when isoenergetically dense high fat and high carbohydrate foods are consumed *ad libitum,* energy intake of high fat and high CHO foods are similar (Stubbs *et al,* 1996). However it is proposed that the individual differences in the habitual diet of the volunteers should be taken into account and may help to explain the conflicting findings in this area of research.

Also, it might be interesting to investigate whether a change from a high fat diet to a low fat diet has beneficial effects on subsequent food intake, i.e. do HF revert back to their normal eating patterns following exposure to a high carbohydrate preload or is food choice altered as a result? de Graaf *et al* (1997) carried out an investigation to measure energy and fat compensation during a long term consumption of reduced fat products. It was concluded that long term consumption of these low fat products lead to lower energy and fat intake compared to the consumption of full fat products. However, the normal habitual dietary patterns of these subjects were not determined. Is this effect seen immediately after a change in the *habitual* diet? If so, this may have long-term benefits for reducing fat intake and lessening the risk of the development of obesity.

7.2 Objective

The main aim of this part of the study was to investigate the presence of macronutrient compensatory mechanisms following an acute change in the habitual diet. Additionally energy intake, sleeping patterns and food choice preferences were monitored following a high CHO and high fat challenge.

7.3 Method

7.3.1 Recruitment process & Subjects

As previous section (see 6.1.3.2 and 6.1.3.3)

7.3.2 Experimental Design

The purpose of the study was to assess the compensatory effect in response to a high fat and high carbohydrate challenge in high and low fat phenotypes. The study was a 2 x 2 fully repeated measures design with both HF and LF participating in two experimental conditions:

A: LOW FAT CONDITION

- FIXED low fat breakfast, snack and lunch
- AD LIB evening meal

B: HIGH FAT CONDITION

- FIXED high fat breakfast, snack and lunch
- AD LIB evening meal

The two conditions were presented in a counterbalanced order one week apart.

7.3.3 Procedure

Volunteers were provided with a fixed breakfast, a mid-morning snack two hours post-breakfast and a fixed lunch four hours post breakfast (see chapter 6, section 6.3.3.1 for macronutrient breakdown of these meals). Four hours post lunch volunteers were provided with an *ad libitum* evening meal. This consisted of a selection of high fat and low fat (high CHO) foods, both savoury and sweet, and volunteers were instructed to eat as much or as little as they wanted until they had reached a comfortable level of fullness. The forced choice photograph method (see chapter 4) was administered pre- and post- evening meal in order to assess 'state' food preferences. Four hours post evening meal volunteers were instructed that they were free to consume any food or drink required (except alcohol). Anything that was consumed was to be recorded as detailed and accurately as possible in a food diary. On waking the following morning the volunteers were required to complete a copy of the Leeds Sleep Questionnaire (LSQ), which had been adapted to measure sleeping patterns for that particular night (see Appendix vib).

7.3.3.1 Ad libitum test meal

The fixed test meal challenge was as the previous chapter. Both conditions required the consumption of a fixed breakfast, mid morning snack and lunch. Condition A was the low fat challenge and condition B was the high fat challenge. The energy and weight of these conditions were kept constant with only the fat and carbohydrate content varying. Four hours after each lunch volunteers were provided with an *ad libitum* meal containing a mixture of high fat and high carbohydrate foods. Table 7.1 shows the energy and macronutrient composition of this test meal.

7.3.4 Data analysis

2 by 2 repeated measures ANOVAs were used to analyse the macronutrient and energy intakes during the *ad lib* meal and for the rest of the day and the sleep variables. A five way ANOVA was carried out on the forced choice data using GROUP (HF v LF) by CONDITION (A low fat v B high fat) by TIME (pre v post) by FOOD TYPE (highfat food v lowfat food) by FOOD TASTE (savoury v sweet). Post hoc within and between groups *t*-tests were carried out where significant differences were found.

Table 7.1 Ad libitum test meal composition

g per 100g of food, % energy

FOOD ITEM	KCAL (/100g)	FAT	CHO	PROTEIN
Go Ahead ham & cheese pizza	223 kcal	4.1g, 20.1%	35.5g, 59.7%	11.2g, 20.1%
Cheese & onion quiche	242.4 kcal	13.5g, 50.1%	25.3g, 39.1%	6.5g, 10.7%
Lettuce	12.1 kcal	0.4g, 29.8%	1.2g, 37.2%	1.0g, 33.1%
Tomato	14.1 kcal	0.0g, 0.0%	2.8g, 74.5%	0.9g, 25.5%
Cucumber	10.1 kcal	0.1g, 8.9%	1.8g, 66.8%	0.6g, 23.8%
Coleslaw	207.5 kcal	18.4g, 79.8%	9.9g, 17.9%	1.2g, 2.3%
Jelly Babies	314.1 kcal	0.0g, 0.0%	79.5g, 94.9%	4.0g, 5.1%
White chocolate button	527.7 kcal	31.3g,53.4%	57.5g, 40.9%	7.9g, 5.8%
Malt loaf	312 kcal	1.7g, 4.9%	66.5g, 79.9%	7.6g, 9.7%
Shortbread	512.4 kcal	29g, 50.9%	61.6g, 45.1%	5.1g, 4.0%

7.4 Results

7.4.1 Compensation Effects

Table 7.2 shows the total macronutrient and energy intakes for both phenotypes on each condition. They were calculated from the sum of intake during the *ad-lib* meal and the rest of the day as recorded in the food diary. Overall the HF consumed approximately 2MJ more than LF over the measurement period. The first ANOVA tested whether these observed differences in energy intake across conditions between phenotypes were significant. No significant main effect of GROUP was found ($F_{[1, 14]}$ =0.712, p=0.413) and no significant main effect of CONDITION was found ($F_{[1, 14]}$ =1.125, p=0.307. However a significant GROUP by CONDITION interaction was found ($F_{[1, 14]}$ = 13.9, p<0.005). HF were found to have consumed significantly more calories compared to the LF during condition B (high fat condition) (t=-2.19, df= 14, p<0.05) but no significant difference was found during condition A (t=0.812, df=14, p=0.430). Also HF were found to have consumed significantly more calories during the high fat condition (B) compared to the low fat condition (A) (t=-7.28, df=7, p<0.001). No significant difference in energy consumed between conditions was found for LF (t=1.412, df=7, p=0.201).

Table 7.2 Ad libitum dietary intakes following a low and high fat challenge (mean +/- SD)

	LF		HF	
CONDITION	**A (high CHO)**	**B (high fat)**	**A (high CHO)**	**B (high fat)**
WEIGHT (g)	937.4 +/- 370.2	905.8 +/- 634.6	884.9 +/- 247.8	1539.3 +/- 792.7
ENERGY (kJ)	6503.7 +/- 2447.0	5266.4 +/- 2796.0	5640.5 +/- 1743.9	7862.2 +/- 1860.1
EI (kcal)	1555.9 +/- 585.4	1259.9 +/- 668.9	1349.4 +/- 417.2	1880.9 +/- 445.0
FAT (g)	60.0 +/- 34.1	54.0 +/- 20.0	47.1 +/- 17.5	81.2 +/- 24.0
CHO (g)	220.6 +/- 54.0	166.6 +/- 72.4	199.2 +/- 65.8	250.3 +/- 78.4
PRO (g)	47.2 +/- 18.5	37.6 +/- 12.5	44.6 +/- 10.6	53.1 +/- 18.1
FAT (%)	34.7 +/- 8.7	38.6 +/- 10.8	31.4 +/- 6.3	38.9 +/- 5.8
CHO (%)	53.2 +/- 12.7	49.6 +/- 13.0	55.4 +/- 6.0	49.9 +/- 8.7
PRO (%)	12.1 +/- 0.83	11.9 +/- 2.8	13.2 +/- 1.5	11.3 +/- 2.6

The second ANOVA tested whether there was a significant difference in the amount of fat (g) consumed across conditions and phenotypes. No significant main effect of CONDITION was found ($F_{[1, 14]}$ =0.162, p=0.694). That is regardless of phenotype group no significant difference in the amount of fat consumed during conditions A and B was found. Also no significant main effect of GROUP was found ($F_{[1, 14]}$ = 0.032, p=0.86). HF and LF consumed similar amount of fat across both conditions. However a significant GROUP by CONDITION interaction was found ($F_{[1,14]}$ = 6.32, p<0.05). There were no significant between-groups differences (Cond A: t=1.614, df=14, p=0.129; Cond B: t=-1.675, df=14, p=0.116), however within groups post hoc *t*-tests revealed that the HF ate significantly more fat following condition B than condition A (t= -2.518, df=7, p<0.05). No significant difference in the amount of fat consumed between condition A and condition B was found for the LF (t=1.296, df=7, p=0.231). No significant main effects for GROUP or CONDITION (or interactions) were found for the remaining macronutrient variables.

7.4.2 Food Preferences

Figure 7.1 shows the pre and post-meal preference ratings given in the Forced Choice questionnaire for high fat and low fat food types during each condition, and Figure 7.2 shows the preference ratings given for savoury and sweet foods. For ratings given for food taste (high or low fat), overall there was no main effect for GROUP ($F_{[1,14]}$ = 2.778, p=0.118) or CONDITION ($F_{[1,14]}$ =0.368, p=0.554). That is regardless of phenotype group (and condition) high fat and low fat options were preferred (chosen) equally.

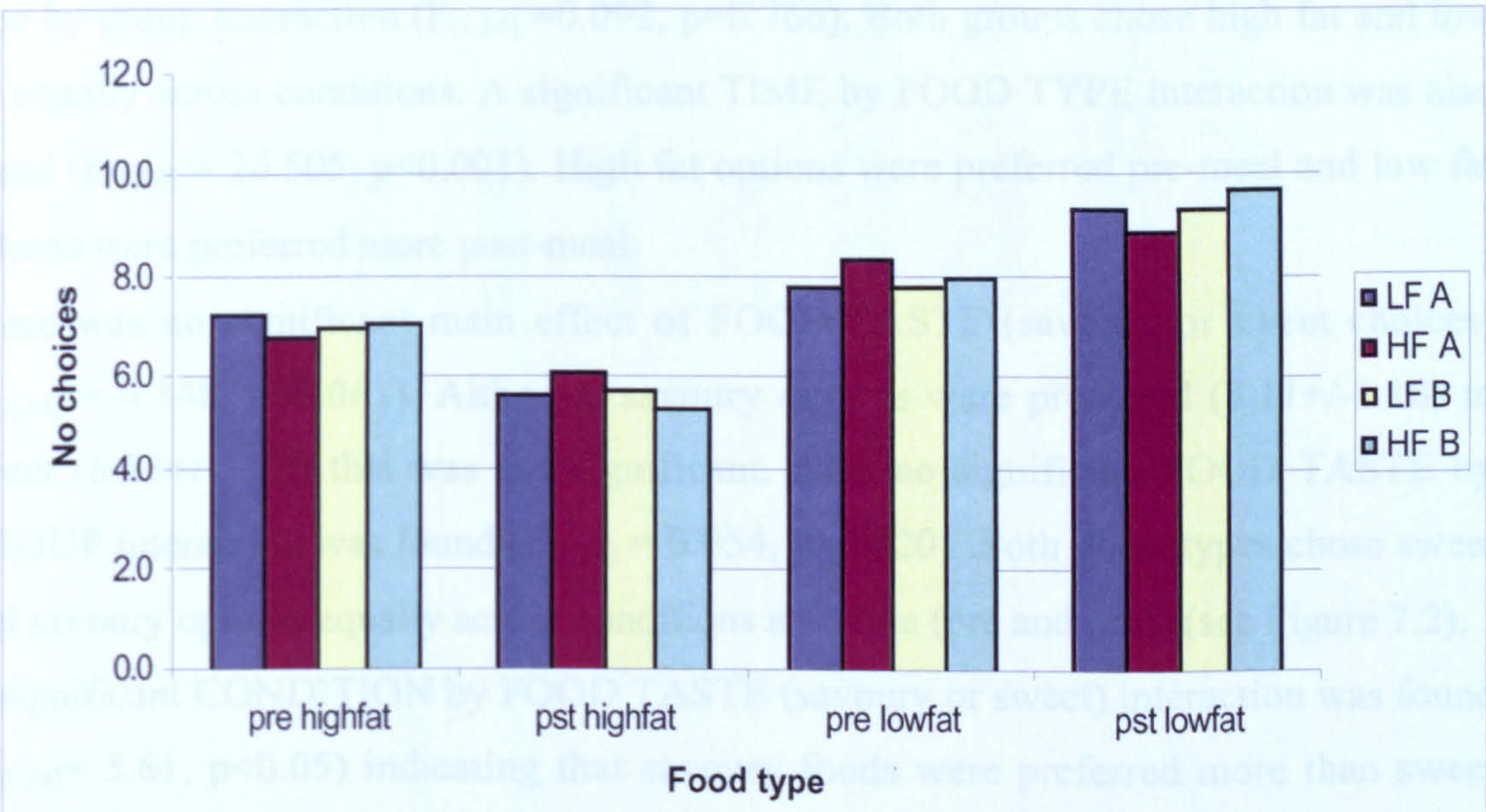

Figure 7.1- Pre- and post-meal preference ratings given on the Forced Choice questionnaire for high fat and low fat food (TYPE).

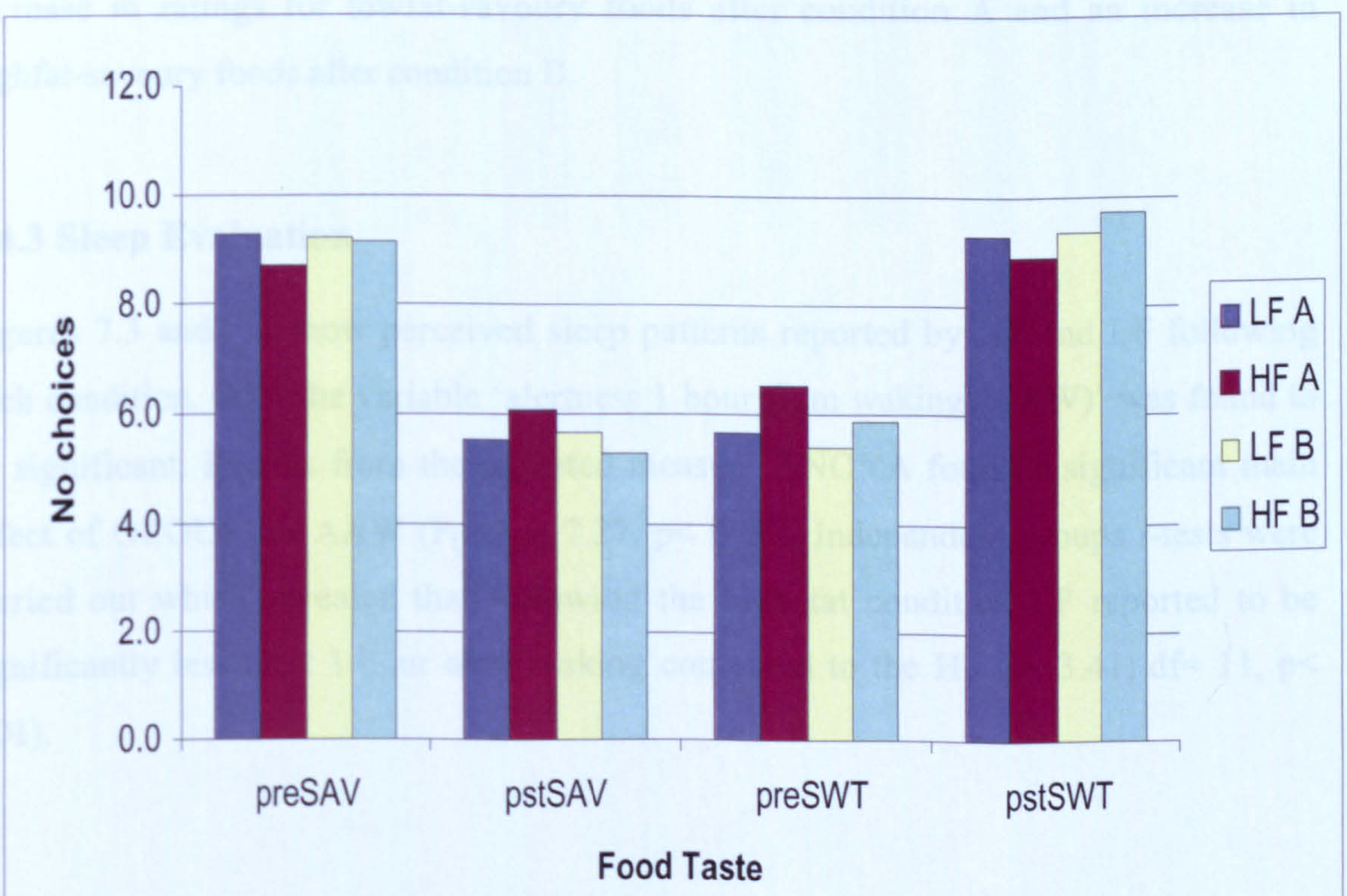

Figure 7.2 Pre- and post-meal preference ratings for savoury and sweet foods (TASTE).

There was a main effect of FOOD TYPE (high fat or low fat choices) ($F_{[1,14]} = 31.65$, $p<0.0001$). Overall low fat options were chosen more frequently (8.65+/-0.79) compared to high fat options (6.34+/-0.81) (see figure 7.1). However there was no food type by group interaction ($F_{[1,14]} = 0.092$, $p=0.766$). Both groups chose high fat and low fat equally across conditions. A significant TIME by FOOD TYPE interaction was also found ($F_{[1,14]} = 26.505$, $p<0.001$). High fat options were preferred pre-meal and low fat options were preferred more post-meal.

There was no significant main effect of FOOD TASTE (savoury or sweet choices) ($F_{[1,14]} = 4.148$, $p=0.061$). Although savoury options were preferred (8.11+/-1.18) to sweet (6.88+/-1.18) this was not significant. Also no significant FOOD TASTE by GROUP interaction was found ($F_{[1,14]} = 0.054$, $p=0.820$). Both phenotypes chose sweet and savoury options equally across conditions and time (pre and post) (see Figure 7.2).

A significant CONDITION by FOOD TASTE (savoury or sweet) interaction was found ($F_{[1,14]} = 5.61$, $p<0.05$) indicating that savoury foods were preferred more than sweet foods following condition B (high fat condition). A TIME by FOOD TASTE interaction was also found ($F_{[1,14]}=19.03$, $p<0.001$) showing a greater preference for savoury food pre-meal and a greater preference for sweet foods post-meal. There was a CONDITION by FOOD TYPE by FOOD TASTE interaction ($F_{[1,14]}= 24.04$, $p<0.001$). There was an increase in ratings for lowfat-savoury foods after condition A and an increase in highfat-savoury foods after condition B.

7.4.3 Sleep Evaluation

Figures 7.3 and 7.4 show perceived sleep patterns reported by HF and LF following each condition. Only the variable 'alertness 1 hour from waking (AAW)' was found to be significant. Results from the repeated measure ANOVA found a significant main effect of GROUP for AAW ($F_{[1,11]} = 7.27$, $p< 0.05$). Independent groups *t*-tests were carried out which revealed that following the high fat condition LF reported to be significantly less alert 1 hour after waking compared to the HF ($t= 3.41$, $df= 11$, $p< 0.01$).

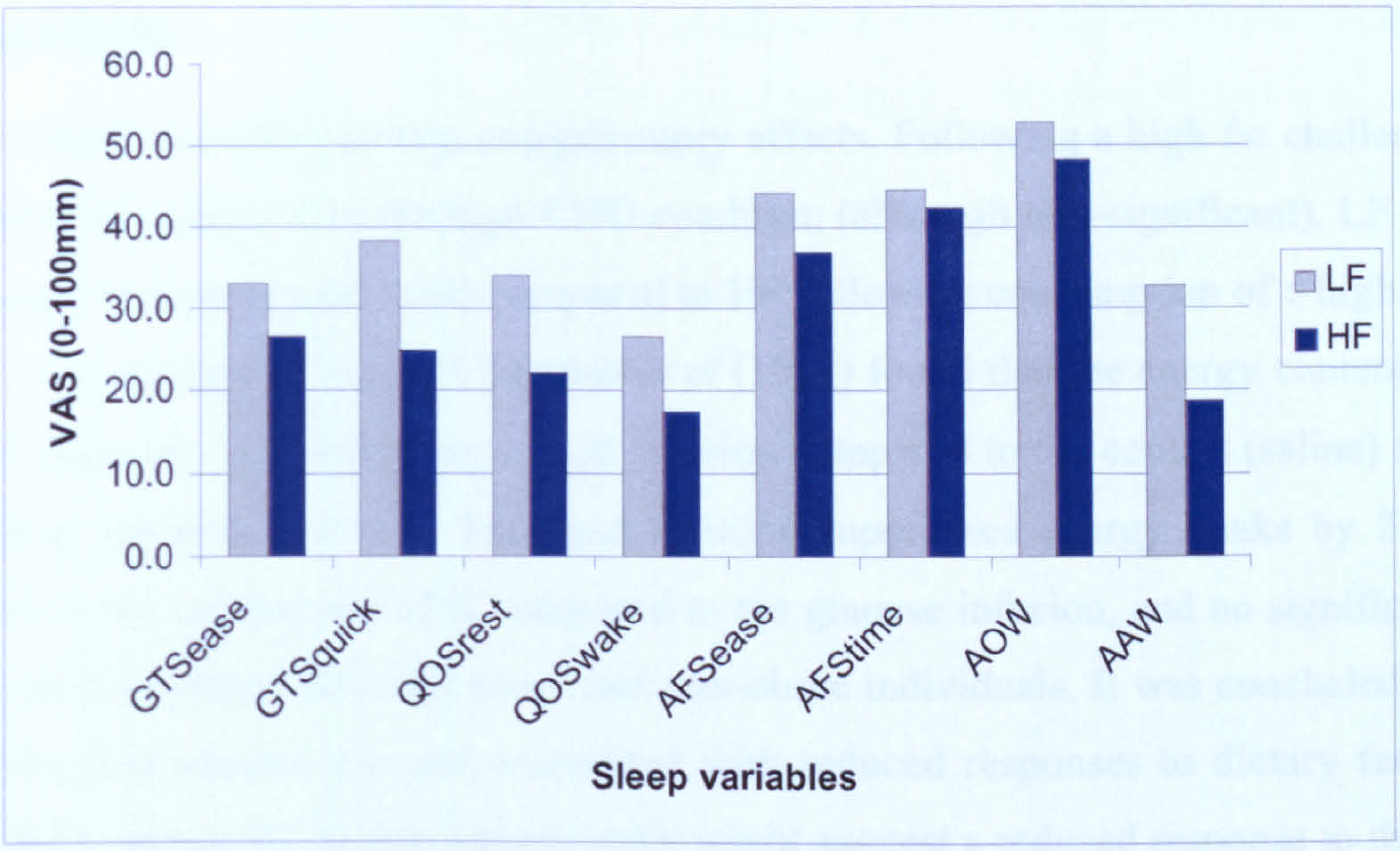

Figure 7.3 Results summary of the LSQ: low fat (condition A)

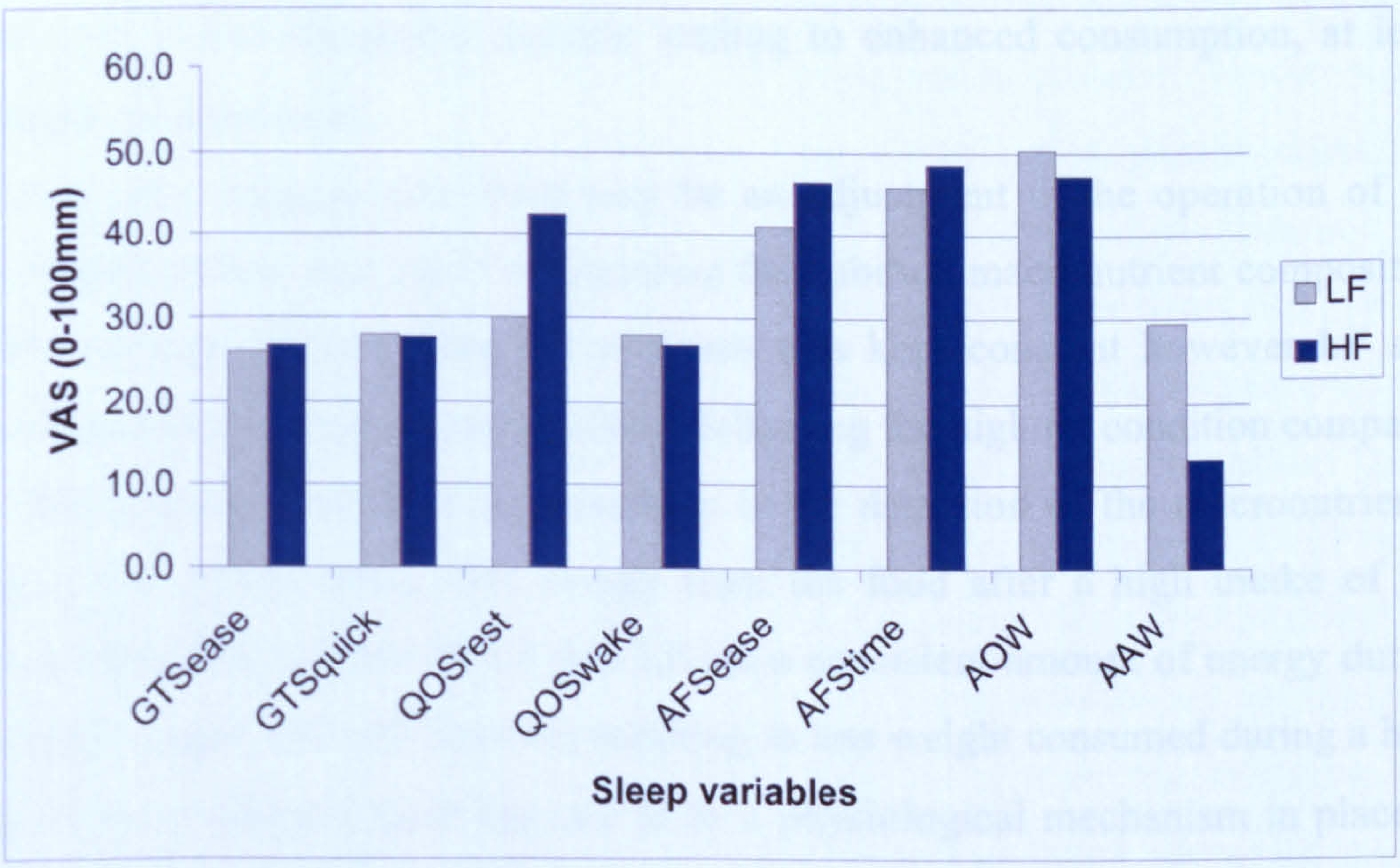

Figure 7.4 Results summary of the LSQ: high fat (condition B)

7.5 Discussion

LF were found to exhibit certain compensatory effects. Following a high fat challenge LF ate less fat compared to the high CHO condition (although non-significant). LF ate significantly less energy (in kcal) compared to HF following consumption of a high fat preload. A study carried out by Chapman *et al* (1999) found that the energy content of the food eaten was less following a lipid infusion compared to the control (saline) and the glucose infusion ($p<0.05$). The lipid infusion suppressed energy intake by 22% compared to the control and 15% compared to the glucose infusion, and no significant differences were found between obese and non-obese individuals. It was concluded by the authors that obesity was not associated with reduced responses to dietary fat or carbohydrate. However, as this present study might suggest a reduced response to these macronutrients may be involved in the development (risk factor) rather than the maintenance stages of this condition, as HF were shown to significantly increase energy and fat intake following a high fat preload. Indeed in habitual HF consumers, high fat food seems to further disinhibit appetite leading to enhanced consumption, at least under certain circumstances.

This finding also suggests that there may be an adjustment in the operation of the appetite control system as a result of changing the habitual macronutrient composition of the diet. Energy intake during the preloads was kept constant however LF still showed a marked difference in energy intake following the high fat condition compared to HF. This indicates that there is sensitivity to the detection of the macronutrients, resulting in this group eating less energy from the food after a high intake of fat. Cooling and Blundell (1998a) found that LF ate a consistent amount of energy during the two meals (high CHO and high fat) resulting in less weight consumed during a high fat meal. In these subjects there appears to be a physiological mechanism in place in order to compensate for an increase of fat intake earlier in the day. This may be viewed as a protective mechanism in this group that could help to prevent passive overconsumption. HF on the other hand appear to be more prone to overconsumption as a result of an increased amount of fat (but not energy) in a preload, with an increase in both energy intake and fat intake following condition B (high fat). French *et al* (1995) found that two weeks of high fat overfeeding gave rise to greater hunger and intake at a test meal.

HF showed some adjustments following the high CHO challenge compared to a high fat challenge. HF ate significantly less energy and less fat following condition A (high

CHO) compared to condition B (high fat). A study by Cotton *et al* (1994) found similar results to that shown by the HF in this study. Carbohydrate-supplemented breakfast suppressed intake but fat supplemented breakfasts did not. This shows that there are immediate benefits from switching from a high fat diet to a more judicious low fat diet. de Graaf *et al* (1997) looked at the long term effects of the consumption of low fat products and found that this lead to lower energy and fat intakes compared to the consumption of full fat products. It appears from this study that these benefits are apparent as soon as the diet is altered and particularly for habitual high fat consumers. Whether these adjustments can be maintained warrants further exploration.

In general, subjectively evaluated sleep variables were not markedly changed by this dietary manipulation. Improvements were seen with HF on the sleep variables following high CHO (although non-significant). LF showed a significant decrease in alertness one-hour after waking following condition B (high fat). It seems there is a 'knock on' effect of exposure to a high fat challenge causing alertness problems the following day. It might be inferred that this would result in an increase in tiredness, decreased cognitive performance and also subsequent effects on eating patterns. However this remains to be demonstrated. In previous studies on the effect of macronutrients on cognitive performance Kelly *et al* (1994) compared low and high carbohydrate and low and high fat lunches and revealed no effects on psychomotor tasks. However little is known about the subsequent effects the following day. Lloyd *et al* (1994) showed that the optimal performance was seen with a medium fat – medium carbohydrate lunch, whereas higher proportions of either fat or carbohydrate caused subjects to be more drowsy, uncertain and muddled, impairing cognitive efficiency. In a study carried out by Paz and Berry (1997) looking at the effect of dietary composition on performance during and after night shift work, subjects performed better when the test meal was closest to their habitual (preferred regular) diet, and one that had a metabolic profile similar to the carbohydrate diet used (CHO 70%). Similar results were seen here in the LF group who reported themselves to be less alert following a high fat preload the previous day.

From the forced choice photograph method, it was found that there were no significant effects of group on the preference ratings. This provides no real indication that HF and LF differ in their taste/food preferences. It might therefore be the case that habitual consumption is independent of current taste preference and introduces the idea that dietary selection may have become a 'habit'. Habit has previously been defined as a behaviour that is automatic or out of awareness (Saba *et al,* 1999). Berridge (1996) proposed that preference (that is 'liking' and 'wanting') can exist without subjective awareness. It may therefore be the case that these individuals are not consciously aware of the diet they are choosing. The reasons for making particular food choices may have occurred many years earlier, such that the eating behaviour has now become truly 'habitual'. There are many other factors that may play a role in the development of the habitual diet, both biological and environment (and combinations of the two), such as family influence, social situations, beliefs and attitudes. This leads to the question 'what are the underlying values in the individual food selection process?' Understanding these individual processes may give a better idea of the antecedents and factors influencing the maintenance of the habitual dietary selection. Could these variables explain the current choice of foods? This concept will be investigated later in this thesis.

As an interim statement, it may be concluded that low fat (high CHO) foods can therefore function as protection factors which oppose dietary risk factors and help prevent the loss of appetite control (see Blundell and Le Noury, 2001). However, it should be recognised that the link between carbohydrates and appetite control does not constitute a biological inevitability. This study highlights once again the importance of taking an individual's habitual diet into account when investigating changes in energy intake and also cognitive performance following any dietary manipulation.

7.6 Summary

This study has shown that there are differences in the way preloads varying in macronutrient content (but not energy or weight) are dealt with in low fat and high fat phenotypes. Subsequent energy intake, fat intake and possibly performance were effected as a result of exposure to high fat or low fat loading in the first half of the day.

- LF ate significantly less energy during an *ad libitum* meal and for the rest of the day following a high fat preload compared to HF consumers.

- HF ate significantly more energy and fat following high fat preloading compared to a high CHO preloading.

- No significant differences in 'state' food preference were found between groups following nutrient preloading indicating that habitual consumption may be independent of current taste and expressed food preferences.

- High fat pre-loading promoted later intake (and hunger, Ch. 6) in the HF phenotypes.

- LF reported themselves to be less alert the following morning after a high fat preload the previous day.

Chapter 8

RESISTANCE & SUSCEPTIBILITY TO OBESITY: comparison of HF lean, HF overweight and LF lean in their free-living environment

8.1 Introduction

As previously discussed, obesity is now a worldwide epidemic and the effects this has not only on the economy but also on quality of life can be profound. Weight gain is induced when energy intake exceeds energy expenditure. Concerning behaviour, this situation may be brought about by either an increase in food (energy) intake or increased sedentariness (decreased activity). It is widely believed that the role of fat may be important for promoting weight gain via the elevation of energy intake. This may occur through a number of processes, due to the high palatability of fatty foods, higher energy density and the ease with which passive overconsumption can occur (Lawton *et al,* 1993).

However in studies addressing the relationship between fat intake and obesity there is still a large amount of inter-individual variability (Macdiarmid *et al,* 1996a). It is fair to say therefore, that this relationship is not a biological inevitability. From the analysis of a large database of nutritional information from 1240 individuals, it was calculated that out of those people defined as habitually eating a diet high in fat, a higher proportion were overweight or obese compared to those consuming a more judicious low fat diet. However this still illustrates that not <u>all</u> those high fat consumers were overweight, and there was still a significant proportion within the normal BMI range, some even being underweight (Macdiramid *et al,* 1996a). This subgroup may be defined as *'resistant'* to dietary induced obesity (DIO). Furthermore the group of individuals seen to have gained weight (and perhaps still gaining) on the same diet may be termed as *'susceptible'*.

As yet it is still unclear what characteristics (physiological and/or behavioural) confer vulnerability and resistance to weight gain. Understanding the key factors at play will help to gain a better understanding of how to amplify DIO-resistant traits in individuals who are susceptible to DIO. This study aims to begin characterisation of these individuals in their own free-living environment, with the collection of dietary information, eating behaviour and activity patterns.

8.2 Objective

The aim of this study was to identify key features of resistance and susceptibility (characterisation) to obesity in free-living subjects. This was designed in order to provide a detailed analysis of their psychological, behavioural and physiological characteristics.

8.3 Method

8.3.1 Recruitment process & Subjects

In total 212 male volunteers were recruited from the staff-student population of Leeds University. Volunteers were recruited via poster advertisements on university notice boards, distribution of flyers and advertisements in the student paper. All volunteers were given the initial screening questionnaire pack consisting of the recruitment information sheet (including demographic details), food frequency questionnaire (FFQ), DINE and the short fat questionnaire (SFQ) (see chapter 4). From the initial screening process, 16 HF-L (high fat- lean), 16 LF and 13 HF-O (high fat- overweight) males were selected to take part. The HF-L were defined as consuming >120g/d of fat and >43% energy from fat and had a BMI of between 20-25 kg/m^2. The LF were defined as eating <70g/d and <33% energy from fat and a BMI of between 20-25 kg/m^2. HF-O were defined as consuming approximately 120g/d of fat and >43% energy from fat and a BMI of >27 kg/m^2, therefore making this group the highest fat consumers of the overweight/obese cohort. All volunteers were aged between 18 and 30 years. Each subject was required to read and sign a participant information sheet and consent form as required by the School of Psychology, University of Leeds Ethical Committee, following ethical approval of this study.

8.3.2 Experimental Design

The purpose of the investigation was to characterise physiology, eating and behaviour patterns in habitual HF-L, HF-O and LF phenotypes in their free-living environment. The study took an independent groups design.

8.3.3 Materials

8.3.3.1 Assessment of Psychological Characteristics

The following questionnaires were used in order to assess differences in psychological (behavioural) characteristics between groups:

- Three Factor Eating Questionnaire (TFEQ) (Stunkard and Messick, 1985) to assess restraint, disinhibition of control and susceptibility to hunger.
- Food Choice Questionnaire (FCQ) (Steptoe *et al,* 1995) to provide a multidimensional measure of the motives related to food choice.
- Eating Attitudes Test (EAT-26) (Garner *et al,* 1982) to assess patterns (degree) of disordered attitudes towards eating.
- Leeds Sleep Questionnaire (LSQ) (Parrot and Hindmarch, 1980) to assess habitual sleep architecture.
- Baecke Physical Activity Questionnaire (Baecke *et al,* 1982) to measure habitual physical activity patterns. An overall Baecke score was obtained along with breakdown scores showing activity levels relating to work, sporting activity and activity during leisure time.

8.3.3.2 Measures used during the three-day probe

The following measures were used during each of the three study probe days:

- Food Diary: to assess habitual energy and macronutrient intake.
- End of Day questionnaire: to summarise subjective feelings across the day and to provide additional information about any food craving and general health.
- Heart rate monitor: to monitor activity and arousal.

For more in depth details regarding the above measures please see Chapter 4.

8.3.4 Procedure

Those volunteers selected to take part arrived in the Human Appetite Research Unit (HARU) between 08:00 and 10:00 in the morning in a fasted state. Height was measured in centimetres using a KaWe (Germany) stadiometer, weight was measured using a digital balance (Adam Equipment, MSP-200, accurate to 0.1kg) and body composition was measured using the InBody 3.0 Composition Analyzer (Biospace Co., Ltd, 1999). Following completion of the additional psychological measures (TFEQ, FCQ, EAT-26, and LSQ) and the Baecke questionnaire, participants were then thoroughly briefed on how to use the equipment required for the three-day probe. These profile days were carried out on two week days and one weekend day (not necessarily consecutive). During each profile day volunteers were instructed to wear a heart rate monitor (POLAR Sports Tester PE 4000, Finland), which was to be worn for the full 24 hours of the study day including the time spent bathing, showering and sleeping. Subjects were required to fit and start the monitor immediately after rising on each study day. Heart rate readings were taken every 60 seconds. This was used to give a measure of physical activity patterns and arousal during sleep and non-sleep. Food diaries were provided with which volunteers were asked to keep a detailed and accurate record of everything they ate and drank during the study day. Subjects recorded the time of consumption, whether the eating episode was considered a meal or a snack, amount eaten and a brief, but accurate, description of what was consumed. This was used to assess total energy and macronutrient intakes. Before retiring to bed on each probe day the volunteers were also given an End of Day Questionnaire (EDQ). Section A consisted of VAS questions (concerning hunger motivation, mood and mental alertness) which subjects are asked to answer with reference to how they have been feeling across the whole day. Section B required subjects to give information on any cravings or strong desires to eat experienced across the day, their general health and anything that may have effected their eating. Subjects were instructed not to alter their normal routine or eating pattern and were not restricted on exercise or sleep.

8.3.5 Data analysis

One-way ANOVAs were carried on the data followed by post hoc tests (Bonferroni) where a significant difference between groups was found. Analysis of the data was conducted using SPSS for Windows (version 6.1) statistical software package (SPSS Inc. Chicago, IL). Heart rates were averaged over 30min periods (i.e. 48 periods per day) and analysed using a repeated measures ANOVA with time as the within subjects factor and high or low fat phenotypes as the between subjects factor. In all statistical tests performed p-values < 0.05 were considered significant and the data are presented as means +/- SDs. Food diaries were analysis using Diet5 for Windows (The Robert Gordon University, Aberdeen).

8.4 Results

8.4.1 Screening data

From the analysis of the screening data (FFQ, DINE and SFQ) a number of significant differences were found (see Table 8.1). A significant main effect of group on energy intake was found ($F_{[2,42]}=7.635$, $p<0.001$). HF-L reported consuming significantly more energy per day compared to LF ($p<0.001$). HF-O also reported to consume more energy compared to LF ($p<0.05$). A significant main effect was found for fat intake in grams ($F_{[2,42]}=20.212$, $p<0.0001$). As expected, by definition, LF reported consuming significantly less fat (g) compared to HF-L ($p<0.001$) and HF-O ($p<0.001$).

This finding was reinforced by the data from the DINE ($F_{[2,42]}= 13.495$, $p<0.001$) whereby no significant difference in fat intake was reported between HF-L or HF-O. However LF reported to consume significantly less fat than HF-L ($p<0.001$) and HF-O ($p<0.01$). The same pattern was found from the SFQ data ($F_{[2,42]}= 5.984$, $p<0.005$). HF-L reported a higher fat intake compared to LF ($p<0.001$). However this measure failed to show a significant difference between HF-O and LF.

According to the FFQ, when expressed as percent energy from fat ($F_{[2,42]}=66.735$, $p<0.0001$) HF-L reported consuming significantly more fat than HF-O ($p<0.01$) and LF ($p<0.001$). HF-O reported to consume more fat % than LF ($p<0.001$).

All groups reported to consume a similar amount of carbohydrate (in grams). However when expressed as percent energy from CHO a significant effect was found ($F_{[4,42]}=48.474$, $p<0.0001$). LF consumed more percent energy from carbohydrate compared to both HF-L ($p<0.001$) and HF-O ($p<0.001$).

A significant main effect of group was found for protein intake (in grams) ($F_{[2,42]}= 6.282$, $p<0.01$). LF reported consuming significantly less protein compared to HF-L ($p<0.01$) and HF-O ($p<0.01$). When expressed as a percentage of total energy intake (PRO %) no significant differences were found between groups ($F_{[2,42]}=0.086$, $p=0.917$).

Table 8.1 Screening data collected from the FFQ, DINE, SFQ and BMI [mean (+/- SD)] (Key: a- significant from HF-L; b- significant from HF-O; c- significant from LF; FE= food energy)

	HF-L	HF-O	LF
AGE	20.6 (2.3)	23.1 (3.5)	22.3 (3.6)
ENERGY INTAKE (kJ)	12529.6 (2909.3)^{c}	1120.5 (2875.0)^{c}	8790.1 (2053.2)^{a,b} **
ENERGY INTAKE (kcal)	2997.5 (696.0)^{c}	2681.7 (687.8)^{c}	2102.9 (491.2)^{a,b} **
FAT (g)	139.2 (35.6)^{c}	118.3 (40.8)^{c}	65.9 (18.3)^{a,b} **
FAT (% FE)	46.5 (2.7)^{b,c}	41.4 (5.7)^{a,c}	29.9 (3.8)^{a,b} **
CHO (g)	283.2 (57.4)	287.5 (58.9)	291.6 (68.9)
CHO (%FE)	39.9 (4.2)^{c}	43.6 (6.0)^{c}	55.3 (3.9)^{a,b} **
PRO (g)	110.4 (30.2)^{c}	103.0 (27.4)^{c}	78.8 (18.3)^{a,b} *
PRO %	16.3 (1.5)	16.5 (2.6)	16.1 (2.4)
SUGAR (g)	116.8 (31.8)	113.5 (33.3)	115.1 (29.2)
STARCH (g)	164.9 (34.5)	171.9 (42.6)	175.2 (54.9)
DINE	41.6 (9.5)^{c}	34.8 (9.9)^{c}	24.3 (8.9)^{a,b} **
SFQ	30.8 (4.8)^{c}	26.8 (4.8)^{c}	22.6 (9.1)^{a} **

*p < 0.01, ** p < 0.00001

8.4.2 Anthropometry

Height, weight and body composition were measured when volunteers were in a fasted state. Table 8.2 shows this data. The BMR was an estimated value given by the InBody 3.0 body composition output (calculated from impedance equations). Unlike previous studies no significant differences were found between groups ($F_{[2,42]}$=2.76, p=0.075). This is not surprising since the calculation is based on a formula rather than on oxygen consumed. A significant main effect of group on weight was found ($F_{[2,42]}$= 22.313, p<0.0001). HF-O were significantly heavier than HF-L (p<0.0001) and LF (p<0.0001). The same pattern was found for BMI ($F_{[2,42]}$= 51.382, p<0.0001), body fat (kg) ($F_{[2,42]}$= 43.77, p<0.0001), percent body fat ($F_{[2,42]}$= 30.47, p<0.0001), muscle mass (kg) ($F_{[2,42]}$=5.36, p<0.01), lean body mass (kg) ($F_{[2,42]}$= 3.36, p<0.01) and total body water ($F_{[2,42]}$= 5.37, p<0.01).

Table 8.2 – Anthropometry/ body composition data [mean (+/- sd)] (Key: a- significant from HF-L; b- significant from HF-O; c- significant from LF) measured by the bio-impedance method.

	HF-L	HF-O	LF
HEIGHT (m)	1.81 (0.009)	1.79 (0.006)	1.78 (0.006)
WEIGHT (kg)	71.1 (11.1)^{b}	94.1 (7.1)$^{a, c}$	72.0 (8.3)^{b} ***
BMI	21.8 (2.1)^{b}	29.5 (2.3)$^{a, c}$	22.5 (2.1)^{b} ***
Estimated BMR	2014.2 (245.4)	2167.1 (218.3)	1979.2 (207.3)
Muscle Mass (kg)	59.4 (8.4)^{b}	67.9 (7.7)$^{a, c}$	59.5 (6.9)^{b} **
Lean body mass (kg)	62.7 (8.8)^{b}	71.6 (8.0)$^{a, c}$	62.8 (7.2)^{b} **
Body fat (kg)	9.5 (3.1)^{b}	23.8 (7.5)$^{a, c}$	9.1 (2.5)^{b} ***
Body fat (%)	13.0 (3.5)^{b}	24.9 (7.1)$^{a, c}$	12.5 (3.0)^{b} ***
Total body water	43.5 (6.1)^{b}	49.8 (5.6)$^{a, c}$	43.6 (5.1)^{b} **

** p<0.001, ***p<0.0001

8.4.3 Attitudes to eating

The data from the TFEQ (used to give a measure restraint, disinhibition and hunger) and the EAT-26 to measure disordered eating is given in Table 8.3. No significant differences were found for the variables restraint ($F_{[2,42]}$=2.233, p=0.119), hunger ($F_{[2,42]}$=0.691,p=0.506), or EAT-26 ($F_{[2,42]}$=1.626, p=0.209). However a significant difference was found for the variable disinhibition ($F_{[2,42]}$= 9.82, p<0.001). HF-O reported higher levels of disinhibition compared to HF-L (p<0.001) and LF (p<0.01).

Table 8.3: Attitudes to eating: TFEQ and EAT-26 [mean (+/- sd)] (Key: a- significant from HF-L; b- significant from HF-O; c- significant from LF)

	HF-L	HF-O	LF
RESTRAINT	3.1 (2.5)	5.7 (3.4)	5.5 (4.9)
DISINHIBITION	4.4 (2.0)^{b}	7.9 (1.7)$^{a, c}$	5.1 (2.9)^{b} **
HUNGER	6.4 (2.8)	7.4 (3.2)	6.1 (2.8)
EAT-26 score	2.6 (2.4)	5.7 (7.8)	6.9 (9.0)

The Food Choice Questionnaire (FCQ) was administered to measure food choice in relation to a number of factors including health reasons, sensory appeal and ethics (see Figure 8.1).

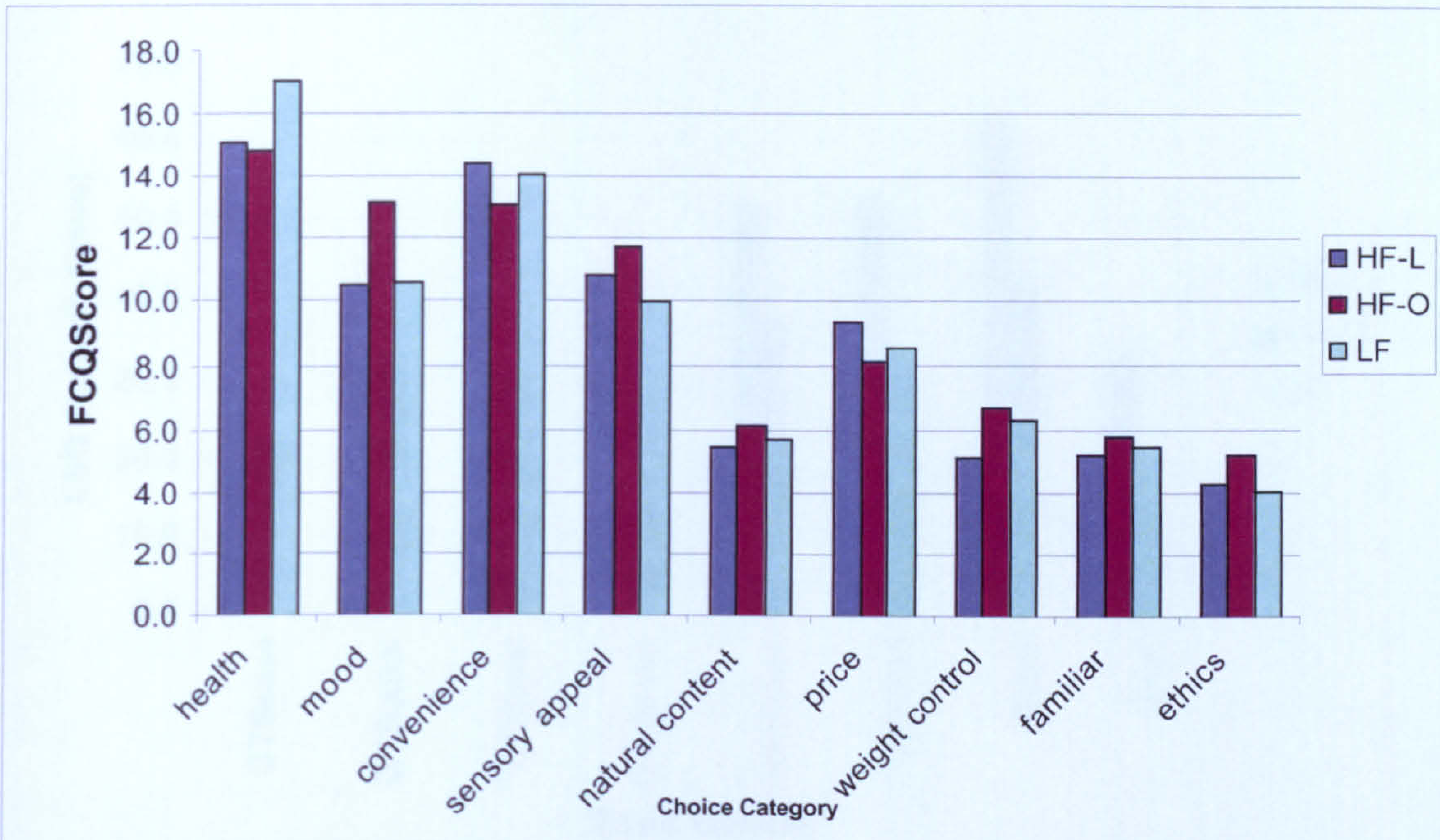

Figure 8.1 Motives related to food choice (FCQ data).

One-way ANOVA revealed a significant main effect on group for the variable MOOD ($F_{[2,43]}$= 3.24, p<0.05). Post hoc tests showed that the overweight group scored significantly higher on this variable compared to the HF-L (p<0.05) and significantly higher than the LF (p<0.05). No other significant differences were found between groups, however it might be worth noting that LF scored higher than the HF groups on the variable health .

8.4.4 Habitual sleeping patterns

Figure 8.2 shows the data from the habitual LSQ. A significant main effect was found for time to awake from sleep (AFStime) ($F_{[2,42]}$= 3.13, p<0.05). HF-L reported taking significantly longer to wake up in the mornings compared to HF-O (p<0.05) but not compared to LF (p=0.92). HF-O and LF did not significantly differ on the time to wake from sleep (p=0.399). Also significant differences were found for alertness on waking (AOW) ($F_{[2,42]}$= 3.34, p<0.05) and alertness 1hr after waking ($F_{[2,42]}$= 3.36, p<0.05), with HF-L reporting to be less alert immediately following waking and also 1 hr after compared to HF-O (p<0.05). No significant differences were found between HF-L and LF (p=0.99 for both variables) or HF-O and LF for these variables (p=0.104 and p=0.158, respectively).

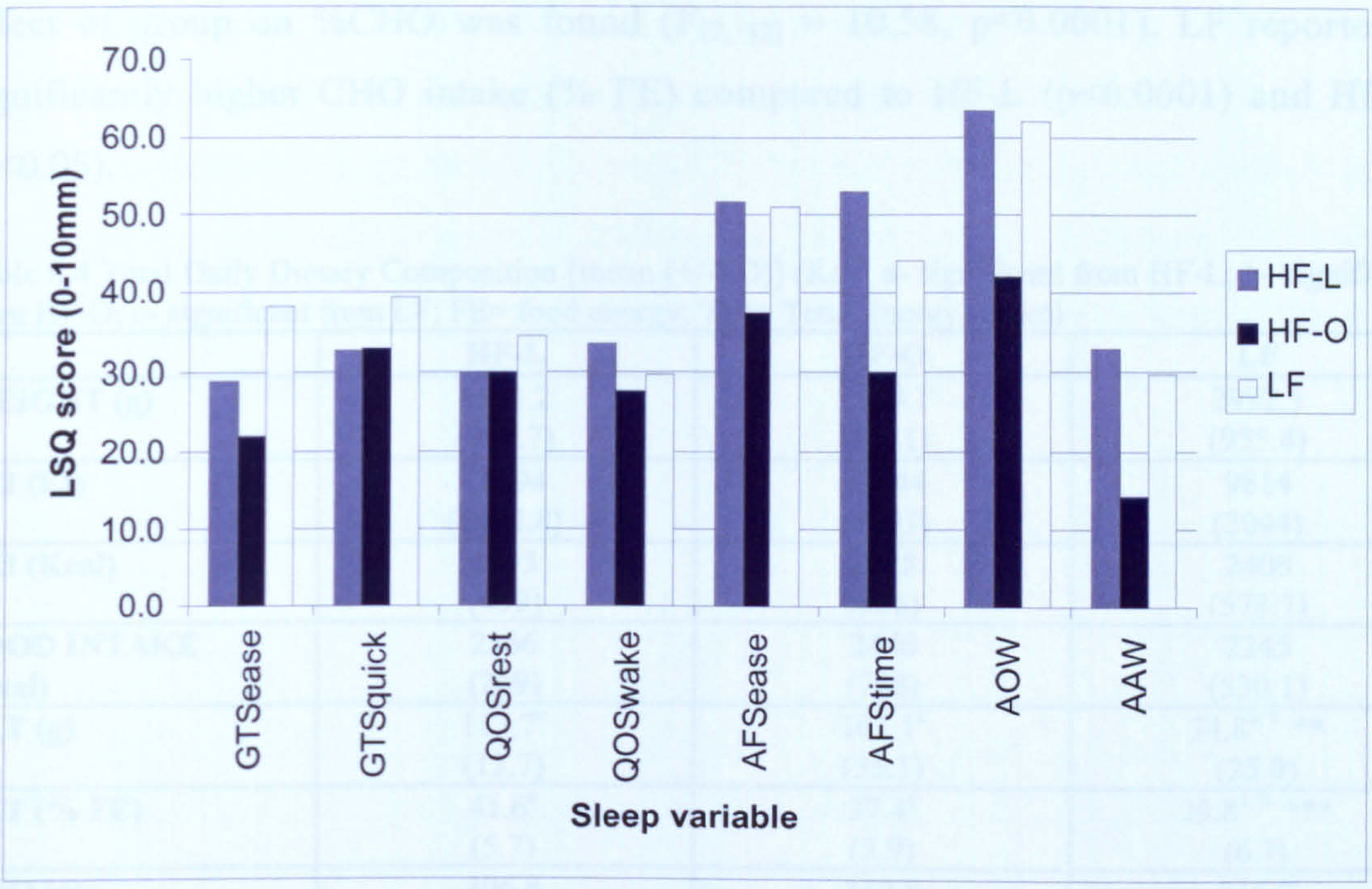

Figure 8.2 Habitual sleep variables measured using the LSQ (Key: GTSease- ease of getting to sleep; GTSquick- time to get to sleep; QOSrest- quality of sleep (restfulness); QOSwake- quality of sleep (no. of wakeful periods); AFSease- ease of waking from sleep; AFStime- time taken to wake; AOW- alertness on waking; AAW- alertness 1hr from waking) NB- 0=Not at all difficult/100=extremely difficult.

8.4.5 Free living diary analysis

Daily energy intake and macronutrient consumption as reported from the three-day food diaries are shown in Table 8.4. In general the group trends indicated by the FFQ for energy intake, CHO and fat intake were also observed in the food diary data. In particular, both dietary measures gave equivalent results for mean total energy intake (TEI) in HF-O and for mean % food energy as each macronutrient for LF.

One-way ANOVA was carried out on the data, which revealed a number of significant differences. A significant main effect for group on fat intake (in grams) was found ($F_{[2, 42]}$= 11.902, p<0.001). Post hoc tests revealed that HF-L ate significantly more fat (g) compared to the LF (p<0.001). The overweight group ate significantly more fat (g) compared to the LF (p<0.05). FAT (% FE) was also found to show a significant main effect of group ($F_{[2,42]}$=17.66, p<0.001). Post hoc tests revealed that the HF-L ate significantly more fat % compared to the LF (p<0.0001). Also the overweight group was found to eat significantly more fat (% FE) compared to the LF (p<0.01). No significant group differences were found for intakes of absolute amounts of the macronutrients CHO ($F_{[2, 42]}$=0.046, p=0.955) or protein ($F_{[2,42]}$= 0.587, p=0.56). However when expressed as a percentage of food energy intake a significant main effect of group on %CHO was found ($F_{[2, 42]}$ = 10.58, p<0.0001). LF reported a significantly higher CHO intake (% FE) compared to HF-L (p<0.0001) and HF-O (p<0.05).

Table 8.4 Total Daily Dietary Composition [mean (+/-SD)] (Key: a- significant from HF-L; b- significant from HF-O; c- significant from LF; FE= food energy; TEI= Total Energy Intake)

	HF-L	HF-O	LF
WEIGHT (g)	3351.2 (994.7)	3199.1 (1511)	2992.3 (955.4)
TEI (kJ)	11794 (1932.8)	11044 (4003)	9814 (2044)
TEI (Kcal)	2813 (459)	2628 (955)	2408 (578.7)
FOOD INTAKE (Kcal)	2566 (269)	2440 (788)	2245 (530.1)
FAT (g)	117.7[c] (12.7)	101.1[c] (35.1)	74.8[a, b] ** (25.0)
FAT (% FE)	41.6[c] (5.7)	37.4[c] (3.9)	29.8[a, b] *** (6.7)
CHO (g)	306.8 (69.2)	312.8 (108.6)	315.7 (80.6)
CHO (% FE)	44.5[c] (5.9)	47.6[c] (4.0)	52.8[a,b] *** (5.3)
PRO (g)	89.2 (18.3)	89.3 (24.6)	97.0 (26.5)
PRO (% FE)	13.9[c] (1.9)	15.1 (2.3)	17.3[a] ** (3.3)
STARCH (g)	160.7 (42.2)	165.0 (71.1)	170.9 (61.6)
SUGAR (g)	126.2 (45.6)	133.7 (51.2)	132.2 (30.8)
ALCOHOL	35.3 (34.1)	26.5 (37.6)	11.6 (16.8)

* p<0.05; ** p<0.001; *** p<0.0001

Also a significant main effect of group on protein intake (% FE) was found (F[2,42]= 7.34, p<0.01), with LF reporting to consume significantly more protein (% FE) than HF-L (p<0.001) but not HF-O (p=0.074).

Results from the food diary data showed good correlations with the data from the FFQ on reported energy intake (r=0.312, p<0.05), percent energy from fat (r= 0.64, p<0.0001) and fat in grams (r=0.55, p<0.0001) (see Figure 8.3 also). However for the HF-L food diaries indicated a slightly lower mean TEI than FFQ whereas the opposite was true for LF.

8.4.5.1 EI: BMR ratios

As shown in Table 8.2, no significant differences were found in mean estimated BMR values across groups, although these values were higher in HF-O (2167 kcal/d) than HF-L (2014 kcal/d) and LF (1979 kcal/d). Mean EI: BMR ratios were calculated using the estimated BMR and the mean total energy intake from both the FFQ screening questionnaire and the food diary data to give an approximate measure of underreporting from both measures. Results are shown in Table 8.5 and suggest that there is some underreporting in the HF-O group (1.2 using food diary) and LF (1.2 using FFQ and 1.2 using food diary). However since these figures were derived from estimated measures their value is limited.

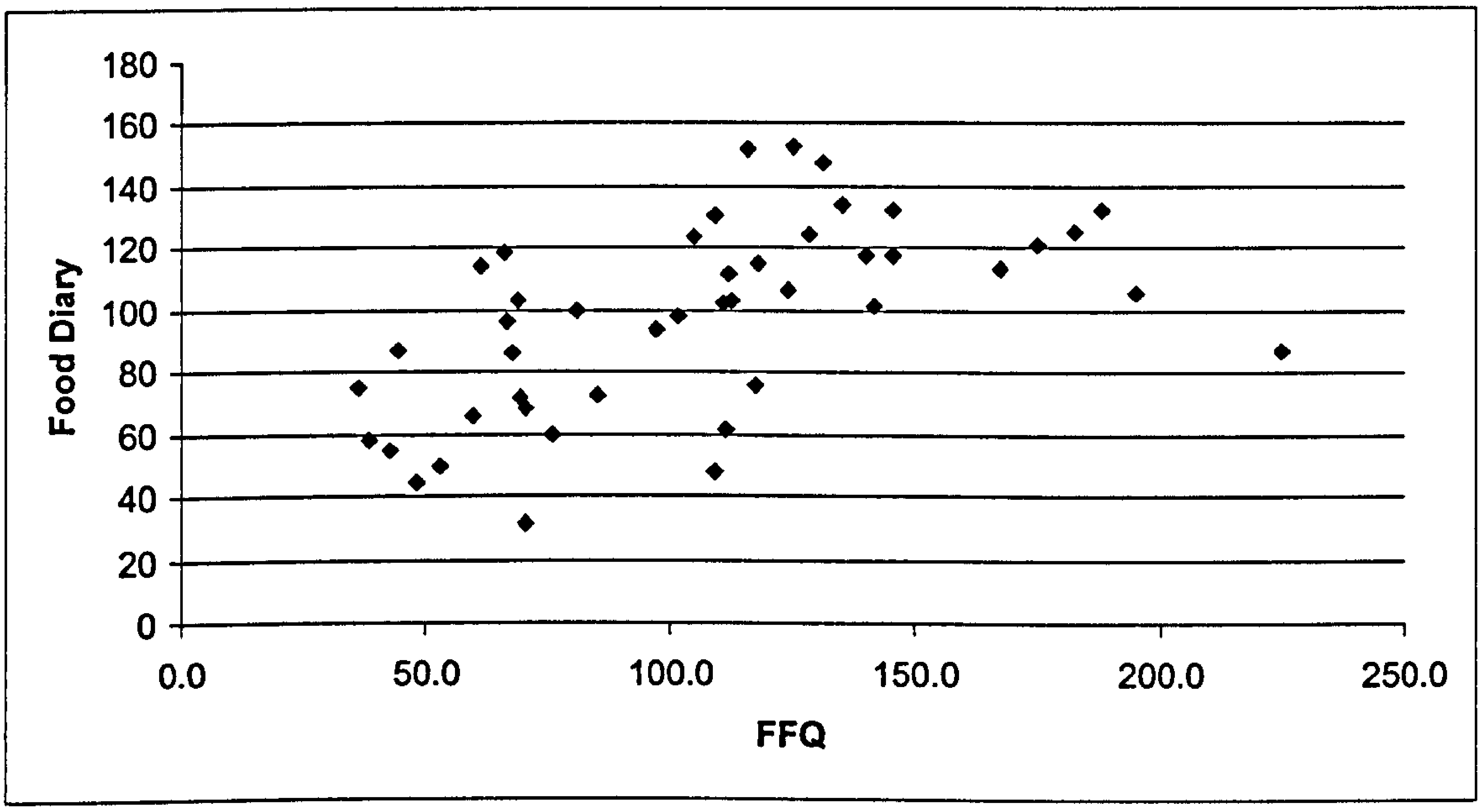

Figure 8.3- Fat Intake (in grams): correlation between FFQ and food diary measures (r=0.55, p<0.0001)

Table 8.5- Mean EI: BMR ratios

	HF-L	HF-O	LF
FFQ	1.8	1.5	1.2
FOOD DIARY	1.4	1.2	1.2

8.4.6 End of day questionnaires

Figure 8.4 shows the mean end of day questionnaire data. LF reported themselves to be more irritable, alert and less tired compared to the other groups, however results from the one-way ANOVA showed no significant differences for these variables in a free-living environment.

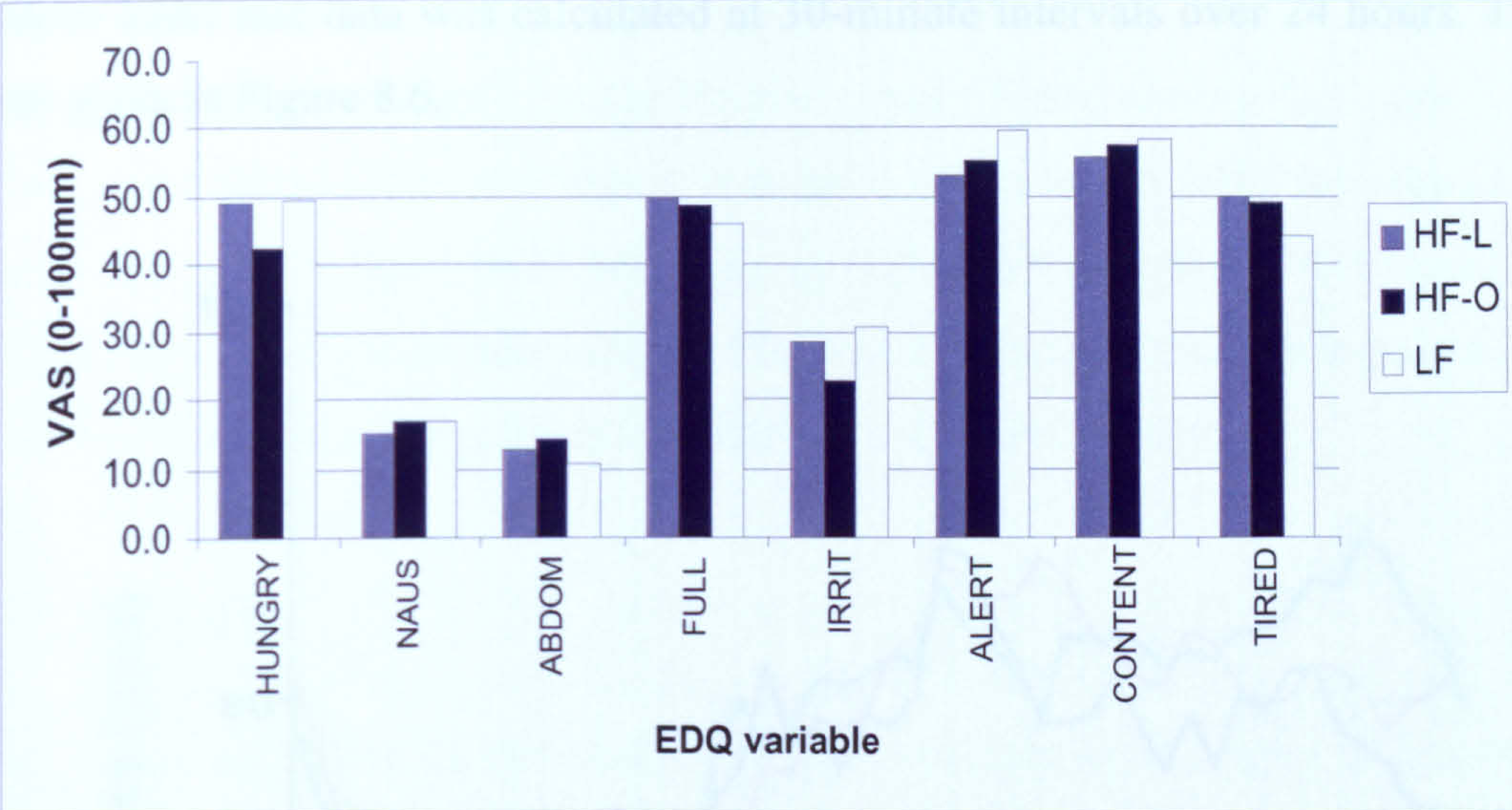

Figure 8.4 Free living end of day questionnaire data measuring subjective feelings across the probe day (Abbreviations: NAUS= nauseous; ABDOM= abdominal discomfort; IRRIT= irritability).

8.4.7 Physical activity and arousal

Figure 8.5 shows the breakdown of physical activity patterns between groups as reported from the Baecke activity questionnaire.

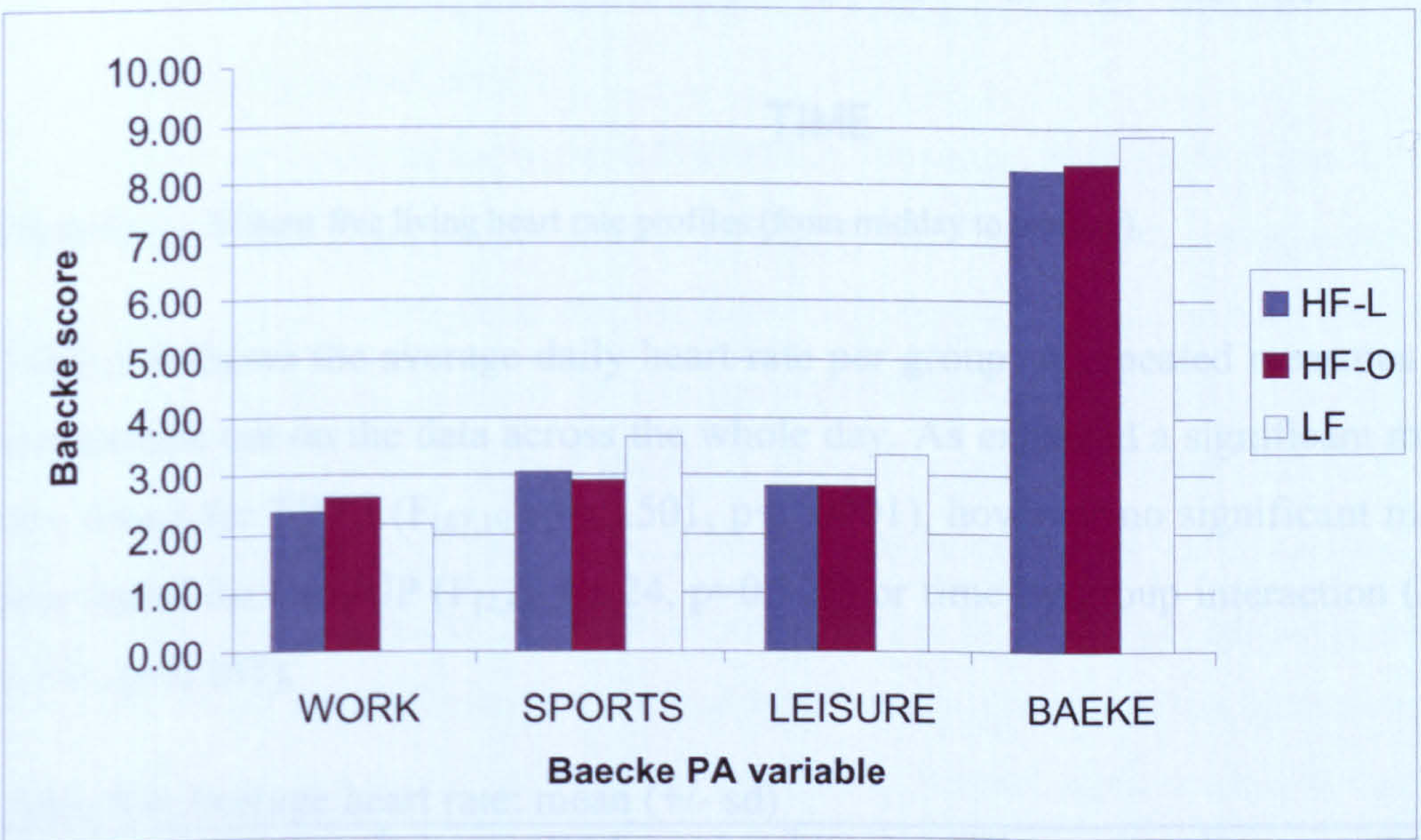

Figure 8.5 Habitual physical activity patterns as reported on the Baecke PA questionnaire

A main effect of group was found on the variable sport ($F_{[2,42]}$= 3.784, $p<0.05$). Post hoc tests revealed the LF scored significantly higher on this variable compared to HF-O ($p<0.05$). No significant difference was found between HF-L and LF.

Mean heart rate data was calculated at 30-minute intervals over 24 hours. The results are given in Figure 8.6.

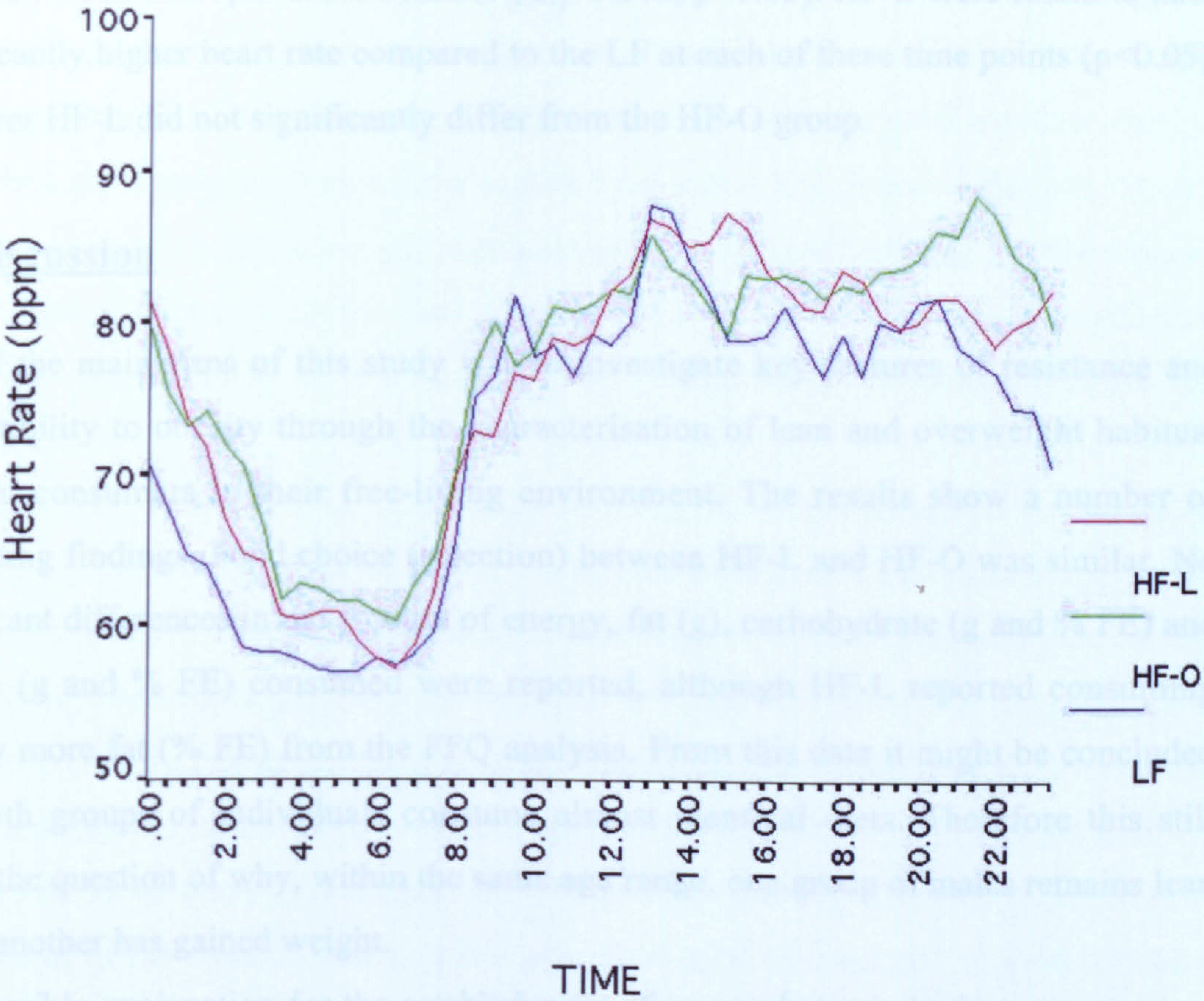

Figure 8.6 — 24 hour free living heart rate profiles (from midday to midday).

Table 8.6 shows the average daily heart rate per group. A repeated measures ANOVA was carried out on the data across the whole day. As expected a significant main effect was found for TIME ($F_{[47,1927]}$=42.501, p<0.0001), however no significant main effect was found for GROUP ($F_{[2,41]}$= 1.24, p=0.301) or time by group interaction ($F_{[94, 1927]}$= 1.148, p=0.161).

Table 8.6 Average heart rate: mean (+/- sd)

	HF-L	HF-O	LF
Av. 24hr	75.5 (6.7)	77.0 (9.1)	72.5 (8.1)
Av. 11.30pm-1.30am	77.3 (4.6)	76.4 (3.1)	67.5 * (3.2)
Av. 3.30am-8.30am	61.8 (5.0)	64.2 (5.1)	60.0 (5.5)

*p<0.05

Again, as Study 1 (see Ch. 5), the night-time heart rate between 3.30 – 8.30am was isolated, however no significant differences were found during this period ($F_{[2, 42]}$= 0.832, p=0.442). However a significant main effect of GROUP was found slightly earlier between 11.30pm and 1.30am ($F_{[2,41]}$=3.305, p<0.05). HF-L were found to have significantly higher heart rate compared to the LF at each of these time points (p<0.05). However HF-L did not significantly differ from the HF-O group.

8.5 Discussion

One of the main aims of this study was to investigate key features of resistance and susceptibility to obesity through the characterisation of lean and overweight habitual high fat consumers in their free-living environment. The results show a number of interesting findings. Food choice (selection) between HF-L and HF-O was similar. No significant differences in the amount of energy, fat (g), carbohydrate (g and % FE) and protein (g and % FE) consumed were reported, although HF-L reported consuming slightly more fat (% FE) from the FFQ analysis. From this data it might be concluded that both groups of individuals consume almost identical diets. Therefore this still leaves the question of why, within the same age range, one group of males remains lean whilst another has gained weight.

One possible explanation for the establishment of energy balance in these groups may be linked to levels of physical activity. If both groups are in fact eating identical diets (in terms of weight, energy and macronutrient intakes) then it is possible that the HF-L remain lean due to an increase in energy expenditure through physical activity and amount of time spent in vigorous exercise. However, no significant differences in self reported levels of activity spent at work, during sports or leisure were reported between groups. Also no significant differences were found in heart rate readings across the whole free living days. However, it should be kept in mind that the heart rate profiles represent the raw heart rate scores and were not calibrated against oxygen uptake. It is possible that the amount of time spent above flex may have yielded a different outcome but this analysis was beyond the scope of the present study.

Another explanation may lie in the EI:BMR analysis. HF-O are seen to underreport their energy intakes more frequently than HF-L (1.5 and 1.8 using the FFQ). A number of studies have previously found that overweight individuals are more likely to underreport energy and fat intake when asked to report their food intake (Goris *et al*, 2000). This may therefore, not be a surprising outcome in this study and may account for the element of underreporting in the HF-O for this dietary assessment measure. It should be acknowledged at this point that the FFQ analysis uses frequency of consumption and does not take into account portion size. From the correlational analysis of the FFQ and food diary for energy and macronutrient (fat) intake it suggests that the FFQ is better at giving the proportion of macronutrient intake (%) rather than the absolute values. Therefore if an individual eats a small portion of a wide variety of foods then the dietary analysis will be accurate. However if an individual habitually eats a limited variety of foods but in large amounts the FFQ is likely to underestimated energy intake. This may be the case for the HF-O. Unfortunately, it is impossible to guarantee the accuracy of free-living food intake data collected under natural conditions.

Therefore the HF-L and HF-O groups may be eating identical foods, however the HF-O may simply be eating more of them. This idea of increased portion sizes in the overweight group is further supported by the findings from the TFEQ and FCQ. HF-O reported significantly higher scores for disinhibition, indicating that they are more disinhibited in the presence of food (i.e. sight, smell) and more likely to eat in response to mood compared to the HF-L (see FCQ results). This might be linked to the findings from the previous study (see chapter 6), which found that HF-L may be less likely to overeat due to the absence of a possible enhanced hedonic response to food. Could it also be the case, then, that HF-O have a high hedonic response to food, resulting in greater disinhibition under certain circumstances?

The inclusion of the third LF phenotype also showed some interesting results. LF were seen to consume different habitual diets compared to the HF-L and HF-O. Differences between groups are not total food selection as all groups reported consuming equal amounts of carbohydrate in grams (from both FFQ and food diary). However both HF-L and HF-O eat additional fat on top of this. HF-L have increased energy intake compared to HF-O but have similar intakes of fat. Although when expressed as a percentage of total energy intake clearer differences are suggested.

The issue of underreporting in the LF group is highlighted although it is admitted that the argument is circular. LF showed an increase in total energy intake in the food diary compared to the FFQ but the same percent food energy from the macronutrients. This may be a methodological problem with the FFQ in underestimating energy intake and, like the HF-O, is probably linked to portion size analysis. One possible method of investigating this issue is to examine volunteers over a longer period of time to establish whether these groups are in fact gaining, losing or weight stable.

In spite of these issues the comparison between FFQ and food diary showed good correlations for the variables energy and fat intake. This is a promising finding and provides support for the use of the FFQ method of identifying all three phenotypes within a given population at least as an initial method of screening, providing the data are backed up with food diary analysis.

Although no differences in food choice variables were found between groups (although the HF-O reported being significantly more influenced by mood compared to LF and HF-L), LF may be participating in more 'health' behaviours. This is evident from not only their food selection (lower fat intake) but they also reported spending significantly more time in sports activities compared to the HF groups. This may also be one explanation for why the LF group showed a lower heart rate (increased fitness) particularly during the later part of the day. However, increased fitness in LF was not seen in a previous study (Cooling and Blundell, 2000).

The present study has given some further clues about the existence of HF-L, HF-O and LF phenotypes. However methodological limitations need to be acknowledged and the experimental procedures strengthened in order to provide clean phenotypes for future analysis.

8.6 Summary

This study showed a number of interesting findings:

- HF-L and HF-O have very different body composition (measured by bio-impedance) despite reporting to consume similar dietary intakes (although similarity in actual portion sizes is questionable at this stage).

- HF-O showed higher TFEQ-disinhibition scores and are more likely to overeat and eat in response to mood than HF-L and LF. This could be linked to the reward mechanisms and hedonic response.

- HF-O have fewer self-reported sleep problems than HF-L (as reported on the LSQ).

- HF-O and LF are more likely to underreport than HF-L (however it should be noted that these data are derived from estimates and are therefore not totally secure). However, good correlations were found between FFQ and food diary data providing support for the use of this screening method.

- LF reported taking part in significantly more sporting activities than their HF counterparts.

Despite some methodological difficulties in this area of work, it has been shown that HF-O select a diet high in fat and are more likely to overeat. It is now necessary to investigate these issues further by addressing the differences in food intake, portion size and the possible underlying mechanisms relating to energy balance.

Chapter 9

FOOD CHOICE AND HEDONIC RESPONSE: differences between overweight and lean high fat phenotypes

9.1 Introduction

Dietary fat is a major risk factor for weight gain and obesity. However previous work has identified two different groups of individuals within a population where the cultural and environmental influences are the same. Both groups have similar normal BMIs but demonstrate quite different dietary patterns (high fat and low fat phenotypes) in terms of their habitual food choices and percent energy from fat consumed. So far a number of physiological and behavioural differences between these groups have been demonstrated. In addition to their contrasting food choice (e.g. 27% vs. 45% dietary fat intakes), differences have also been found for appetite control (response to energy, weight and macronutrient content of meals), physiology (BMR, heart rate and leptin) and time spent in sedentary activity. However all these individuals are lean. In an attempt to help understand the underlying mechanisms responsible for the achievement of energy balance, the previous study (chapter 8) identified two groups of people with similar habitual dietary intakes (HF) but have quite different BMIs (mean: 21.8 vs. 29.5 kg/m^2). So why does eating a high fat diet lead to weight gain in some (susceptible; HF-O) individuals but not in others (resistant; HF-L)? As yet it is unclear which physiological or psychological features are important.

Results from the previous study suggest that HF-O may indeed consume the same types of (fatty) foods, however these individuals may consume them in larger amounts. Pearcey and de Castro (2002) found that weight-gaining individuals consumed excess amounts of food and showed specific food habits including the consumption of fatty foods. This idea can be linked to the results from the TFEQ in the previous study whereby HF-O scored significantly higher on the disinhibition variable compared to HF-L. It was concluded that these overweight men are therefore more likely to overeat in the presence of food than their lean counterparts. Could it be then that hedonic response to food is involved in this process? If so, it could be the case that hedonic response is involved in food choice and susceptibility to obesity. If people who gain weight and become obese have different responses to the palatability of food compared to those who remain lean, it is important to establish whether the food is perceived as more or less pleasant. If the hedonic response to food is suppressed in the obese it might be proposed that these individuals would eat more to gain an adequate level of pleasantness. Alternatively if these individuals demonstrate a super-sensitive response to foods, that is they find food *very* pleasant, then this would in turn stimulate more eating through increased sensations of hunger or in order to gain maximal pleasure. Yeomans (1996) found that more palatable foods gave rise to increases in hunger during a meal, therefore resulting in an increased intake during the eating episode. So a link between hedonic response to food (palatability) and obesity is potentially very important.

This present study aims to examine these concepts further. The previous study investigated the phenotypes in their natural free-living environment, which although having high ecological validity, due to the high number of extraneous variables in the 'real world', is weak on internal validity. As such, conclusions can only be made with this in mind. In an attempt to address the number of questions this study brought to light, a follow up study was designed to investigate food choice and hedonic response in a laboratory setting. This is a more controlled environment, whereby methodological limitations such as underreporting are virtually eliminated. Two main questions were addressed: first to establish if there were any differences in the amount of (the same) food consumed between HF-O and HF-L; secondly to investigate the hedonic response to foods eaten. That is, when food choice is controlled, do these two groups show differences in other aspects of appetite control?

9.2 Objective

This study aims to investigate aspects of eating behaviour and hedonic response to food, and how these factors may be involved in determining body weight in these groups. Hunger, portion size, hedonic response and heart rate following high fat preloading were investigated in high fat/lean (HF-L), high fat/ overweight (HF-O) and low fat/ lean (LF) phenotypes.

9.3 Method

9.3.1 Recruitment process & Subjects

All volunteers who had taken part in the previous free-living study were brought back into the lab for this follow up study (see section 8.3.1). All volunteers were members of the staff-student population of the University of Leeds and had completed the food frequency questionnaire (FFQ), DINE and the short fat questionnaire (SFQ) to establish phenotype membership. 16 HF-L (high fat- lean), 16 LF and 13 HF-O (high fat-overweight) males took part. From analysis of the FFQ, HF-L reported consuming 139.2g and 46.5% FE of fat and had a mean BMI of 21.8 (+/-2.1) kg/m^2. HF-O reported consuming 118.3g and 41.4% FE from fat, with a mean BMI of 29.5 (+/-2.3) kg/m^2. The LF reported eating 65.9g of fat, 29.9% FE from fat and a BMI of 22.6 (+/- 2.1) kg/m^2. (For further dietary details including food diary analysis please see chapter 8). All volunteers were male aged between 18 and 30 years. Each subject was required to read and sign a participant information sheet and consent form as required by the School Psychology, University of Leeds Ethical Committee, following ethical approval of this study.

9.3.2 Experimental Design

The purpose of this investigation was to further investigate key features responsible for the resistance and susceptibility to obesity, specifically looking at differences in eating patterns and hedonic responses between lean and overweight individuals habitually consuming a high fat diet. The study took an independent groups design. The independent variables were habitual fat intake (2 levels: high vs. low fat intake) and BMI (normal vs. overweight). Three experimental groups were identified: high fat/ lean (HF-L); high fat/ overweight (HF-O); low fat lean (LF).

9.3.3 Procedure

Volunteers were instructed to wear a heart rate monitor from the time they woke on the experimental morning until the same time the following morning. All volunteers had previously been fully briefed on how to use this equipment along with the Psion. Subjects were instructed to consume their normal breakfast in the morning (even if this included no breakfast) and not to eat or drink anything (except water) until arrival at the Human Appetite Research Unit (HARU) for the fixed test lunch at approximately 12:00

(see section 9.3.3.1 for test meals). The subjects were required to eat all food provided during this meal and were then free to leave, again being instructed not to eat or drink anything until arrival back in the HARU four hours post-lunch for the *ad libitum* evening meal (see section 9.3.3.1). During this meal volunteers were instructed to eat as much or as little as they wanted until they have reached a comfortable level of fullness. Following the evening meal volunteers were provided with a snack box, from which they could freely consume during the experimental evening only, and were free to leave. All equipment including the snack box and intake inventory was returned to the HARU as soon as possible the following day.

Along with the 24-hour heart rate readings a number of other measures were administered. A series of VAS were administered using the EARS (Psion) and included ratings for the following variables: hunger, fullness, desire to eat, alertness, tiredness, irritability, happiness and bloatedness. VAS ratings were carried out at the following time points: pre-lunch, post-lunch, 1/2hr, 3/4hr, 1hr, 1 1/2hr, 2hr, 3hr post-lunch, pre-evening meal, post-evening meal and 10pm.

Immediately following both meals (lunch and evening meal) volunteers were given a sensory questionnaire in order to assess how pleasant, tasty, bland, satisfying, salty, filling and healthy they found the meal. The forced choice (photograph) method of assessing food choices was administered immediately pre- and post-lunch and evening meal (see chapter 4 for a detailed description of this method).

9.3.3.1 Test meals

The experimental lunch was a fixed high fat meal consisting of chicken in a tomato based sauce with rice, French bread and margarine, followed by chocolate mousse (see Table 9.1 for recipe and macronutrient breakdown). The evening meal was an *ad libitum* meal whereby volunteers were presented with a buffet-style selection of high fat savoury and sweet foods. This meal consisted of cheese and ham sandwiches (approximately 4-5 rounds), sausage rolls, cheese puffs, coleslaw, strawberry fool and shortbread. Table 9.2 gives the recipe used to make up each round of sandwich, and Table 9.3 gives a breakdown of the macronutrient content of each food (per 100g). The snack box consisted of a selection of high fat savoury and sweet snack foods from which volunteers could freely consume from during the experimental evening (see Table 9.4). Each food type presented during the evening meal and snack box was weighed before being given to the subject and again immediately after in order to calculated dietary intake, using the Melle PJ400- precision instruments (UK) to the nearest 0.1g.

Table 9.1 Lunch: Fixed (high fat) test meal recipe and macronutrient breakdown

g per 100g of food, % energy

FOOD ITEM	PROVISION (g)	FAT	CHO	PROTEIN
Rice	75	1.3g, 8.5%	30.9g, 84.0%	2.6g, 7.5%
Tinned tomatoes with peppers	190	0.2g, 8.3%	4g, 69.4%	1.2g, 22.2%
Olive oil	18	100g, 100%	0g, 0%	0g, 0%
Tomato puree	6	0.2g, 2.6%	12.9g, 71.0%	4.5g, 26.4%
Chicken breast	56	3.2g, 24.8%	0g, 0%	21.8g, 75.2%
Cheddar cheese	16	34.4g, 75.5%	0.1g, 0.1%	25g, 24.4%
Low fat cheddar	2	29.3g, 80.6%	0.1g, 0.1%	15.8g, 19.3%
French bread	38	2.7g, 9.0%	55.4g, 76.8%	9.6g, 14.2%
Flora	10	70g, 99.9%	0.1g, 0.1%	0.1g, 0.1%
Chocolate angel delight	39	10.5g, 23.5%	73.5g, 68.7%	7.8g, 7.8%
Cocoa	1.5	20.8g, 58.7%	10.5g, 12.3%	23.1g, 29.0%
Gelatine	2	0g, 0%	0g, 0%	87g, 100%
Whole milk	66.5	4g, 54.2%	4.7g, 26.5%	3.2g, 19.3%
Double cream	40	48g, 96.3%	2.6g, 2.2%	1.7g, 1.5%
Water	42	0g, 0%	0g, 0%	0g, 0%

Table 9.2 Evening meal: Ad lib sandwiches recipe and macronutrient breakdown

g per 100g of food, % energy

FOOD ITEM	PROVISION (g) per round	FAT	CHO	PROTEIN
Sliced Mighty white bread	68.6	0.5g, 4.9%	19.0g, 78.0%	3.9g, 17.1%
Flora marg	20	70g, 99.9%	0.1g, 0.1%	0.1g, 0.1%
Lean Ham	20	4.5g, 37.9%	0.1g, 0.4%	16.5g, 61.7%
Cheddar cheese	55	34.4g, 75.5%	0.1g, 0.1%	25.0g, 24.4%

Table 9.3 Ad lib evening meal food items and macronutrient breakdown

g per 100g of food, % energy

FOOD ITEM	FAT	CHO	PROTEIN
Sausage roll	21.0g, 59.0%	27.3g, 32.0%	7.2g, 9.0%
Cheese puff	33.6g, 57.3%	50.8g, 36.1%	8.8g, 6.7%
Coleslaw	18.4g, 79.8%	9.9g, 17.9%	1.2g, 2.3%
Strawberry fool	11.2g, 59.6%	15.2g, 33.7%	2.8g, 6.6%
Shortbread	29.0g, 50.9%	61.6g, 45.1%	5.1g, 4.0%

Table 9.4 Ad lib snack box food items and macronutrient breakdown

g per 100g of food, % energy

FOOD ITEM	FAT	CHO	PROTEIN
Crisps	34.0g, 58.9%	50.0g, 36.1%	6.5g, 5.0%
Salted peanuts	53.0g, 79.3%	7.1g, 4.4%	24.5g, 16.3%
White bread rolls	1.9g, 7.5%	46.4g, 76.5%	9.1g, 16.0%
Butter	81.7g, 99.7%	0.0g, 0%	0.5g, 0.3%
Cheese portions	34.4g, 75.5%	0.1g, 0.1%	25.0g, 24.4%
Chocolate buttons	31.3g, 53.4%	57.5g, 40.9%	7.6g, 5.8%
Tuc biscuits	34.7g, 57.2%	53.7g, 36.9%	8.0g, 5.9%
Penguin cake bars	30.8g, 56.7%	50.8g, 39.0%	5.3g, 4.3%

9.3.4 Data analysis

One-way ANOVAs were applied to the data in order to establish any main effects for groups using SPSS for Windows version 9.0. Where significant main effects were found, post hoc Bonferroni tests were applied.

9.4 Results

9.4.1 Total energy intake- *ad libitum* phase (evening meal and snack box)

Four hours post-lunch (high fat preload) volunteers were provided with an adlib evening meal and a snack box (a selection of high fat savoury and sweet foods) from which to eat for the rest of the day. Below is the total amount of weight, energy and macronutrients consumed during this time by each group.

9.4.1.1 Total weight (g) consumed

The total weight of food consumed in the meal and snack is shown in Figure 9.1. A significant main effect of weight was found ($F_{[3,40]} = 4.264$, $p<0.05$). Post hoc tests revealed a significant difference between the amount of food consumed by the HF-L (mean: 698g, se: 52.59) and the HF-O (mean: 1147g, se: 192.04) with the overweight group consuming significantly more in grams ($p<0.05$).

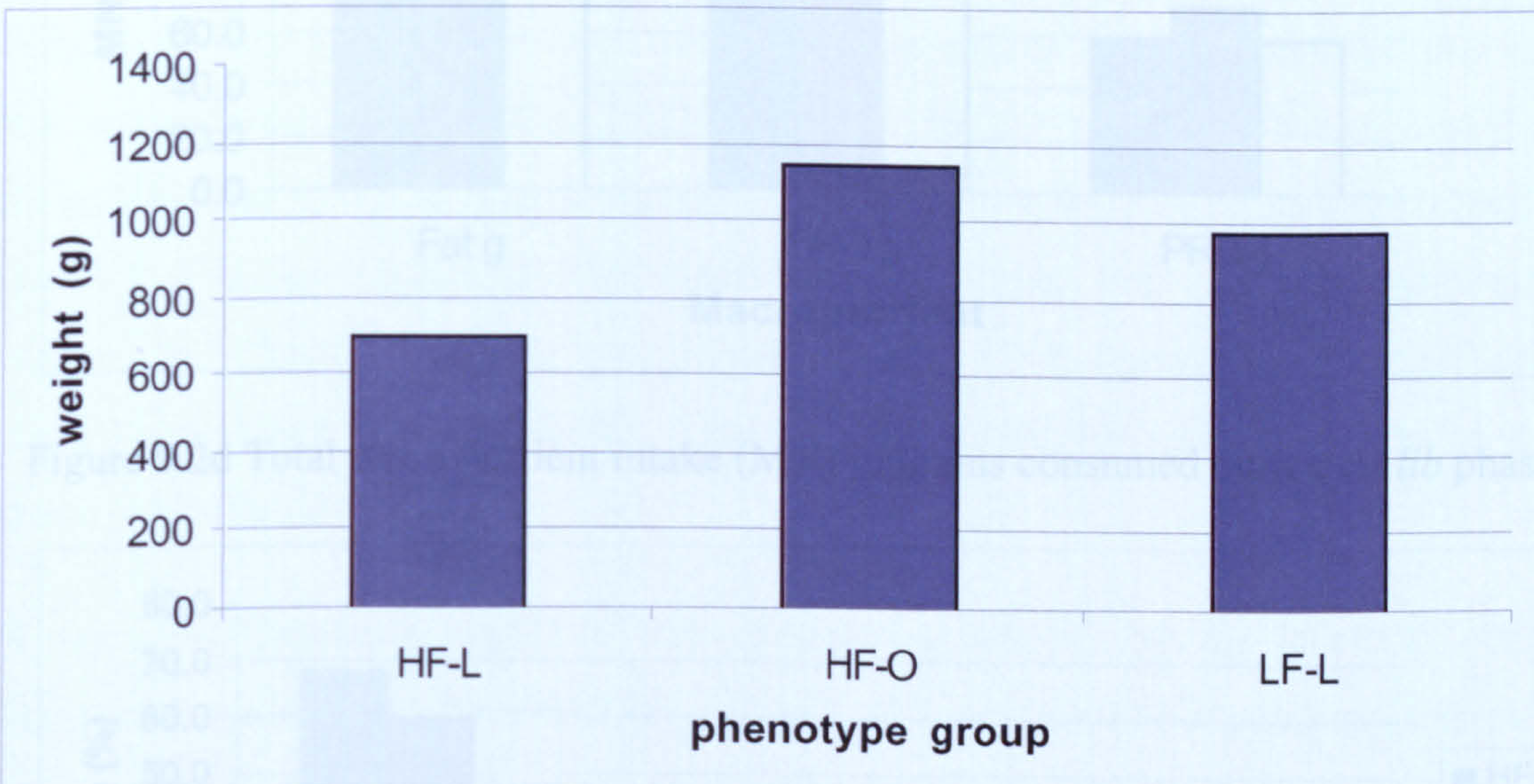

Figure 9.1 Total weight consumed during *ad libitum* phase.

9.4.1.2 Energy and macronutrient intake

Figure 9.2 shows the total amount of energy (9.2a), the amount of macronutrients (9.2b) consumed during the ad-lib phase and expressed as a percentage of the total energy intake (9.2c)

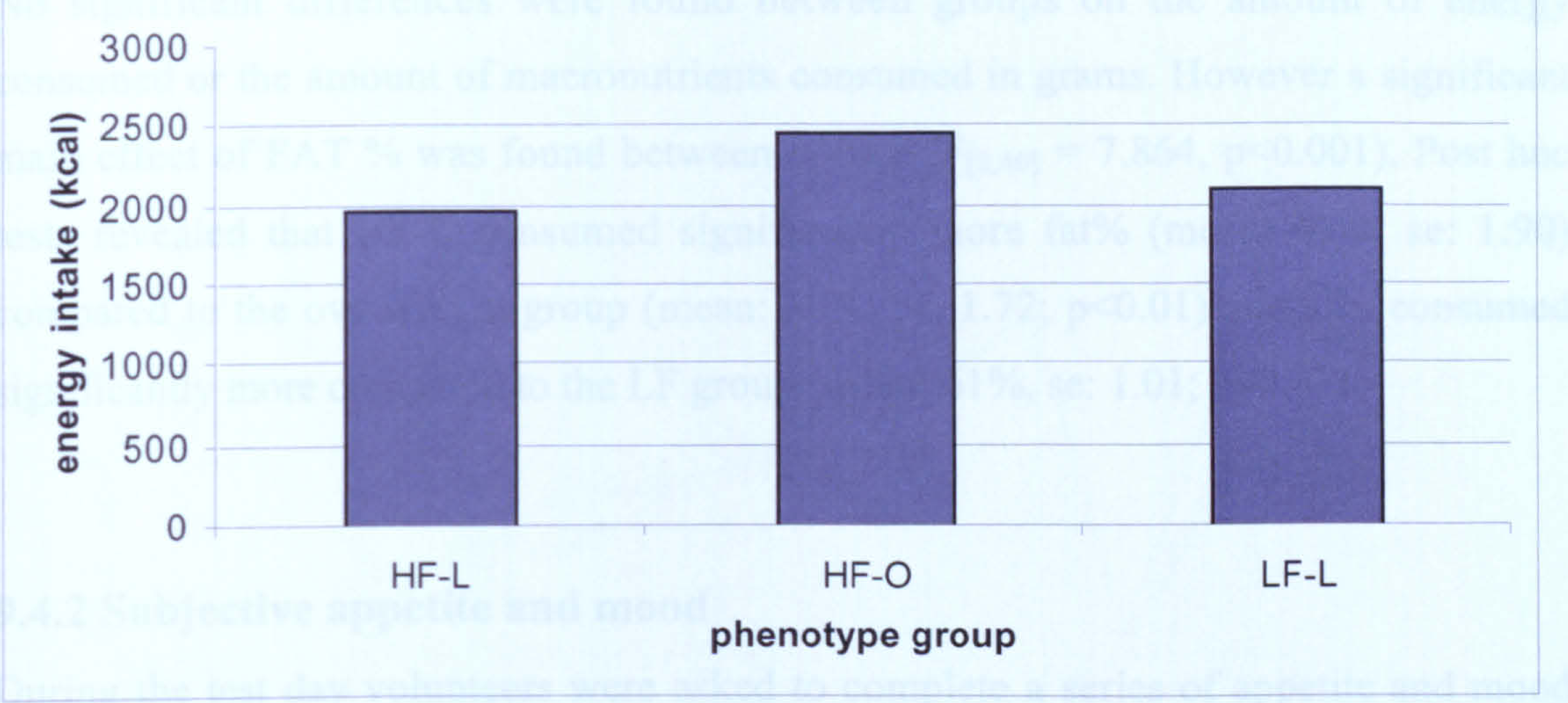

Fig 9.2a Total energy intake consumed during *ad litbium* phase.

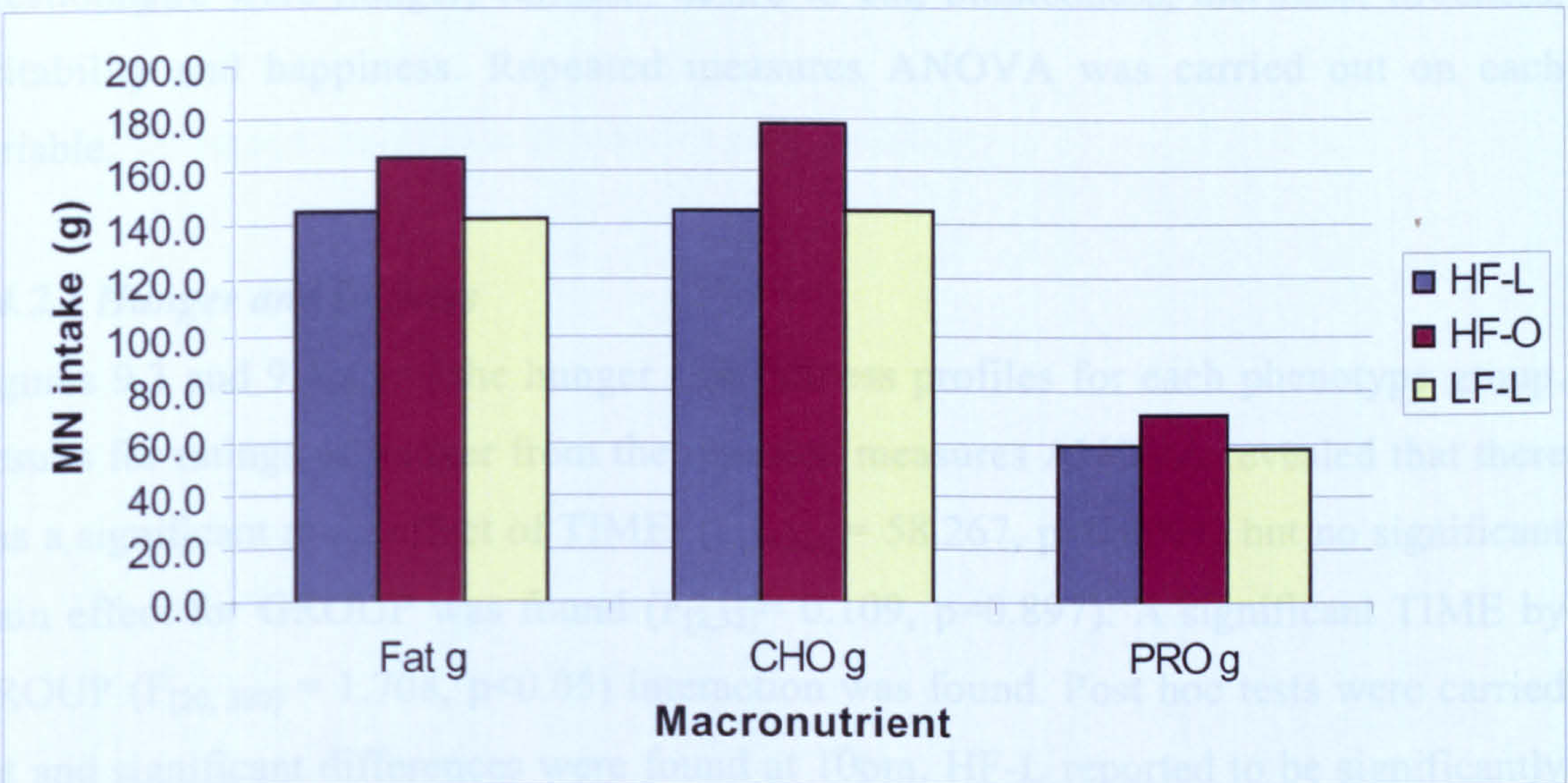

Figure 9.2d Total macronutrient intake (MN) in grams consumed during *ad lib* phase.

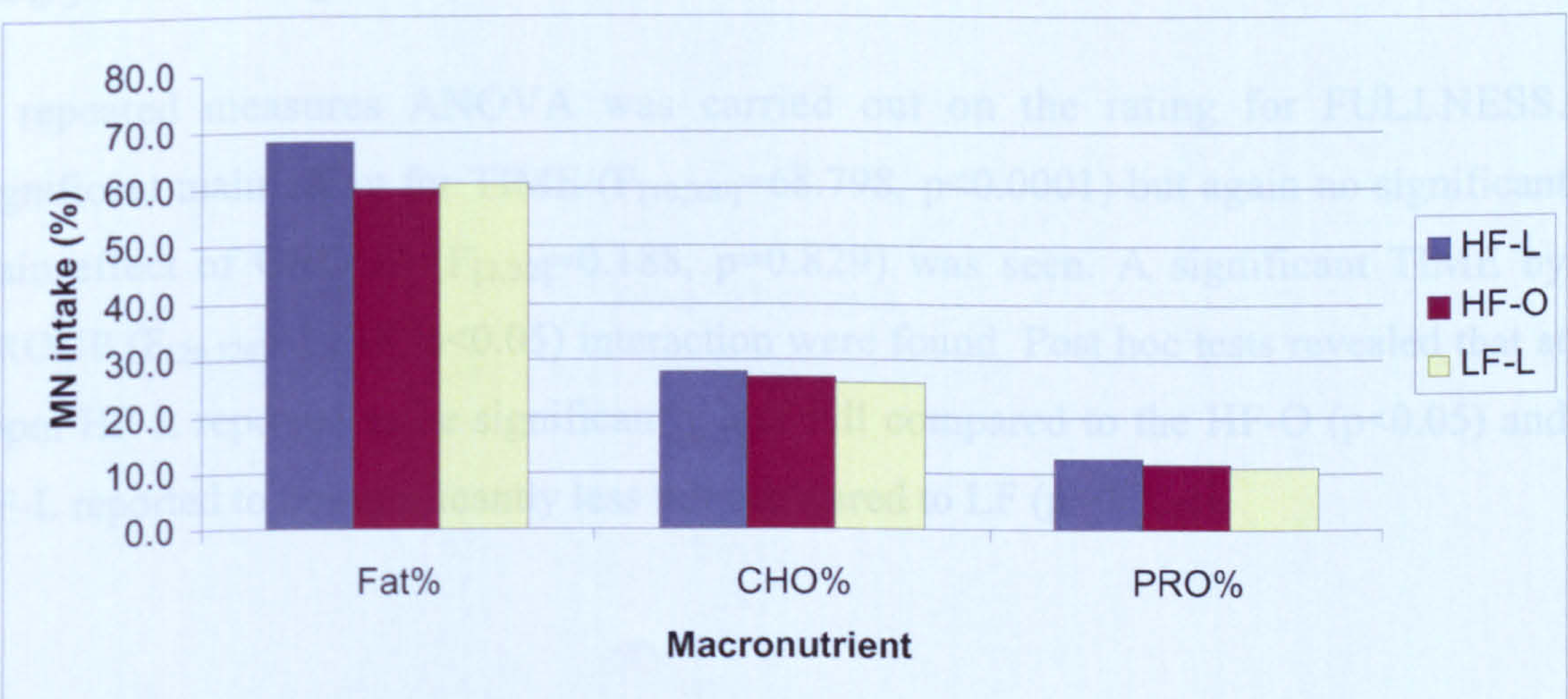

Figure 9.2c Total macronutrient intake (MN) as a % of EI during *ad lib* phase.

No significant differences were found between groups on the amount of energy consumed or the amount of macronutrients consumed in grams. However a significant main effect of FAT % was found between groups ($F_{[2,40]} = 7.864$, $p<0.001$). Post hoc tests revealed that HF-L consumed significantly more fat% (mean: 68%, se: 1.90) compared to the overweight group (mean: 60%, se: 1.72; $p<0.01$) and also consumed significantly more compared to the LF group (mean: 61%, se: 1.01; $p<0.01$).

9.4.2 Subjective appetite and mood

During the test day volunteers were asked to complete a series of appetite and mood responses administered electronically using the PSION. Items included in this questionnaire were hunger, fullness, desire to eat, bloatedness, alertness, tiredness, irritability and happiness. Repeated measures ANOVA was carried out on each variable.

9.4.2.1 Hunger and fullness

Figures 9.3 and 9.4 show the hunger and fullness profiles for each phenotype group. Results for ratings of hunger from the repeated measures ANOVA revealed that there was a significant main effect of TIME: ($F_{[10,320]}= 58.267$, $p<0.0001$) but no significant main effect for GROUP was found ($F_{[2,32]}= 0.109$, $p=0.897$). A significant TIME by GROUP ($F_{[20, 320]} = 1.708$, $p<0.05$) interaction was found. Post hoc tests were carried out and significant differences were found at 10pm. HF-L reported to be significantly more hungry than HF-O ($p<0.05$). Also 2hr post lunch, LF were significantly more hungry than HF-O ($p<0.05$).

A repeated measures ANOVA was carried out on the rating for FULLNESS. Significant main effect for TIME ($F_{[10,320]}=68.798$, $p<0.0001$) but again no significant main effect of GROUP ($F_{[2,32]}=0.188$, $p=0.829$) was seen. A significant TIME by GROUP ($F_{[20,320]}=1.818$, $p<0.05$) interaction were found Post hoc tests revealed that at 10pm HF-L reported to be significantly less full compared to the HF-O ($p<0.05$) and HF-L reported to be significantly less full compared to LF ($p<0.05$).

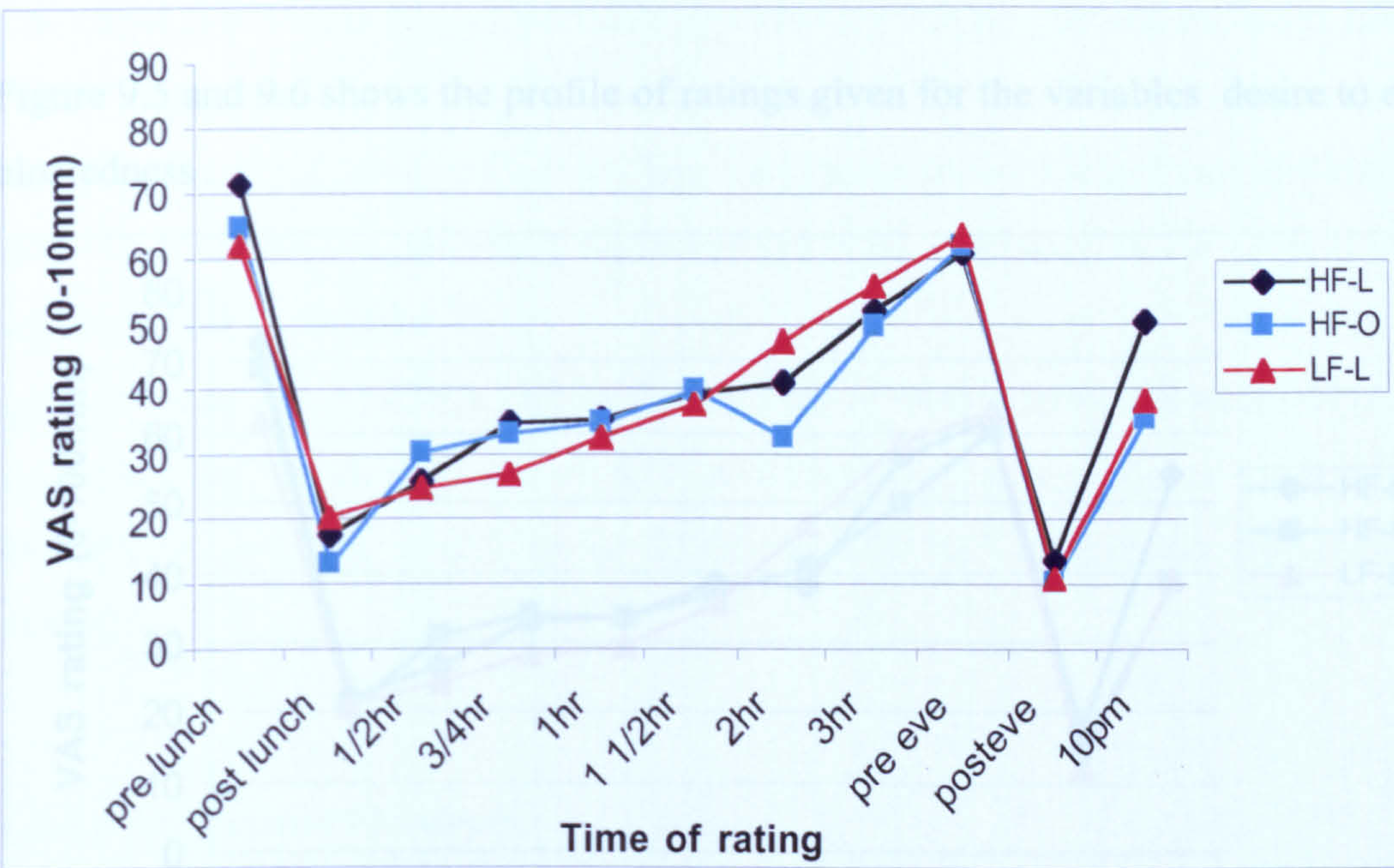

Figure 9.3 Hunger profiles across the experimental day

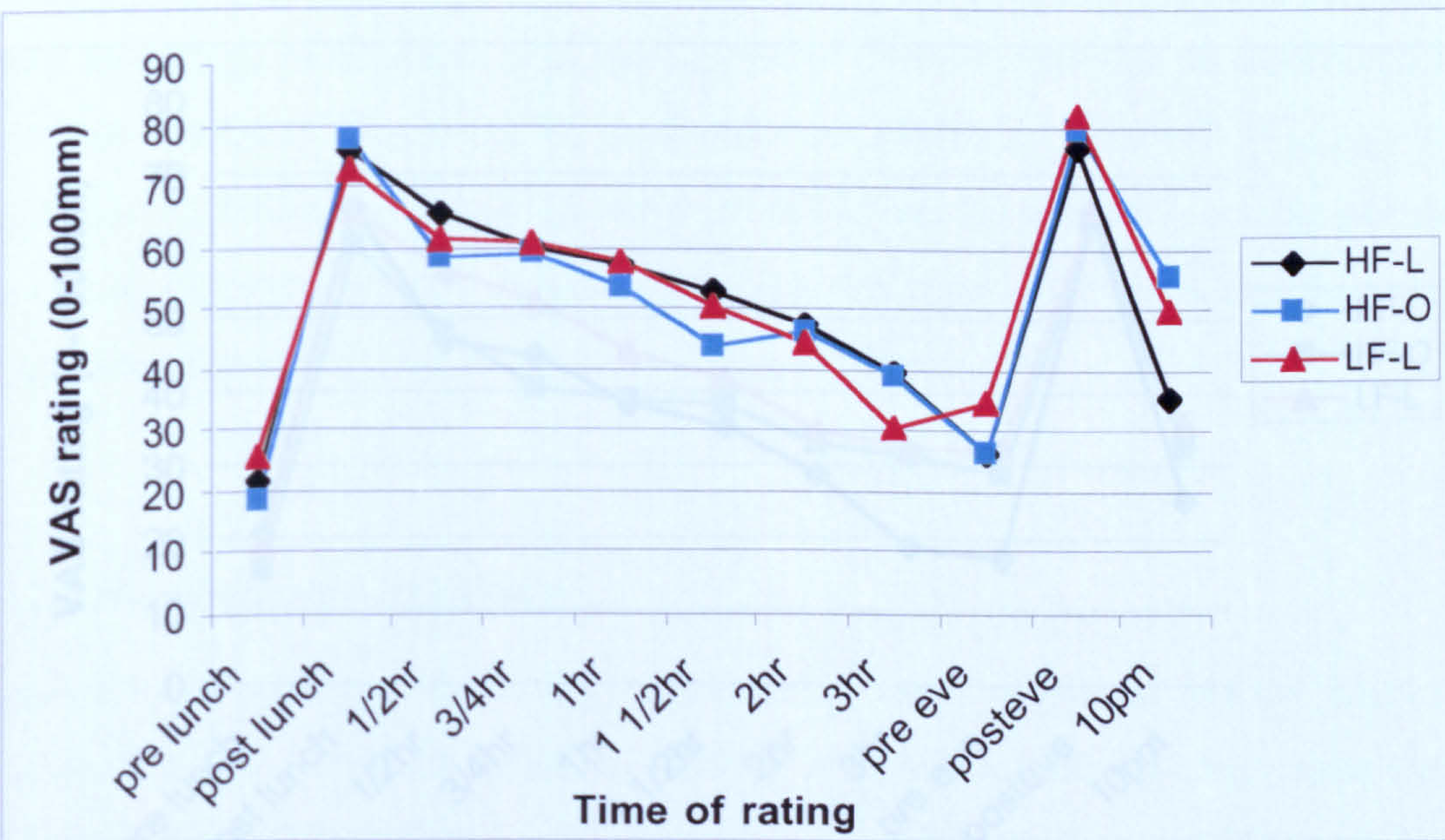

Figure 9.4 Fullness profiles across the experimental day

9.4.2.2 Desire to eat & bloatedness

Figure 9.5 and 9.6 shows the profile of ratings given for the variables desire to eat and bloatedness .

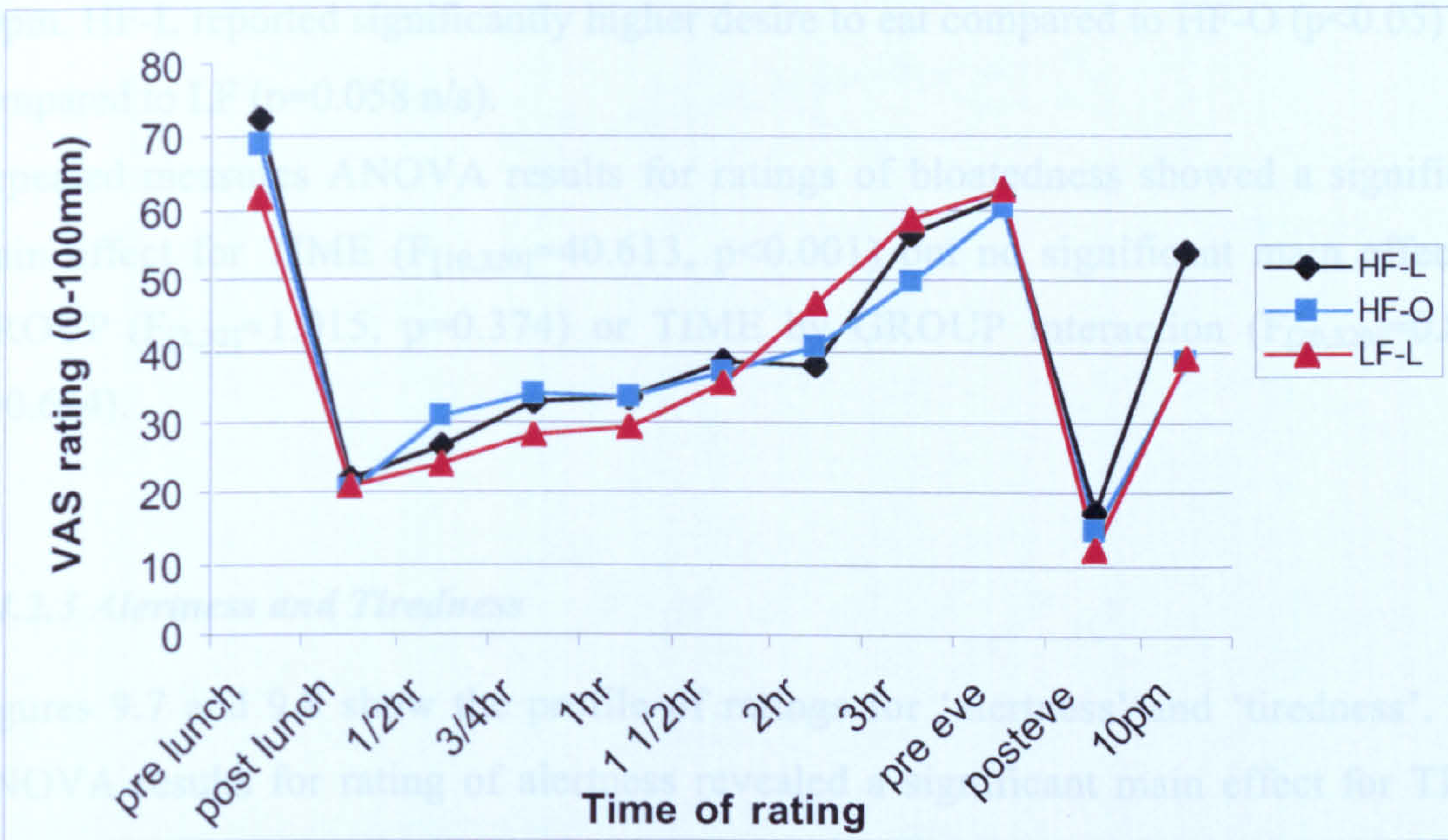

Figure 9.5 — Desire to eat profile across the experimental day

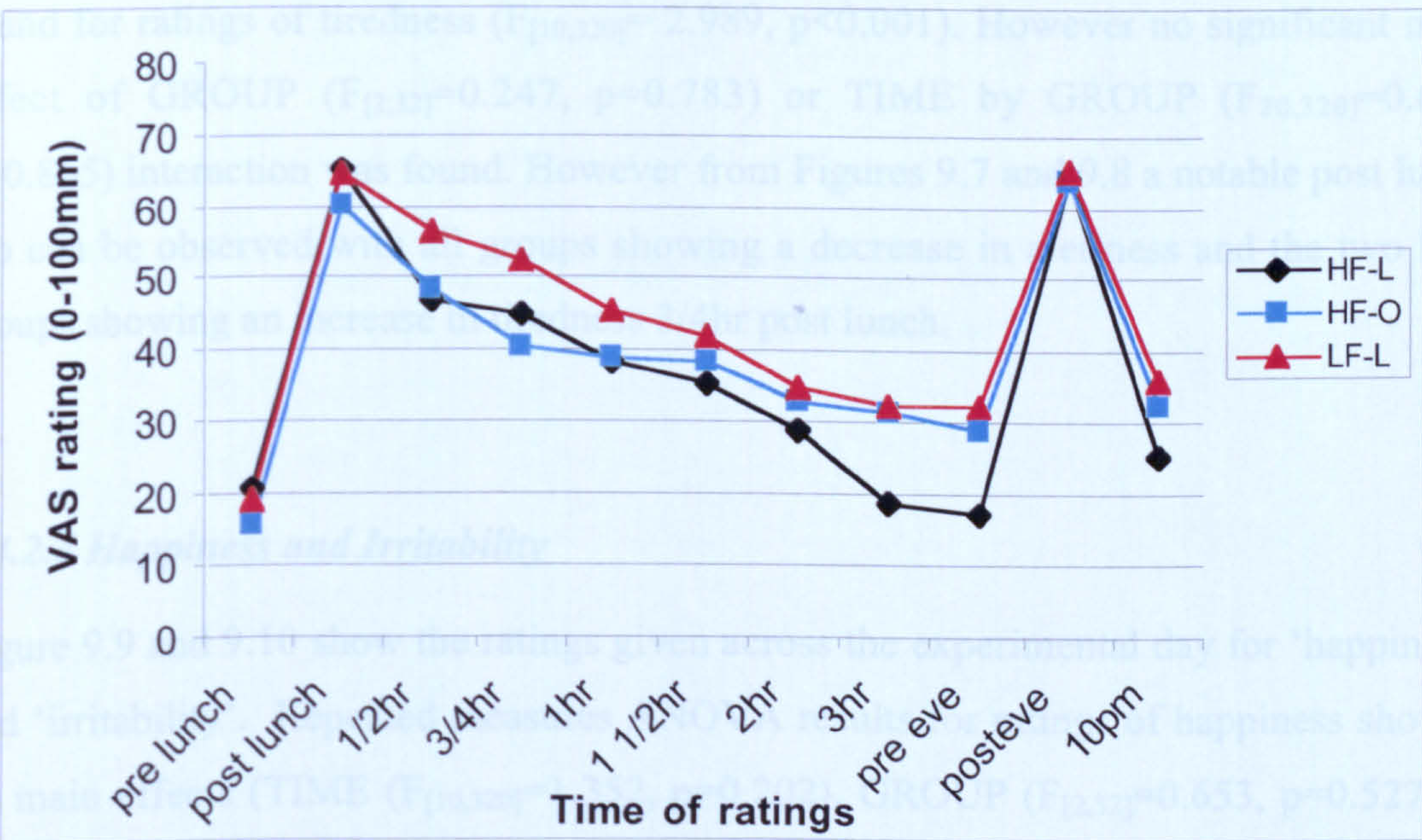

Figure 9.6 Bloatedness profile across the experimental day

Repeated measures ANOVA results for ratings of desire to eat showed a significant main effect for TIME ($F_{[10,320]}$=51.629, p<0.0001) but no significant main effect of GROUP ($F_{[2,32]}$=0.264, p=0.770). A significant TIME by GROUP interaction was found ($F_{[20,320]}$=1.730, p=0.028). Post- hoc tests again showed significant differences at 10pm. HF-L reported significantly higher desire to eat compared to HF-O (p<0.05) and compared to LF (p=0.058 n/s).

Repeated measures ANOVA results for ratings of bloatedness showed a significant main effect for TIME ($F_{[10,320]}$=40.613, p<0.001) but no significant main effect of GROUP ($F_{[2,32]}$=1.015, p=0.374) or TIME by GROUP interaction ($F_{[20,320]}$=0.856, p=0.644).

9.4.2.3 Alertness and Tiredness

Figures 9.7 and 9.8 show the profile of ratings for 'alertness' and 'tiredness'. The ANOVA results for rating of alertness revealed a significant main effect for TIME ($F_{[10,320]}$=3.292, p<0.0001) but no main effect for GROUP ($F_{[2,32]}$=0.263, p=0.770) or TIME by GROUP interaction ($F_{[20,320]}$=1.221, p=0.234). A main effect of TIME was found for ratings of tiredness ($F_{[10,320]}$= 2.989, p<0.001). However no significant main effect of GROUP ($F_{[2,32]}$=0.247, p=0.783) or TIME by GROUP ($F_{20,320]}$=0.659, p=0.865) interaction was found. However from Figures 9.7 and 9.8 a notable post lunch dip can be observed with all groups showing a decrease in alertness and the two lean groups showing an increase in tiredness 3/4hr post lunch.

9.4.2.4 Happiness and Irritability

Figure 9.9 and 9.10 show the ratings given across the experimental day for 'happiness' and 'irritability'. Repeated measures ANOVA results for ratings of happiness showed no main effects (TIME ($F_{[10,320]}$=1.352, p=0.202), GROUP ($F_{[2,32]}$=0.653, p=0.527) or TIME by GROUP interaction ($F_{[20,320]}$=0.707, p=0.819)).

Repeated measure ANOVA results for rating of irritability revealed no main effect for TIME ($F_{[10,320]}$=1.02, p=0.426). No significant main effect for GROUP ($F_{[2,32]}$=1.272, p=0.294) was found, although LF-L reported themselves to be more irritable during the afternoon and the rest of the day compared to the HF groups. Also no significant TIME by GROUP interaction was found for this variable ($F_{[20,320]}$=0.958, p=0.513).

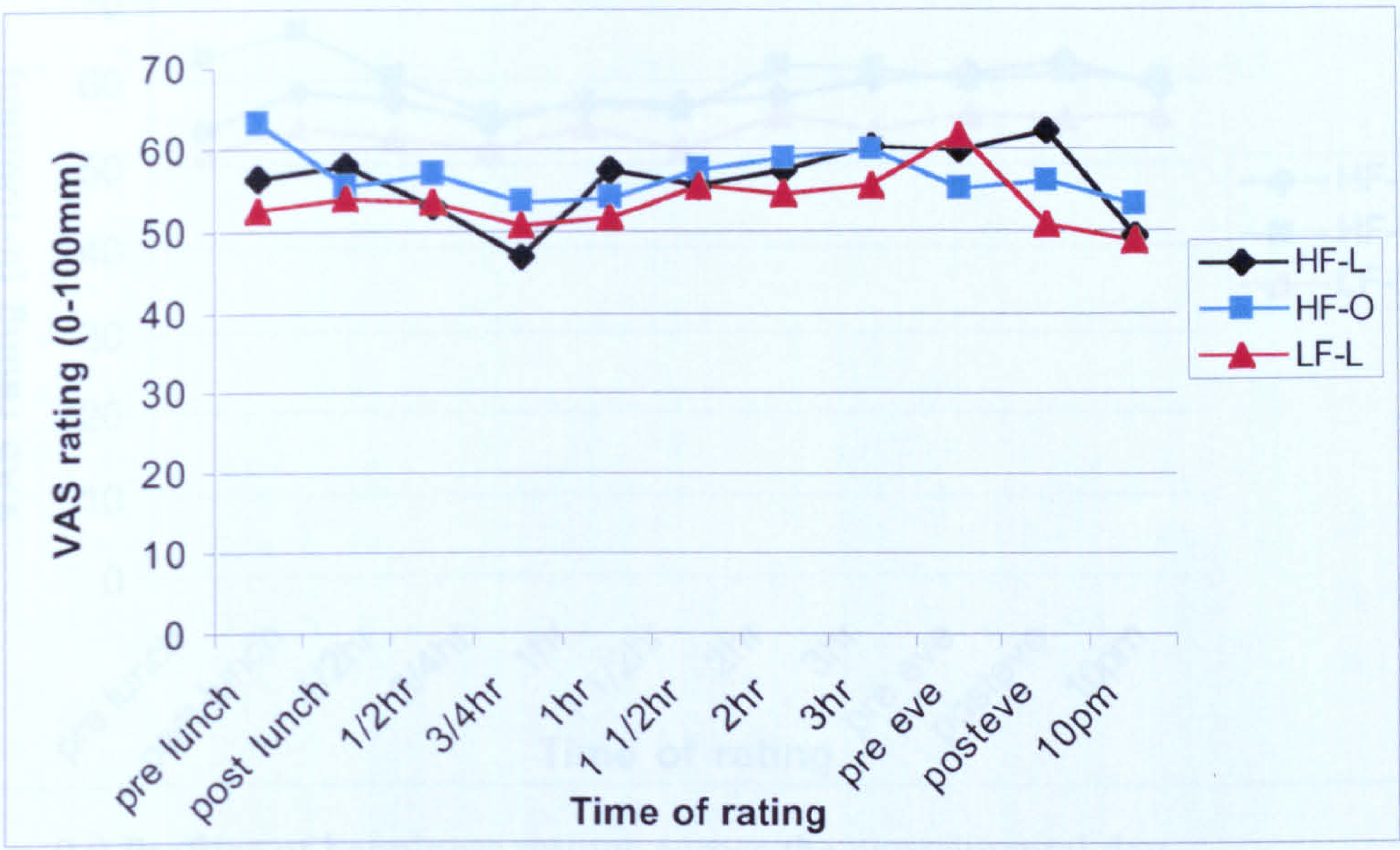

Figure 9.7 Profile of alertness across experimental day.

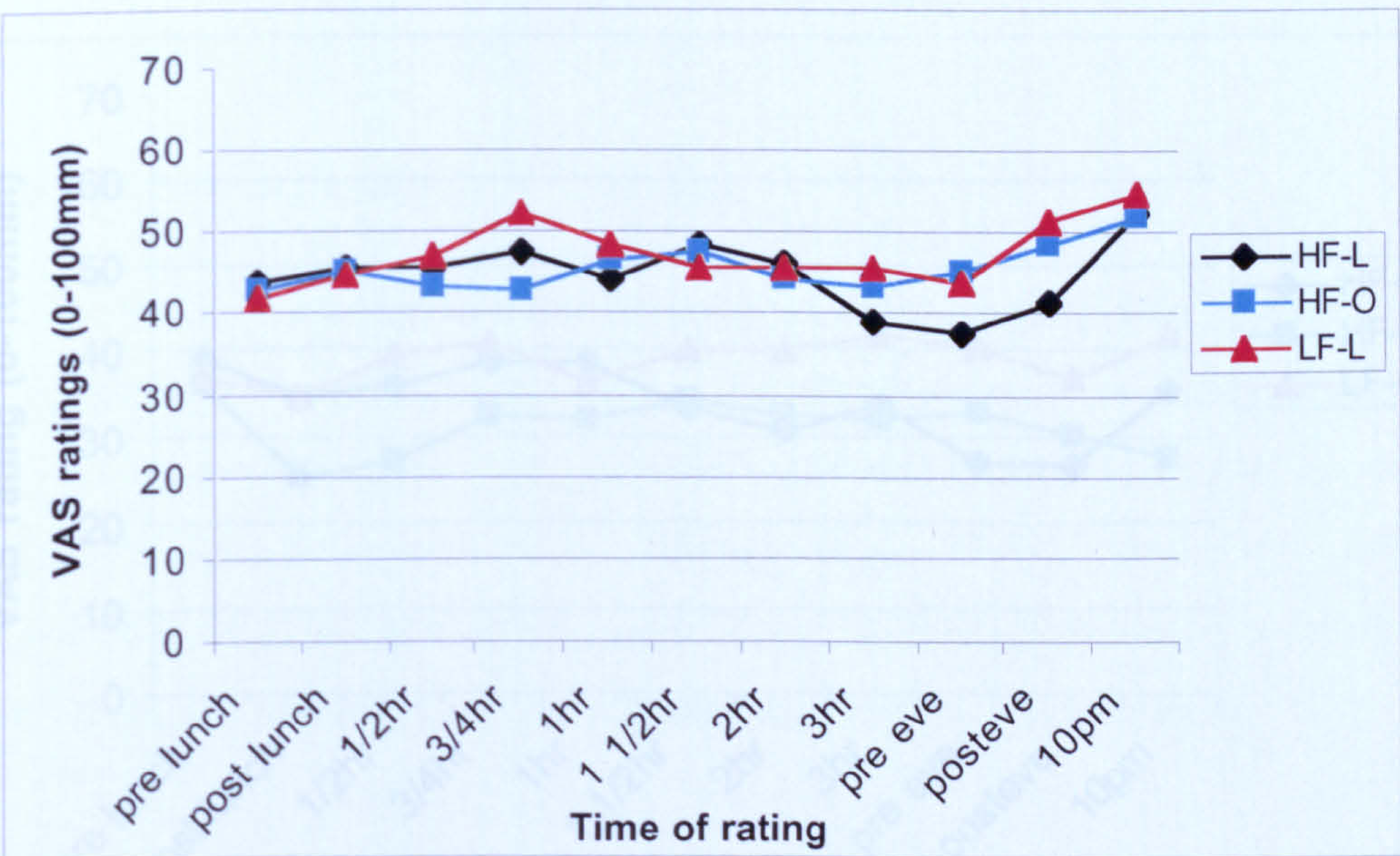

Figure 9.8 Profiles of tiredness across experimental day

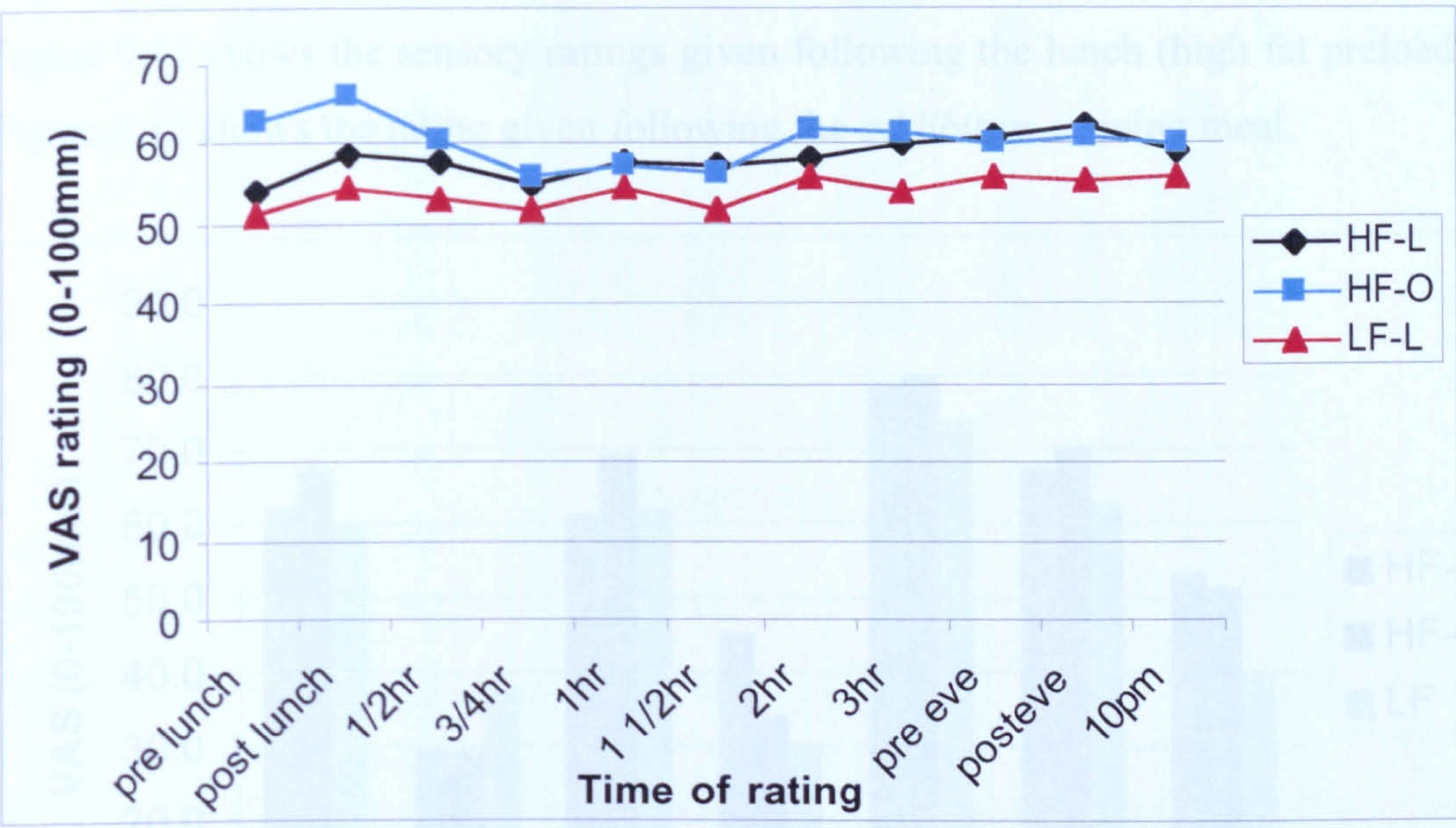

Figure 9.9 Profiles of happiness ratings across the experimental day

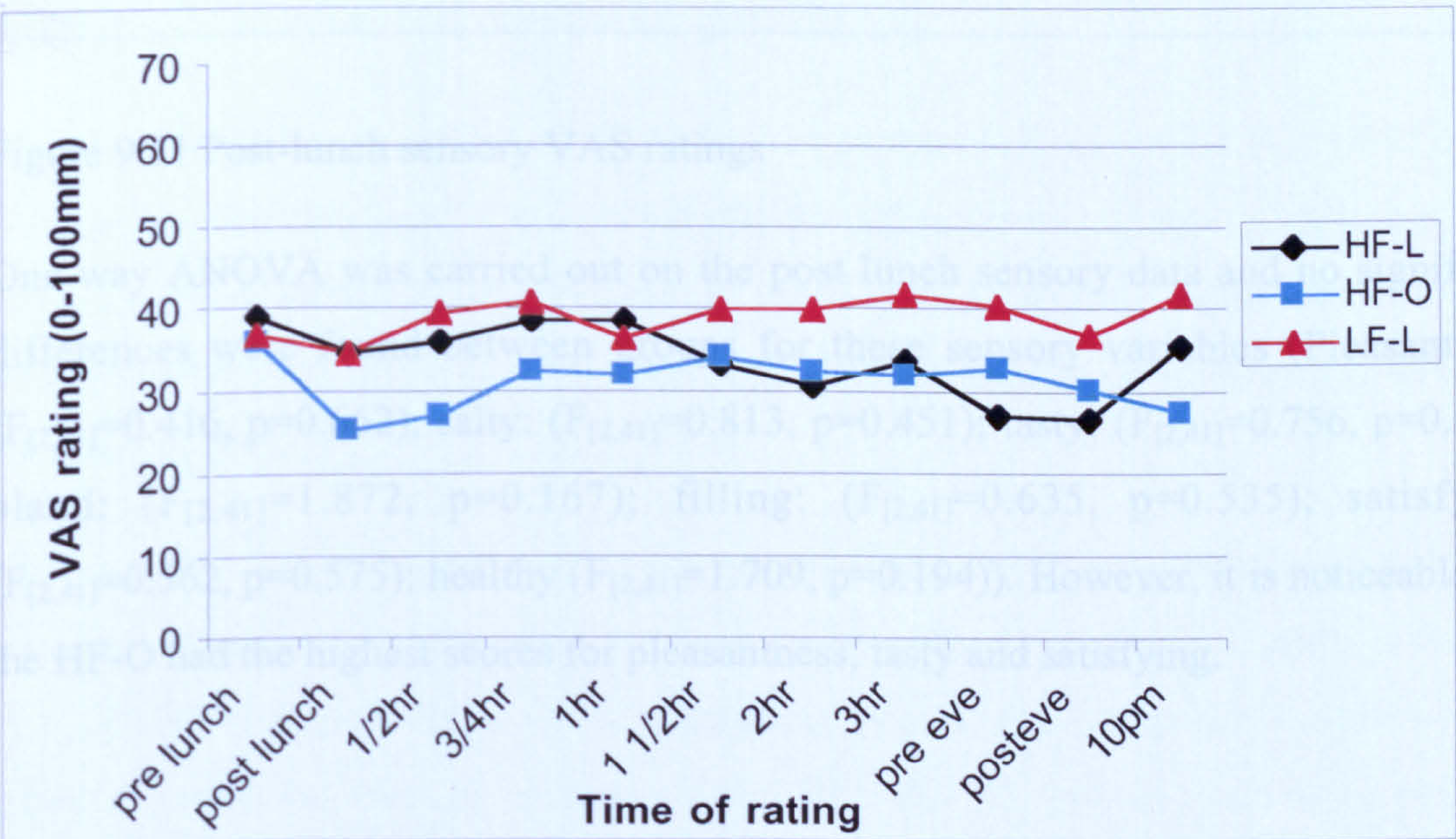

Figure 9.10 Profiles of irritability ratings across the experimental day

9.4.3 Post-meal sensory ratings

A post-meal sensory questionnaire was administered immediately after each test meal. Figure 9.11 shows the sensory ratings given following the lunch (high fat preload) and Figure 9.12 shows the rating given following the *ad libitum* evening meal.

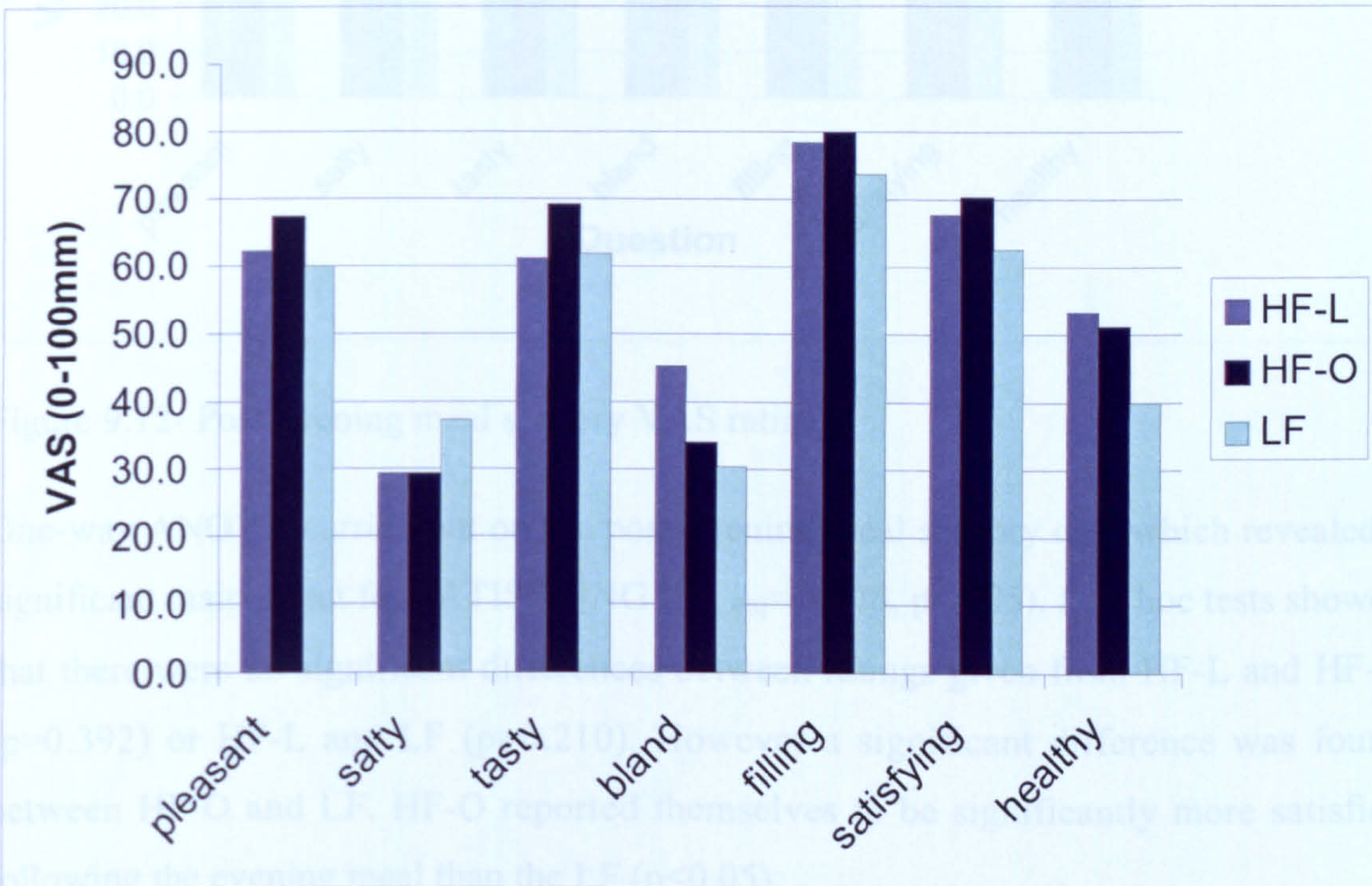

Figure 9.11 Post-lunch sensory VAS ratings

One-way ANOVA was carried out on the post lunch sensory data and no significant differences were found between groups for these sensory variables (Pleasantness: ($F_{[2,41]}$=0.416, p=0.662); salty: ($F_{[2,41]}$=0.813, p=0.451); tasty: ($F_{[2,41]}$=0.756, p=0.476); bland: ($F_{[2,41]}$=1.872, p=0.167); filling: ($F_{[2,41]}$=0.635, p=0.535); satisfying: ($F_{[2,41]}$=0.562, p=0.575); healthy ($F_{[2,41]}$=1.709, p=0.194)). However, it is noticeable that the HF-O had the highest scores for pleasantness, tasty and satisfying.

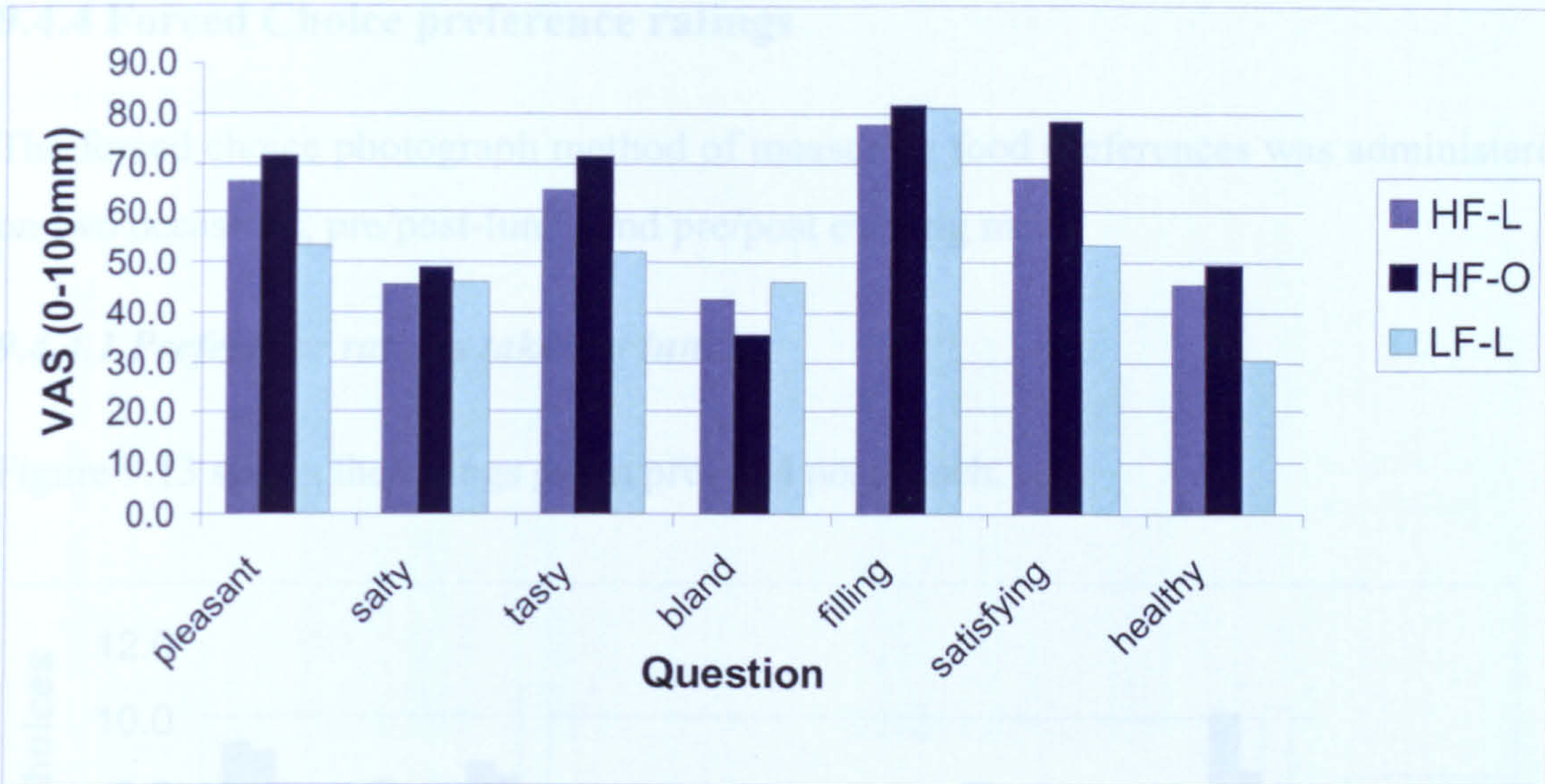

Figure 9.12- Post-evening meal sensory VAS ratings

One-way ANOVA carried out on the post-evening meal sensory data which revealed a significant main effect for SATISFYING ($F_{[2, 40]}$= 4.278, p<0.05). Post hoc tests showed that there were no significant differences between ratings given from HF-L and HF-O (p=0.392) or HF-L and LF (p=0.210). However a significant difference was found between HF-O and LF. HF-O reported themselves to be significantly more satisfied following the evening meal than the LF (p<0.05).

Also a significant main effect of HEALTHY was found ($F_{[2,40]}$ = 3.434, p<0.05). Post hoc test showed that there were no significant differences between rating given from HF-L and HF-O (p=0.874) or HF-L and LF (p=0.110). However a significant difference was found between HF-O and LF. HF-O reported the meal to be significantly healthier than the LF (p<0.05).

Although the effects were weak (i.e. not obvious from the ANOVA results) the following findings may at least be note worthy (TASTY ($F_{[2,40]}$=3.489, p=0.058); PLEASANT ($F_{[2,40]}$=3.424, p=0.062). Exploratory post hoc t-tests that the overweight group reported the meal to be tastier (t= 2.087, df= 25, p<0.05) and more pleasant compared to the LF (t= 1.821, df= 25, p=0.08 n/s) but not compared to the HF-L. As with the post-lunch ratings, HF-O had the highest ratings for pleasantness, tasty and satisfying.

9.4.4 Forced Choice preference ratings

The forced choice photograph method of measuring food preferences was administered on two occasions; pre/post-lunch and pre/post evening meal.

9.4.4.1 Preference ratings taken at lunch

Figure 9.13 shows the ratings given pre- and post-lunch.

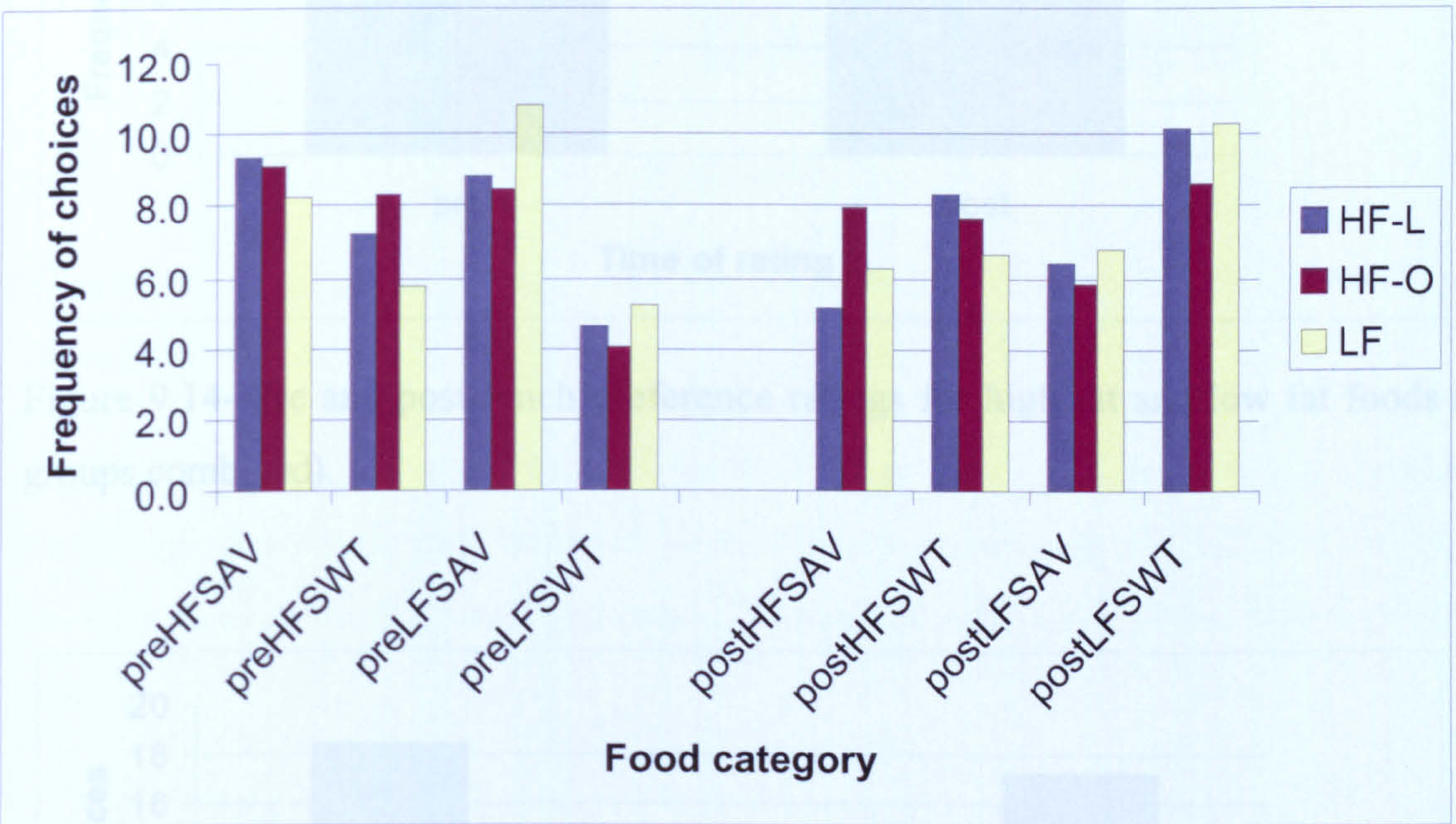

Figure 9.13- Pre- and post-lunch forced choice preference ratings (KEY: HFSAV= high fat savoury food types; HFSWT= high fat sweet food types; LFSAV= low fat savoury food types; LFSWT= low fat sweet food types).

A 2 by 2 by 2 repeated measures ANOVA was carried out on this data and a number of significant differences were found. A significant time by macronutrient by taste interaction was found ($F_{[1, 41]}=41.051$, $p<0.001$). Four post hoc *t*-tests were carried out to evaluate where these differences. Pre-lunch there was no significant difference in high and low fat savoury food choices ($t=-1.069$, $df=44$, $p=0.291$). However high fat sweet foods were chosen significantly more (mean: 7.0+-2.71) compared to low fat sweet foods (mean: 4.67+/-2.83) pre-lunch ($t=3.516$, $df=44$, $p<0.001$).

Again, post-lunch there was no significant difference between high fat and low fat savoury food choices ($t=0.099$, $df=43$, $p=0.922$). However low fat sweet options were chosen significantly more (mean: 9.75+/-3.36) compared to high fat sweet options

(7.55+/-3.28) (t=-2.898, df=43, p<0.01). Figure 9.14 and 9.15 show a breakdown of these responses.

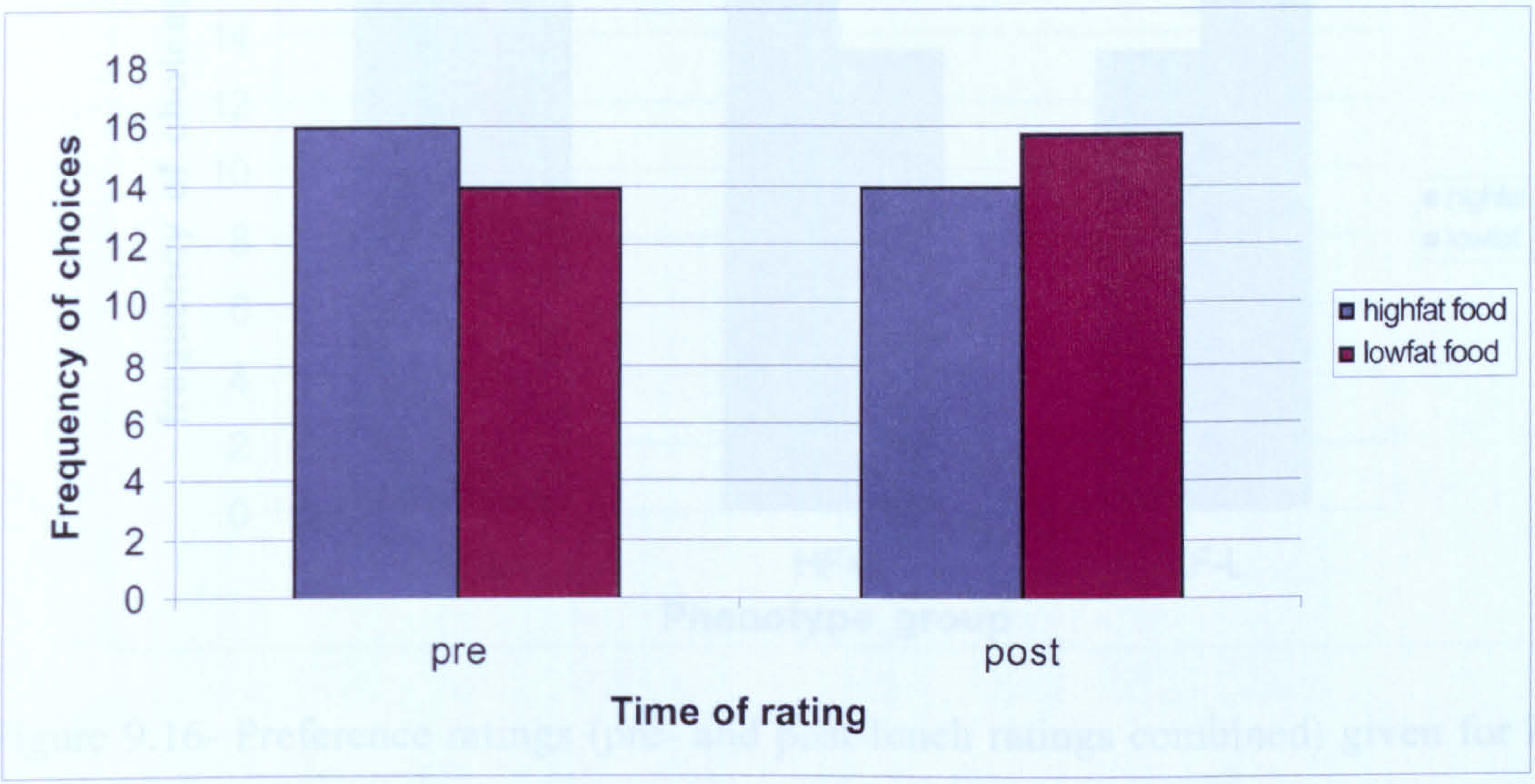

Figure 9.14- Pre and post-lunch preference ratings for high fat and low fat foods (all groups combined).

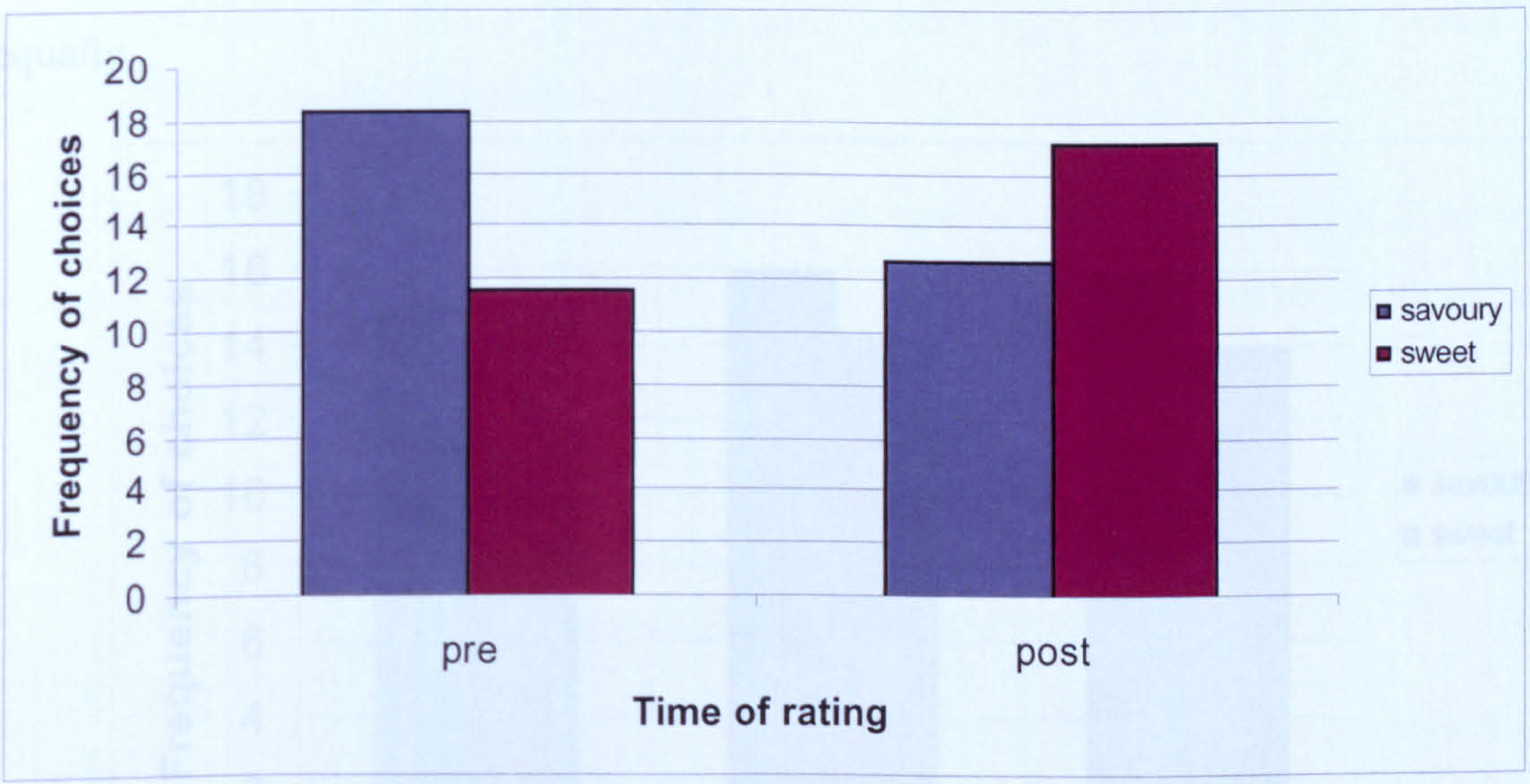

Figure 9.15 Pre and post-lunch preference ratings for savoury and sweet foods (all groups combined).

A significant GROUP by MACRONUTRIENT (high fat or low fat food type) main effect was found ($F_{[2,41]} = 3.45$, $p<0.05$). HF-L reported choosing the high fat and low fat food choices equally. However the overweight group chose the high fat foods more frequently and the LF chose the low fat foods more over both pre- and post-meal ratings (see Figure 9.16).

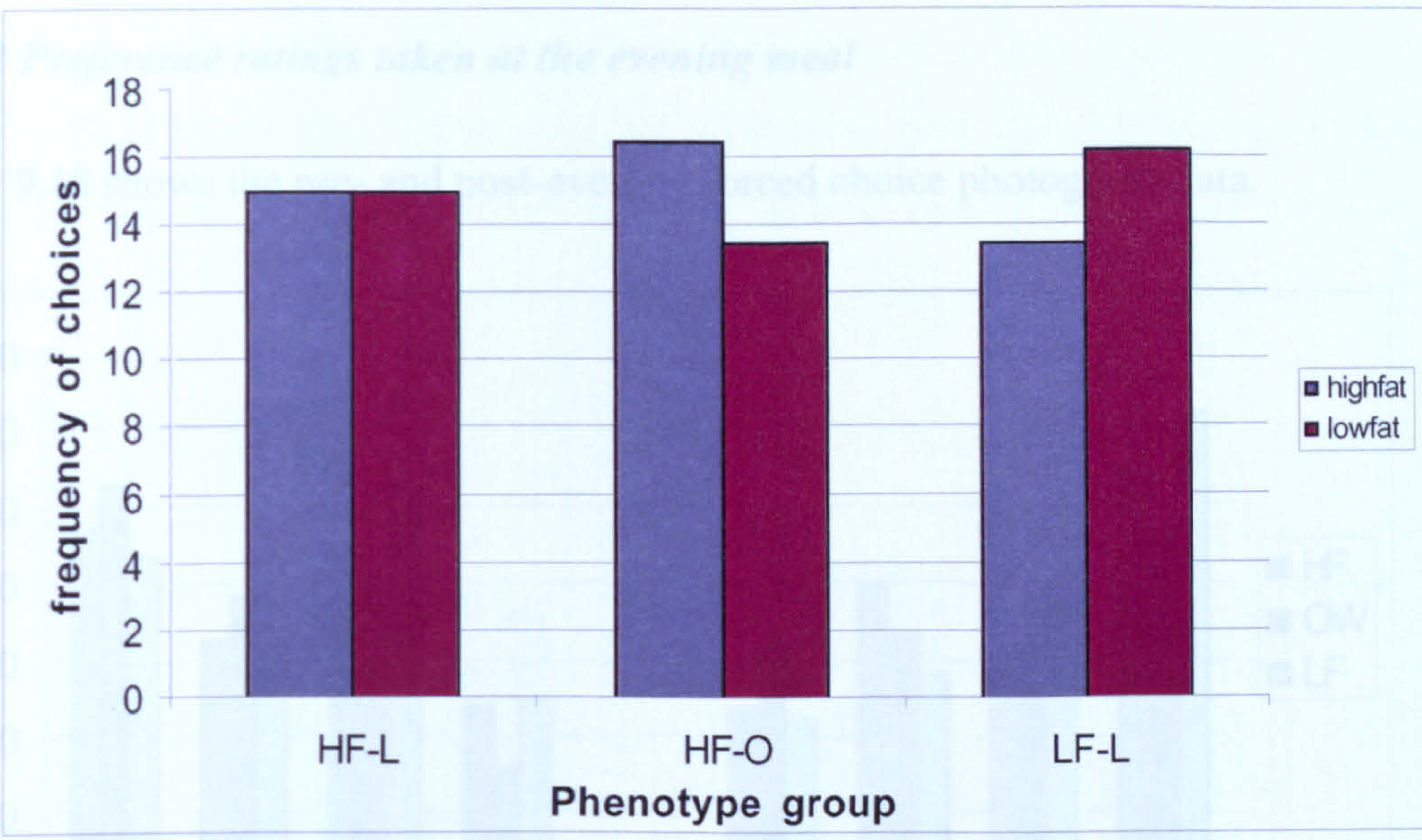

Figure 9.16- Preference ratings (pre- and post-lunch ratings combined) given for high fat and low fat foods.

Figure 9.17 shows the group choices for the savoury and sweet options. No significant main effects were found, however as the figure shows, both HF-O and LF chose savoury foods more frequently compared to sweet foods. HF-L chose both food types equally.

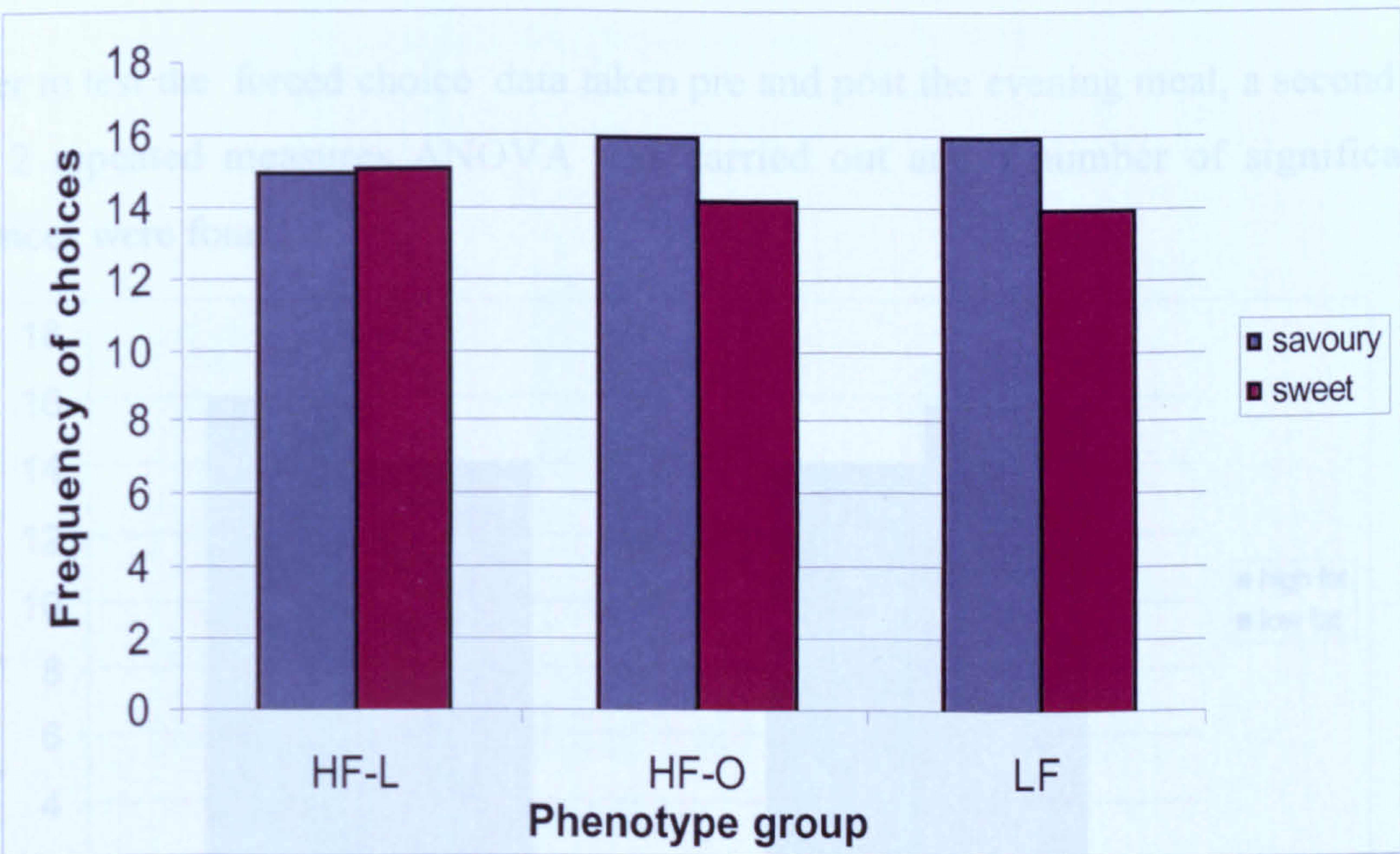

Figure 9.17- Preference ratings (pre- and post-lunch ratings combined) given for savoury and sweet foods.

9.4.4.2 Preference ratings taken at the evening meal

Figure 9.18 shows the pre- and post-evening forced choice photograph data.

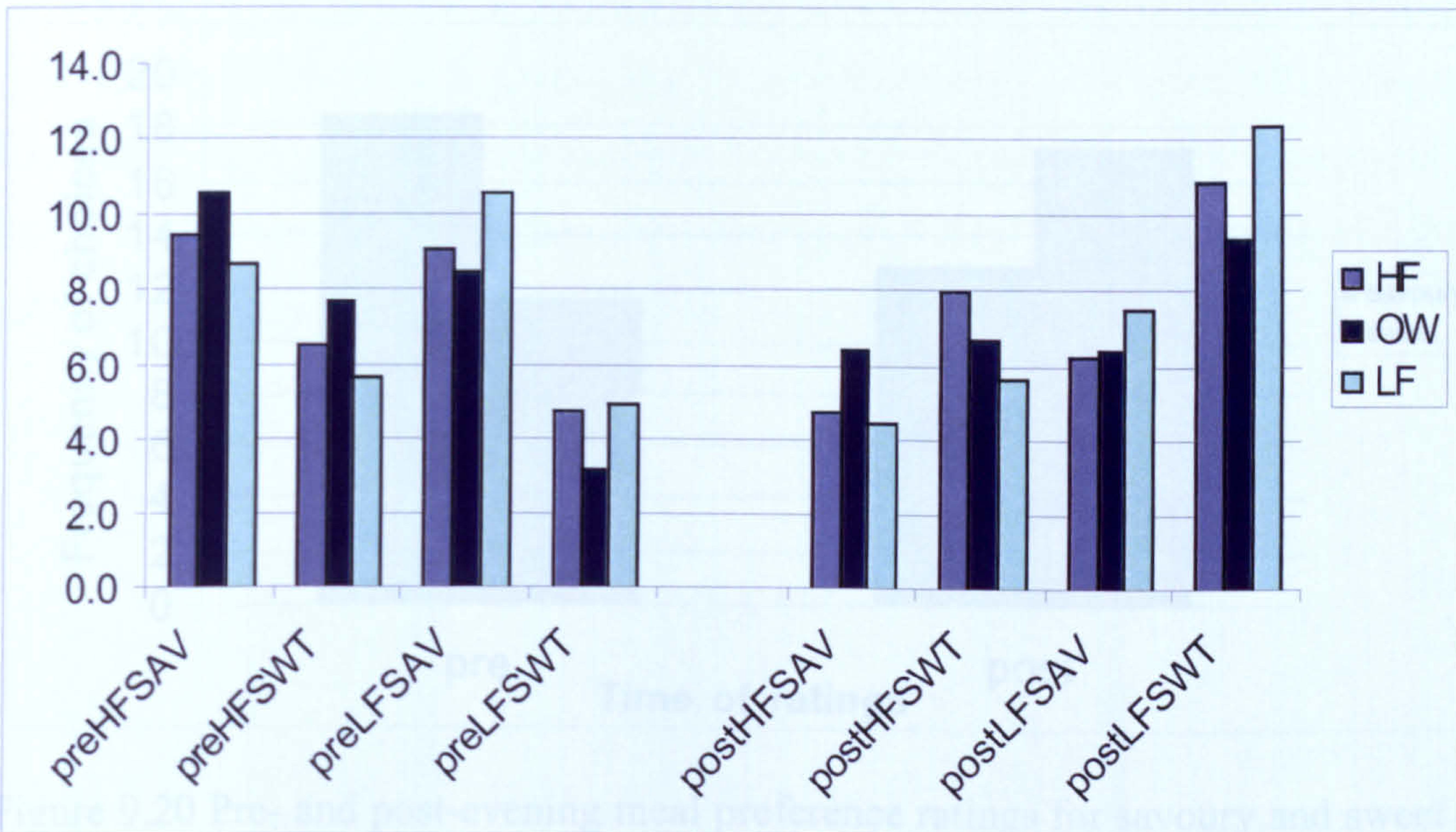

Figure 9.18 Pre- and post-evening meal forced choice preference ratings (KEY: HFSAV= high fat savoury food types; HFSWT= high fat sweet food types; LFSAV= low fat savoury food types; LFSWT= low fat sweet food types).

In order to test the forced choice data taken pre and post the evening meal, a second 2 x 2 x 2 repeated measures ANOVA was carried out and a number of significant differences were found.

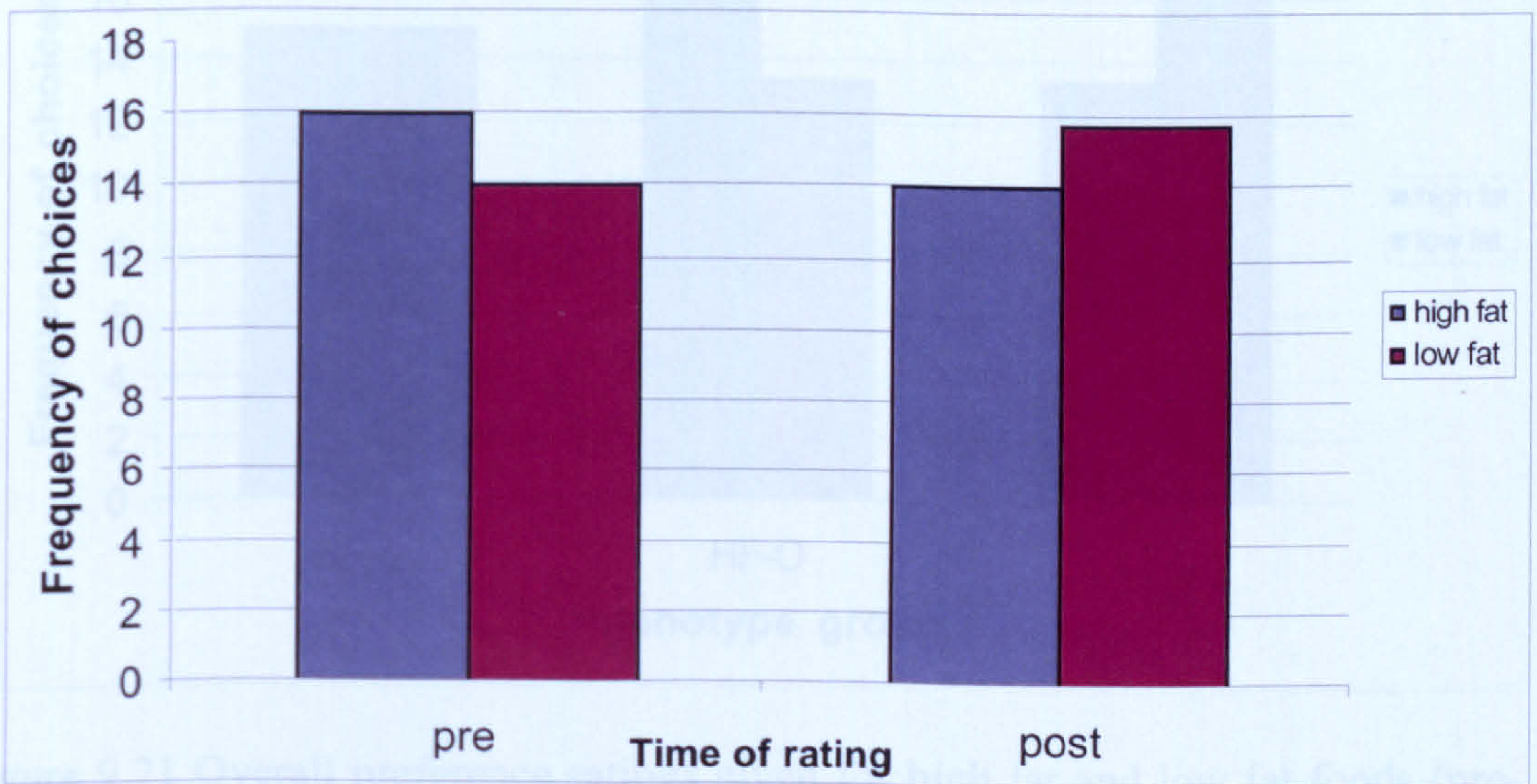

Figure 9.19 Pre- and post-evening meal preference ratings for high fat and low fat foods (all groups combined).

Again a significant TIME by NUTRIENT (high fat or low fat) interaction was found ($F_{[1,40]} = 61.113$, $p<0.0001$). Pre-meal all volunteers preferred high fat food choices overall and post-meal volunteers preferred low fat food choices (see Figure 9.19).

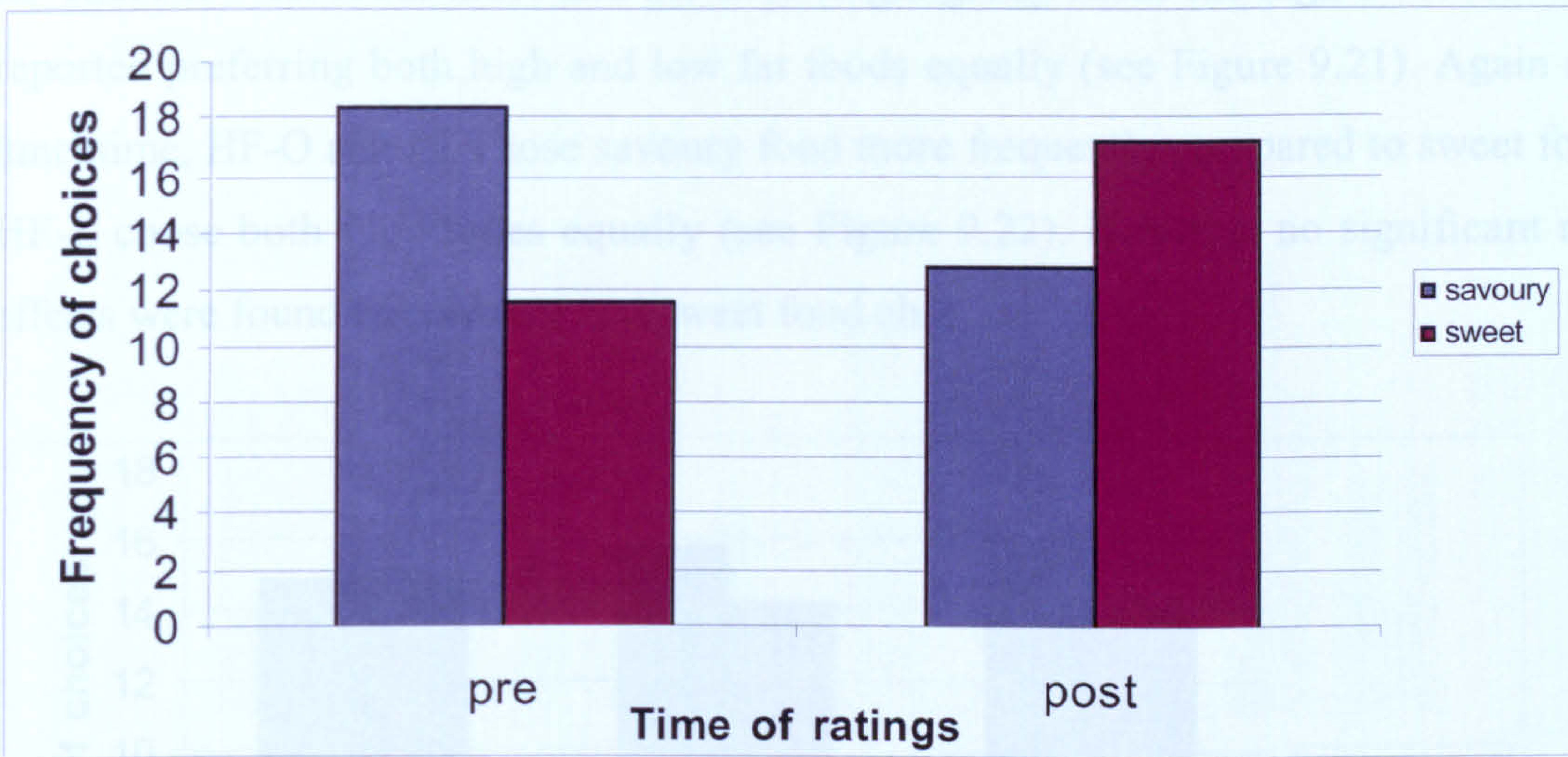

Figure 9.20 Pre- and post-evening meal preference ratings for savoury and sweet foods (all groups combined).

Also a significant TIME by TASTE (savoury or sweet) main interaction was found ($F_{[1,40]} = 82.614$, $p< 0.001$). Pre- meal all volunteers preferred savoury foods and post-meal all volunteers preferred sweet food choices (see Figure 9.20).

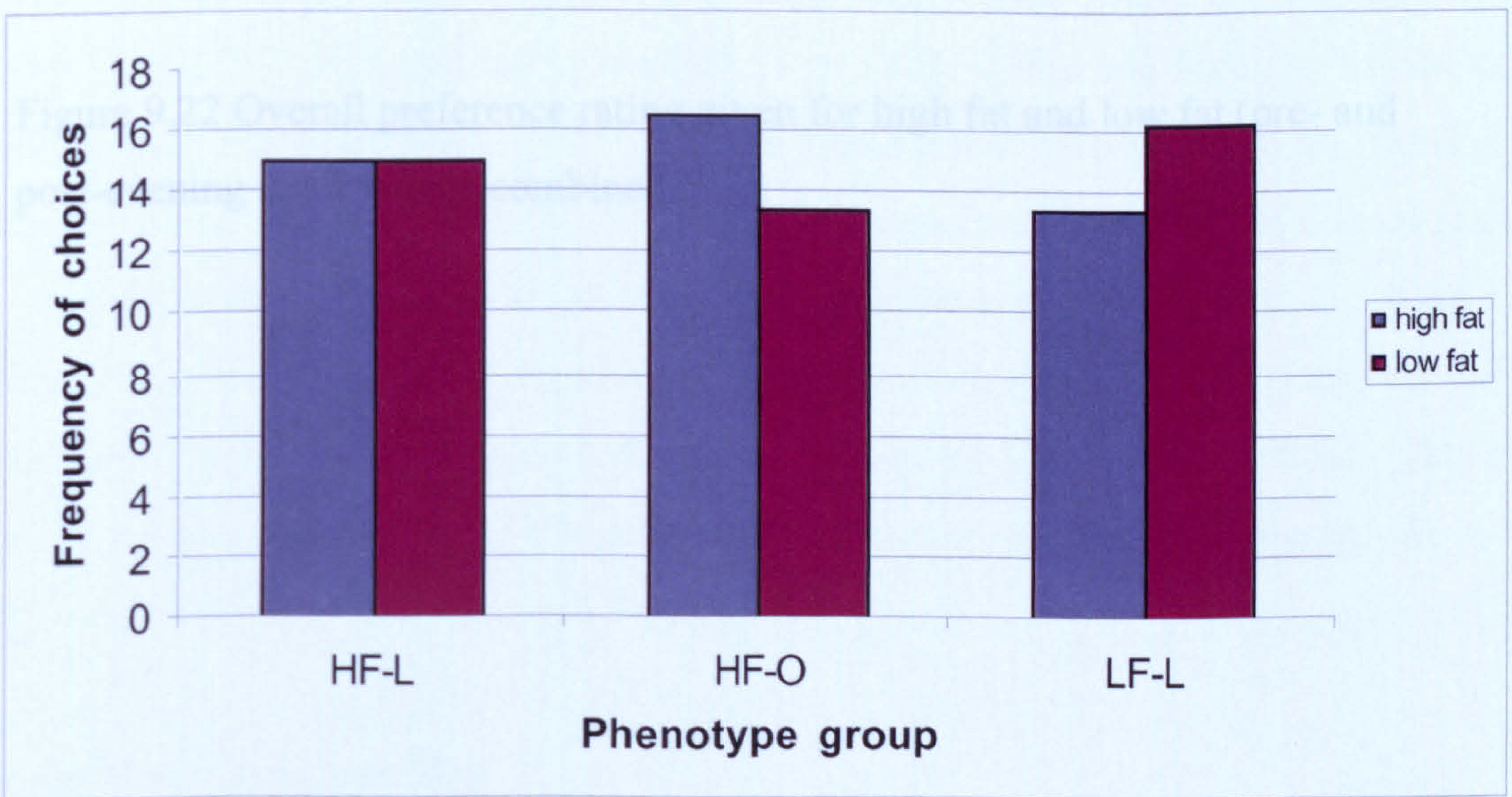

Figure 9.21 Overall preference ratings given for high fat and low fat foods (pre- and post-evening meal ratings combined).

Similar group ratings were found for evening meal forced choice photograph method as found for lunch. A significant MACRONUTRIENT (high or low fat food) by GROUP interaction was found ($F_{[2,40]} = 6.649$, $p<0.01$). Overall both pre- and post-meal ratings, LF chose low fat foods more and the overweight group chose the high fat foods. HF-L reported preferring both high and low fat foods equally (see Figure 9.21). Again as at lunchtime, HF-O and LF chose savoury food more frequently compared to sweet foods. HF-L chose both food types equally (see Figure 9.22). However no significant main effects were found for savoury and sweet food choices.

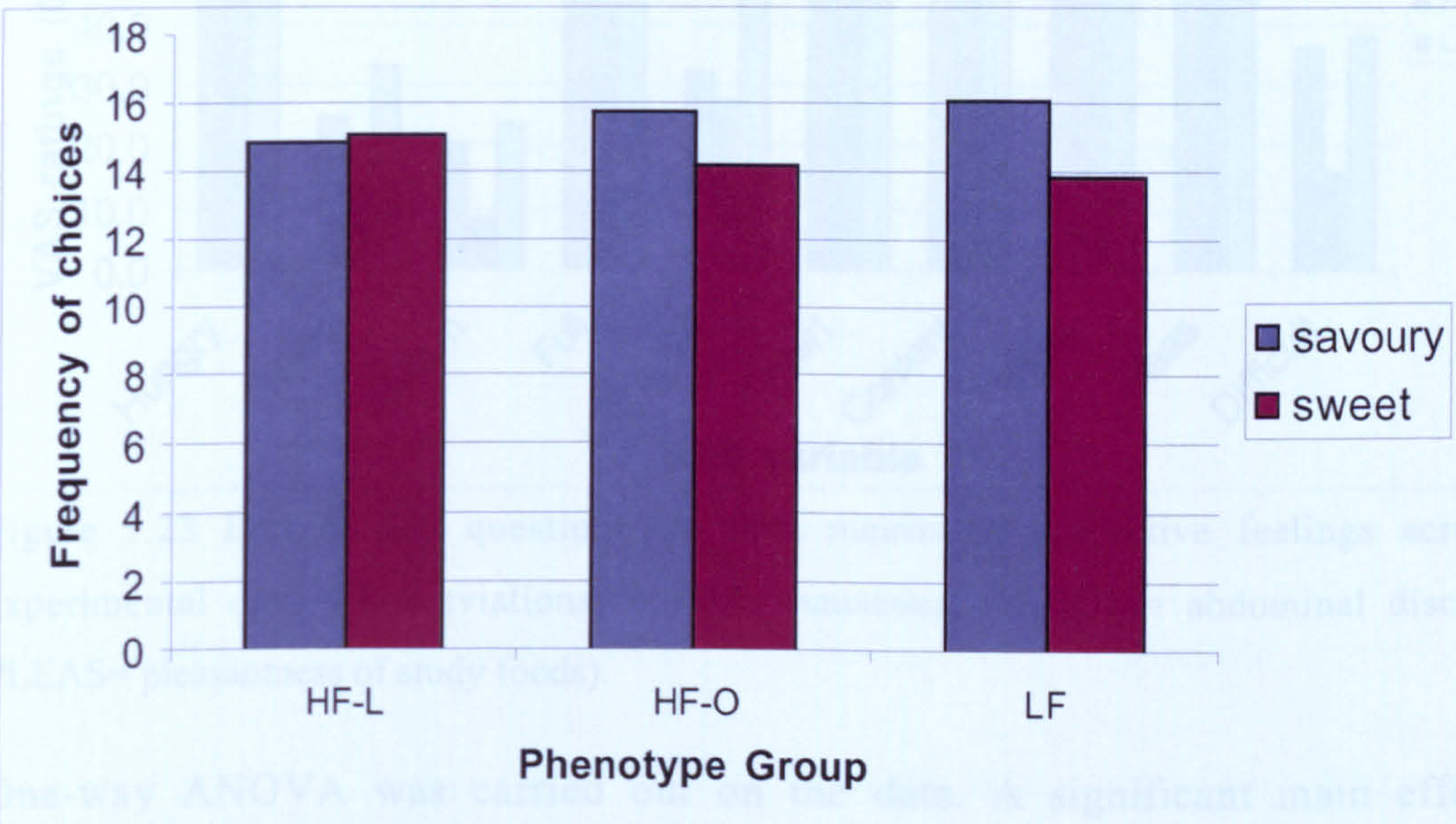

Figure 9.22 Overall preference rating given for high fat and low fat (pre- and post-evening meal ratings combined).

9.4.5 End of day questionnaire

Each volunteer was asked to complete an end of day questionnaire before retiring on the test food day to measure hunger and mood during the day. Figure 9.23 shows the rating given from each group.

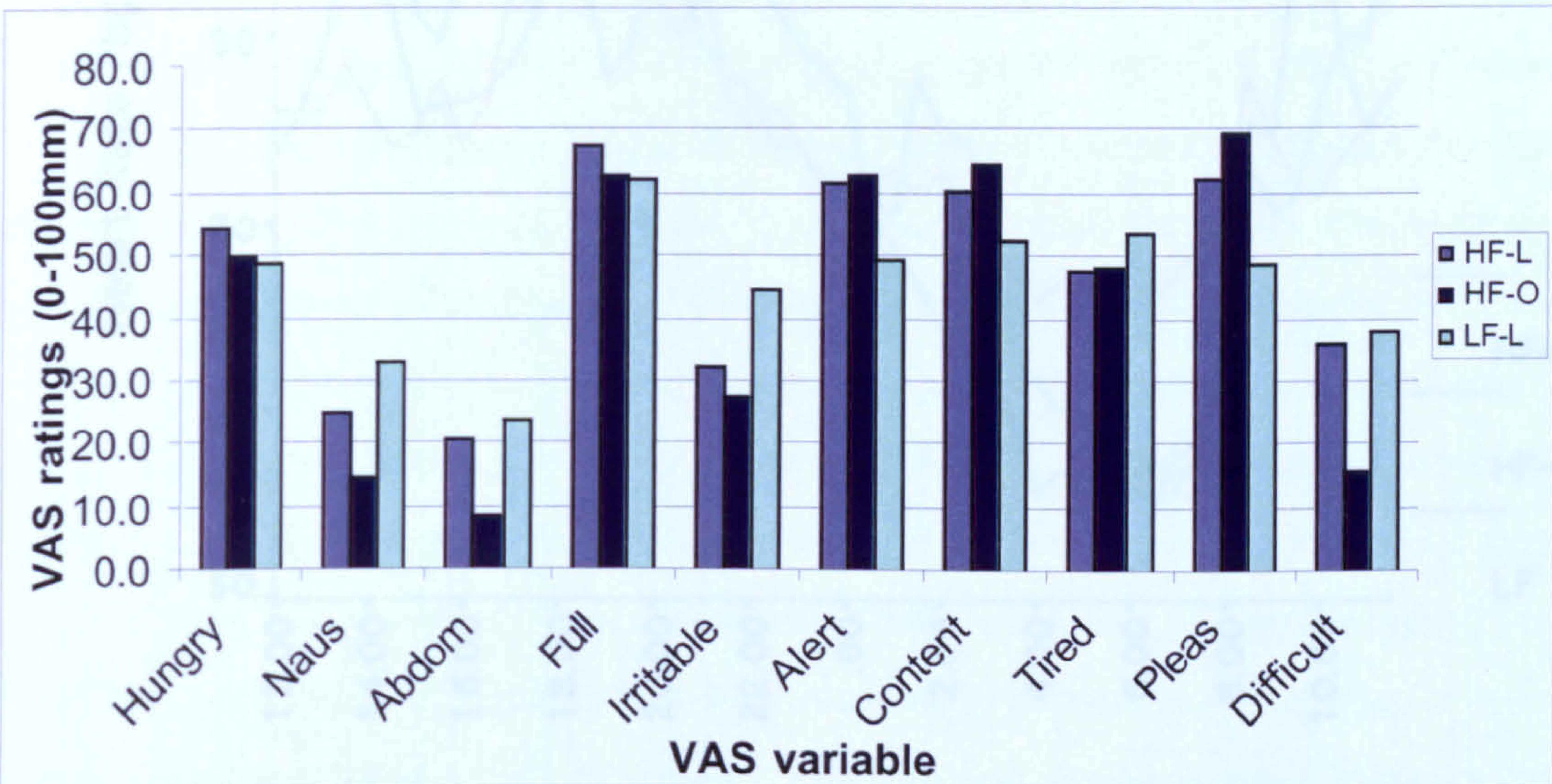

Figure 9.23 End of day questionnaire data measuring subjective feelings across the experimental day (Abbreviations: NAUS= nauseous; ABDOM= abdominal discomfort; PLEAS= pleasantness of study foods).

One-way ANOVA was carried out on the data. A significant main effect for PLEASANTNESS (*How pleasant did you find the study foods?*) was found ($F_{[2,39]}$ =3.673, $p<0.05$). Post hoc tests revealed a significant difference between LF and HF-O volunteers. The overweight group reported finding the study foods to be significantly more pleasant than the LF ($p<0.05$). Also HF-L reported the foods to be more pleasant compared to the LF ($p=0.059$ n/s), suggesting that both HF-L and HF-O found the study foods to be more pleasant. A significant main effect for DIFFICULT (*How difficult did you find it to eat the study food today?*) was found ($F_{[2,39]}$= 4.471, $p<0.05$). The HF-O group reported to find it significantly less difficult to eat the foods compared to both HF-L ($p<0.05$) and compared to LF ($p<0.01$).

9.4.6 Heart rate profiles

Heart rate readings were taken from the time volunteers rose on the test day morning to the same time the following morning. Figure 9.24 shows the mean heart rate profiles for each group. Table 9.5 gives the average 24hr heart rates and mean night time heart rates for each group.

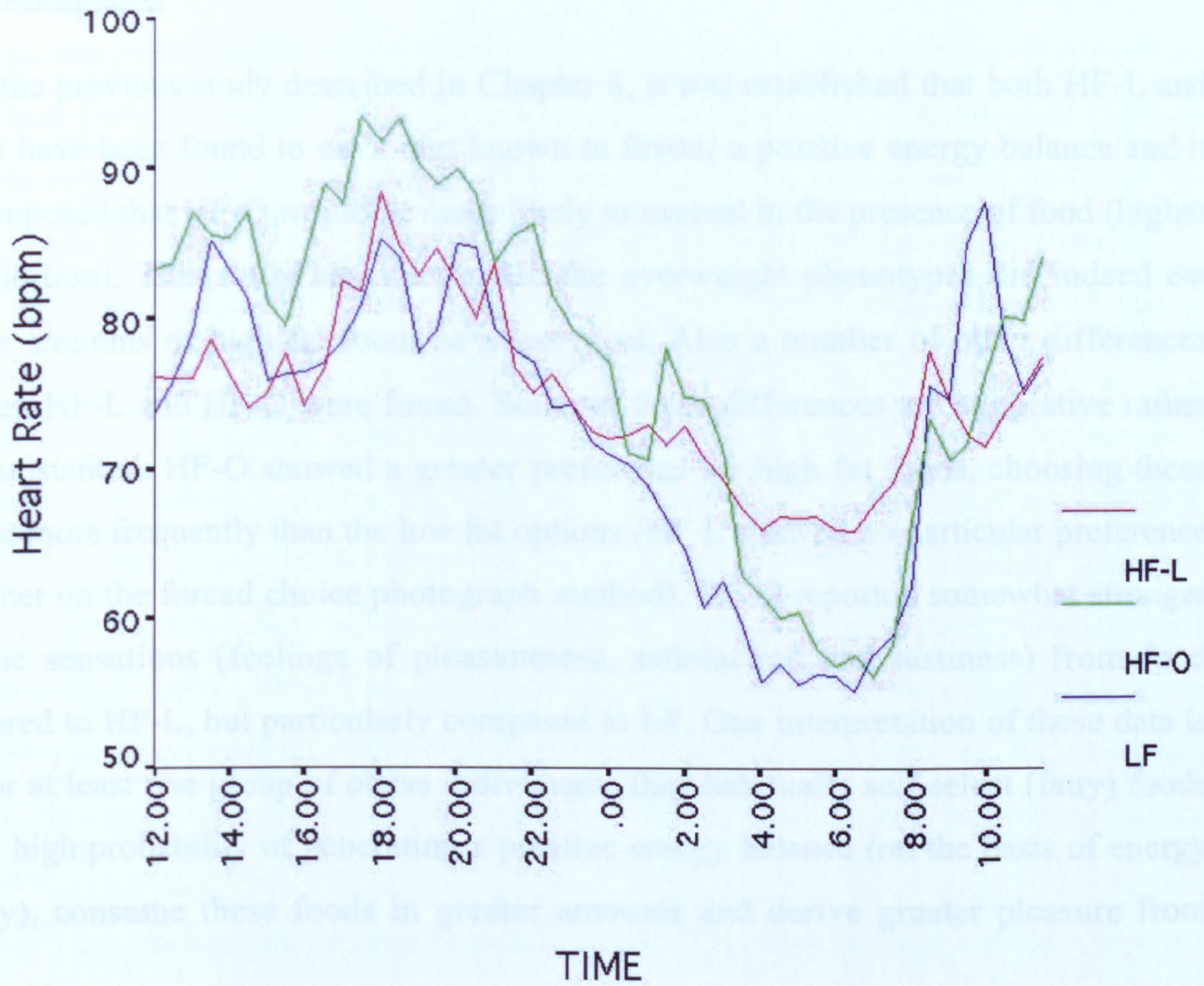

Figure 9.24 Twenty-four hour heart rate profiles (from 12:00 midday).

Repeated measures ANOVA was carried out on the data. A significant main effect was found for TIME: ($F_{[94, 1786]}$=22.169, $p<0.0001$) and TIME by GROUP interaction ($F_{[94, 1786]}$= 2.005, $p<0.0001$). Across the twenty four hour period, no significant main effect for GROUP was found ($F_{[2,38]}$= 1.266, p=0.294).

Table 9.5 Average heart rate: mean (+/- sd)

	HF-L	HF-O	LF
Av. 24hr	74.7 (5.6)	77.4 (11.0)	72.6 (9.8)
Av. 3.30am-8.30am	$68.3^{b, c}$ (8.7)	61.0^{a} (3.5)	59.0^{a} (8.0)

Key: a= significant from HF-L; b= significant from HF-O; c= significant from LF

Night time heart rate readings were isolated from 3.30am to 8.30am (see Table 9.5). Again repeated measures ANOVA was carried out on the data and significant main effect of GROUP was found ($F_{[2,38]}$= 6.316, $p<0.005$). Post hoc tests showed that HF-L had significantly higher heart rate than HF-O ($p<0.05$) and LF ($p<0.005$). LF and HF-O did not significantly differ (p=0.786).

9.5 Discussion

From the previous study described in Chapter 8, it was established that both HF-L and HF- O have been found to eat a diet known to favour a positive energy balance and it was proposed that HF-O would be more likely to overeat in the presence of food (higher disinhibition). This study has shown that the overweight phenotypes did indeed eat greater amounts of high fat foods at a test meal. Also a number of other differences between HF-L and HF-O were found. Some of these differences are suggestive rather than substantial. HF-O showed a greater preference for high fat foods, choosing these options more frequently than the low fat options (HF-L showed no particular preference for either on the forced choice photograph method). HF-O reported somewhat stronger hedonic sensations (feelings of pleasantness, satisfaction and tastiness) from food compared to HF-L, but particularly compared to LF. One interpretation of these data is that for at least one group of obese individuals, they habitually self select (fatty) foods with a high probability of generating a positive energy balance (on the basis of energy density), consume these foods in greater amounts and derive greater pleasure from eating.

From these results it may be concluded that some obese individuals have a disposition to perceive foods as more satisfying than their lean counterparts. This is supported by Mela and Sacchetti (1991) who found a positive relationship between pleasantness of the fat content of food and measures of obesity. More recently it has been found that in monozygotic twins, discordant for body weight, the heavier twin showed a significantly higher preference for fatty foods (Rissanen *et al,* 2002). These studies demonstrate that the levels of body fat are associated with greater ratings of pleasantness of fat containing foods, if it is assumed that the expression of food preference is influenced in part by the pleasure yielded by food. This may indicate a super-sensitivity in the components of the neural circuitry forming the substrate for hedonic properties of foods in obese individuals. If this is the case then, given the capability to obtain higher levels of pleasure from food and eating, it is not surprising that obese people show a tendency to self-select highly palatable foods (i.e. high fatty food). Wang *et al* (2001) found that in obese individuals the D2 receptor, a receptor implicated in the hedonic process, was altered. However as pointed out by Berridge and Robinson (1998) it should be kept in mind that the interpretation of these data is complicated.

This ability to perceive food as more rewarding has implications in terms of the amount consumed during an eating episode. Yeomans (1996) found that an increase in palatability of food caused an increase in subjective hunger during an eating episode, which in turn would lead to an increase in meal size. If this pattern were experienced on a habitual basis it would be sufficient to induce significant weight gain through overconsumption. HF-L may be, in part, protected from this cycle at least for the present time. It is proposed that an enhanced hedonic response should be added to the list of behavioural risk factors associated with obesity, along with patterns of eating, food selection and the drive to eat (Blundell and Cooling, 2000).

Another interesting finding from this study is the results obtained from the twenty-four hour heart rate readings. During the night time phase, when all volunteers were asleep, HF-L had a significantly higher heart rate compared to both the HF-O and LF. Again, it should be pointed out that calibration of heart rate against oxygen/ energy expenditure was not carried out therefore flex may vary between groups. Therefore in this case heart rate may not be an accurate predictor of energy expenditure. However, the heart rate profiles do suggest that the groups may sustain differences in sleep behaviour during the night time.

This study has shown that gaining weight involves food choices plus hedonic response and satiety factors. As previously mentioned an understanding of the key traits of resistance to dietary induced obesity will help in the development of strategies for amplifying these traits in susceptible individuals. This study once again highlights the importance of acknowledging individual differences, which in particular has implications for future intervention programmes for the prevention and treatment of obesity.

9.6 Summary

The main findings from this study can be summarised as follows:

- HF-O ate a greater weight of food in a high fat meal than HF-L.
- HF-O show a greater preference for high fat foods compared to low fat foods and also compared to HF-L who showed no particular preference between these food types.

- In general, HF-O show an increased hedonic response to high fat foods (satisfaction, pleasantness, tasty) compared to HF-L but particularly LF. However, these differences were not particularly strong.

The study described in this chapter has used a complementary design to examine the role of habitual fat intake in body weight control. These findings help in the understanding of the key traits of resistance and susceptibility to dietary induced obesity. It may be concluded that those individuals who are susceptible to weight gain select a high fat diet, eat more of these foods, show a greater preference for high fat foods and derive somewhat greater pleasure (greater reward) from the consumption of these foods. The increased pleasure response is not quantitatively large but may, nevertheless, be meaningful.

Chapter 10

THE ROLE OF ATTITUDES AND VALUES IN THE FOOD CHOICE PROCESS: a qualitative investigation of high fat lean, high fat overweight and low fat phenotypes

10.1 Introduction

Human food choice reflects aspects of society, culture and economics (Rozin, 1998). However, within Western society we are continually faced with an abundance of foods from which to select. Food choice is a complex, dynamic domain. Not only do situational, contextual and temporal factors play a role in the modification of within-individual food choice decisions, but between individual differences can also be recognised. Groups of individuals within our population have been identified who, on a habitual basis select quite contrasting diets. HF and LF phenotypes have been characterised in terms of their habitual macronutrient selection (specifically dietary fat) and eating patterns. However, the question remains, when presented with the same food choices within the same culture and economic climate, why do these individuals make such contrasting choices? A third subgroup has been identified whose members also consume a diet high in fat, however unlike their lean counterparts these individuals have become overweight. What are the mechanisms involved in terms of energy balance? Why do some individuals remain lean whilst others become susceptible to obesity? Genetics may have a role to play here. A prospective study looking at fat intake and subsequent weight gain found that women who exhibited a genetic susceptibility to weight gain showed the greatest tendency to gain weight when exposed to a high fat diet (Lissner and Heitmann, 1995). However, psychological, behavioural and physiological variables are likely to play a key part in either successfully achieving energy balance or inducing a positive energy balance.

The approach favoured previously has emphasised defining and investigating the phenotypes in terms of taste preferences, patterns of eating and physiology, since these can be measured with a reasonable level of accuracy. However attitudes and subjective perceptions should not be overlooked. Individuals identified as specific 'phenotypes' may select particular foods because of their attitudes or beliefs. The use of a qualitative methodological approach may help to provide a different perspective of the food selection process. Conners *et al* (2001) carried out a study (using a diverse population of adults) that examined the ways people managed values in making food choices in various contexts. It was revealed that all participants used a personal food system, which was a dynamic set of processes constructed to enact food choices.

It may be the case that socio-cognitive factors towards certain food types are most important in determining food choice. The Theory of Reasoned Action proposed by Ajzen and Fishbein (1980) states that behaviour is predicted by the conscious decision to perform the action (behavioural intention), which in turn is predicted by a combination of people's attitude towards performing the behaviour, the perceived ease or difficulty of performing the behaviour (perceived behavioural control) and their perception of the social pressure put upon them to perform the behaviour (subjective norm). One way in which to change people's habits (behaviour), therefore, is by changing their attitudes (Ajzen and Fishbein, 1980).

The fat content of the diet is just one of the many choices individuals are faced with on a day-to-day basis. Attitudes towards high fat and low fat foods may play an important role in making these choices. It might therefore be predicted that people with a positive attitude towards the consumption of low fat foods would consume a low fat diet. This study also aims to identify whether this might a contributing factor in the development of the food choice phenotypes.

As food choice often involves a complex set of categories, it is proposed in this present study, that a simplified system for each group might be highlighted to include the top few values; that is those most important in their food choice decisions. This idea of establishing food systems is a means of conceptualising individual food choice. The importance of discovering which values are important to which individuals and how values are managed and food choices made, is crucial in the quest to understand human appetite, food intake and in turn energy balance.

10.2 Objective

The main aim of this study is to investigate the role of attitudes and food values in the food choice process in order to identify the antecedents of food choice and how these factors effect energy balance. Also, the study will explore the potential of a qualitative methodology to increase understanding in this area alongside quantitative procedures.

10.3 Method

10.3.1 Recruitment process & Subjects

Thirty male volunteers, aged between 18 and 30, were selected to take part from the staff-student population at the University of Leeds. Ten lean (BMI <24kg/m^2) high fat phenotypes (HF-L: consuming >120g/d and >43% energy from fat), 10 high fat overweight (HF-O: BMI >27kg/m^2- mean fat intake 130.1 +/-35.7g/d and 42.8+/-3.8% energy from fat) and 10 lean (BMI <24kg/m^2) low fat phenotypes (LF: consuming <70g/d and <33% energy from fat) were selected to take part. The FFQ was used to give a measure of habitual dietary intake. This gave an estimate of habitual energy and macronutrient intake. The results from this questionnaire were then supported by a 3-day self recorded food diary (food energy correlation; r=0.57, df= 28, p<0.01 between FFQ and food diary). For a summary of the subject demographics see Table 10.1.

10.3.2 Experimental Design

The aim of the study was to investigate whether attitudes towards food would predict actual behaviour (and/or intentions) and to investigate the complex food choice system in individuals who habitually chose different diets (HF-L v LF) and to investigate the relationship between food choice and energy balance (HF-L v HF-O). This exploratory study made use of both quantitative (questionnaires) and qualitative (interview) research techniques.

10.3.3 Materials

In addition to the screening questionnaires, the following measures were also used:

- Dutch Eating Behaviour Questionnaire (DEBQ) - to measure restraint, emotional eating and external eating (Van Strien *et al,* 1986).
- Three Factor Eating Questionnaire (TFEQ)- to measure restraint, disinhibition and hunger in response to food (Stunkard and Messick, 1985).
- Nutritional knowledge questionnaire (Tate and Cade, 1990). The first section was used to assess the individual's ability to discriminate between different amounts of fat, protein and carbohydrate in commonly consumed food. The second part was used to assess whether individuals could discriminate between different types of fat (saturated and polyunsaturated). The third and fourth part was used to assess whether individuals could identity from a list of food items those high in CHO (section 3) and those high in fat (section 4). The fifth section was used to assess their understanding of the relationship between fat intake and heart disease (see Appendix xii; see MacDiarmid, 1997 also). A higher score indicates more nutritional knowledge.
- Food preference questionnaire (MacDiarmid, 1997) was used to examine the degree of liking for a range of high and low fat foods regardless of frequency of consumption (see appendix xiii).
- Attitude survey (Armitage and Conner, 1999) was used in order to give a measure of attitudes, intentions, subjective norm, self-identity and ambivalence. This tool was based on the Theory of Planned Behaviour (Ajzen, 1991). These variables were used to investigate which are the best predictors of intention and behaviour to eat a low fat diet. This instrument was included to determine whether or not the habitual consumption of a high or low fat diet was dependent upon (and determined by) the presence of specific attitudes and intentions (see appendix xiv).
- The semi-structured interview was designed to investigate the factors involved in human food choice. The interview began with a detailed description of meal patterns (including number of meal/snacks per day, which meals were consumed, what was habitually eaten during these meals etc.) followed by a discussion of the important factors relating to their food selection, consciousness in food selection and the effects of mood. The interviews were tape recorded for later transcription. The formal structure of the interview, including the questions posed and the mode of recording responses, is set out fully in appendix xv and xvi.

10.3.4 Procedure

Following completion of the initial screening process to confirm group membership, volunteers were asked to come into the HARU. The DEBQ and TFEQ were completed on arrival. Volunteers were then asked to take part in a short interview. This was designed in order to gain a more detailed picture of beliefs and perceptions about their habitual diet and food choices. It was explained prior to the interview that they were not obliged to answer any question they were not comfortable with and permission to tape the interview was confirmed. During the interview each volunteer was asked about their habitual diet, eating habits, attitudes and reasons for food choice. The interview was then followed by completion of the attitude survey, nutritional knowledge and food preference questionnaires.

10.3.5 Data analysis

One way ANOVA were carried out on the data from the questionnaires using SPSS 9.0 for Windows in order to assess main effects for GROUP (HF-L, HF-O, LF-L). Where significant differences were found post-hoc Bonferroni tests were carried out to establish where differences lay. The theory of planned behaviour/ reasoned action variables on the attitudes survey were used to predict eating intentions and behaviour using multiple regression analyses. The interviews were transcribed and thematic analysis was conducted on the data in order to establish the prevalence of themes within the data set. This analysis is an iterative process whereby transcripts are read a number of times, in order to establish a more integrated and higher-order set of themes (see Smith, 1995). The process involves an examination of the data set in terms of form, content, structure, language style and used of words. From this, a common set of categories can be systematically identified across the data. A second experimenter repeated this process in order to ensure inter-rater reliability (for further details see Smith *et al,* 1995; Mason, 1996).

10.4 Results

10.4.1 Subject demographics

Results from the FFQ, DINE and SFQ can be seen in Table 10.1, along with height, weight and BMI variables for the three groups. All subjects met the criteria for inclusion. One way ANOVA revealed significant differences for weight ($F_{[2,29]}$ =9.309, p<0.001) where HF-O weighed significantly more than HF-L (p=0.005) and LF (p=0.005). The same pattern was found for BMI ($F_{[2,29]}$= 28.948, p<0.001). HF-O had higher BMI than HF-L (p<0.0001) and LF (p<0.0001). The same pattern of results was found here as for the previous studies. Significant differences were found for food energy ($F_{[2,29]}$=9.673, p<0.001), fat intake in grams ($F_{[2,29]}$=20.152, p<0.0001), fat intake expressed as a percentage of food energy ($F_{[2,29]}$= 53.172, p<0.0001), CHO expressed as a percentage of food energy ($F_{[2,29]}$= 320.48, p<0.001), protein in grams ($F_{[2,29]}$= 6.587, p<0.01) and DINE ($F_{[2,29]}$= 9.081, p<0.001). Table 10.1 also shows where these significant differences lie between groups as indicated from the post hoc Bonferroni tests.

Table 10.1 Subject demographics (Key: a- significant from HF-L; b- significant from HF-O; c- significant from LF; FE= food energy)

	HF-L	HF-O	LF
Age	19.8 (1.2)	22.0 (2.4)	21.1 (1.8)
Height	1.8 (0.1)	1.8 (0.1)	1.8 (0.1)
Weight	73.3 (13.0)^{b}	91.4 (9.3)$^{a, c}$	73.3 (9.7)^{b} **
BMI	21.9 (2.1)^{b}	29.1 (2.5)$^{a, c}$	22.5 (2.4)^{b} **
Food energy (kcal)	3047.3 (485.0)^{c}	2879.9 (567.0)^{c}	2088.1 (507.4)$^{a, b}$*
Fat (g)	142.3 (27.0)^{c}	130.1 (35.7)^{c}	67.6 (19.7)$^{a, b}$ **
Fat (%)	46.5 (2.9)^{c}	42.8 (3.8)^{c}	31.1 (3.8)$^{a, b}$ **
CHO (g)	291.4 (35.5)	308.7 (52.8)	280.3 (69.8)
CHO (%)	40.1 (4.1)^{c}	42.9 (4.7)^{c}	53.7 (3.4)$^{a, b}$ **
Protein (g)	111.8 (22.3)^{c}	107.0 (22.9)^{c}	80.4 (17.0)$^{a, b}$ *
Protein (%)	16.2 (1.5)	15.8 (2.0)	16.8 (2.7)
DINE	41.9 (6.2)^{c}	37.5 (9.3)^{c}	26.3 (9.4)$^{a, b}$ **
SFQ	30.4 (4.2)	28.1 (5.2)	23.4 (11.3)

(*p<0.01; **p<0.001)

10.4.2 Eating behaviour, preference & nutritional knowledge

Mean scores for the DEBQ and TFEQ are given in Table 10.2. No significant difference was found for restraint (DEBQ: $F_{[2,28]}$= 1.444, p=0.255; TFEQ: $F_{[2, 28]}$=1.210, p=0.314). A significant main effect was found for emotional eating (DEBQ: $F_{[2,28]}$=8.18, p<0.01) and post hoc tests revealed that HF-L did not significantly differ from LF, but the overweight volunteers scored significantly higher than the HF-L (p<0.01) and the LF (p<0.01). Again the same pattern was observed for external eating (DEBQ: $F_{[2,28]}$=5.855, p<0.01) where HF-O scored significantly higher than HF-L (p=0.05) and LF (p<0.01). For ratings of disinhibition, a significant main effect of group was found (TFEQ: $F_{[2,28]}$=6.833, p<0.001). Post hoc test revealed that the HF-O scored significantly higher on this variable compared to both the HF-L (p<0.01) and LF (p<0.05). No significant main effect was found for the TFEQ variable hunger ($F_{[2, 28]}$= 0.273, p=0.763).

Table 10.2- Eating behaviour variables -mean (sd) (Key: a- significant from HF-L; b- significant from HF-O; c- significant from LF)

Measure	Variable	HF-L	HF-O	LF
DEBQ	Restraint	1.91 (0.8)	2.48 (0.68)	1.92 (0.9)
	Emotional Eating	1.79 (0.5)^{b}	2.78 (0.61)^{a,c}	1.92 (0.56)^{b} **
	External Eating	3.15 (0.4)^{b}	3.74 (0.53)^{a,c}	2.96 (0.52)^{b} *
TFEQ	Restraint	3.7 (2.79)	6.89 (5.25)	6.3 (5.87)
	Disinhibition	4.7 (1.77)^{b}	8.44 (1.81)^{a,c}	4.9 (3.38)^{b} **
	Hunger	6.4 (2.68)	7.22 (2.49)	6.5 (2.68)

*p<0.05; **p<0.01

The DEBQ variables were also correlated with BMI and significant positive correlations were found for BMI & restraint (r=0.457, df=28, p<0.05), BMI & emotional eating (r=0.556, df=28, p<0.01) and BMI & external eating (r=0.389, df=28, p<0.05).

Results from the nutritional knowledge questionnaire are given in Table 10.3. Although LF show a higher total score on the nutritional knowledge questionnaire and also score higher on fat type compared to the other group, no significant differences were found between groups (Nutritional identification: ($F_{[2,27]}$=0.217, p=0.807); fat type

($F_{[2,27]}$=0.784, p=0.468); high CHO ($F_{[2,27]}$=0.576, p=0.570); high fat ($F_{[2,27]}$=0.336, p=0.718); heart disease ($F_{[2,27]}$=0.928, p=0.409); total ($F_{[2,27]}$=0.229, p=0.797)).

Table 10.3- Nutritional Knowledge - mean (sd)

	HF-L	**HF-O**	**LF**
Nutritional Identification (Sec 1)	0.67 (2.29)	1.25 (2.92)	0.4 (2.99)
Fat Type (Sec 2)	3.78 (2.68)	3.75 (3.06)	5.2 (2.9)
High CHO (Sec 3)	4.0 (2.4)	3.0 (3.12)	4.3 (2.4)
High fat (Sec 4)	6.11 (1.62)	5.5 (2.07)	6.2 (2.04)
Heart disease (Sec 5)	3.11 (1.05)	3.63 (0.52)	3.2 (0.79)
TOTAL	**17.67 (7.47)**	**17.13 (7.83)**	**19.3 (6.4)**

Results from the food preference questionnaire are given in Table 10.4 below.

Table 10.4: Food Preference data – mean (sd)

PREFERENCE RATING	**HF-L**	**HF-O**	**LF**
High fat foods	81.2 (7.34)	78.8 (6.46)	72.5 (11.82)
Low fat foods	77.4 (7.26)	80.17 (7.11)	78.3 (11.69)

No significant differences were found for preference for high fat foods ($F_{[2,22]}$=2.218, p=0.133) or low fat foods ($F_{[2,22]}$=0.156, p=0.857), although HF-L did report to prefer the high fat foods more, whereas LF reported preferring the LF foods.

10.4.3 Attitudes, intentions and behaviour

Two multiple regression analyses were carried out; firstly to identify possible factors which predict 'intention' to eat healthily and second to identify factors that predict actual healthy eating 'behaviour'. These results are given below.

10.4.3.1 Factors predicting intention toward a low fat diet

TPB was used to predict healthy eating intentions using multiple regression analyses (Table 10.5). From the sample as a whole (not distinguishing between phenotypes), attitude accounted for 65% of the variance in intention, self identity accounted for 11% and subjective norm accounted for 7%. Perceived behavioural control (PBC) contributed a further 0.4% of the variance, however this was not found to make a significant contribution to the model.

So from the group as a whole it can be concluded that as attitude towards eating a healthy diet increases, intention to eat a healthy diet increases. Attitude, self-identity and subjective norm are all predictors of intention to eat a healthy diet but not PBC.

Table 10.5: Hierarchical regression analyses predicting healthy eating intentions: whole sample

PREDICTOR OF INTENTION	R	R^2	INCREMENT TO R^2	F FOR CHANGE	FINAL β
Attitude	0.81	0.65	**0.65**	48.37***	0.461***
Self-identity	0.87	0.76	**0.11**	11.14**	0.341*
Subjective norm	0.91	0.83	**0.07**	10.51**	0.334**
PBC	0.91	0.84	**0.004**	0.55	0.09

*p<0.05, **p<0.01, ***p<0.001

10.4.3.2 Intention toward a low fat diet – the High Fat (lean) phenotype

Table 10.6 shows the regression analysis for the HF-L phenotypes alone. (N.B. the small sample sizes i.e. N=10, in each group should be noted here). Attitudes accounted for 70% of the variance in intention. Self-identity accounted for 12%, subjective norm 5% and PBC 0.1% of the variance but were not found to make a significant contribution to the prediction of intention in HF-L.

Table 10.6: Hierarchical regression analyses predicting healthy eating intentions: HF-L

PREDICTOR OF INTENTION	R	R^2	INCREMENT TO R^2	F FOR CHANGE	FINAL β
Attitude	0.84	0.70	**0.70**	18.79**	0.523*
Self-identity	0.91	0.82	**0.12**	4.82	0.304
Subjective norm	0.937	0.878	**0.05**	2.66	0.307
PBC	0.938	0.879	**0.001**	0.06	-0.061

*p<0.05, **p<0.01, ***p<0.001

10.4.3.3 Intention toward to low fat diet – the Low Fat (lean) phenotype

Table 10.7 shows the regression analysis for the low fat phenotypes alone. Attitudes accounted for 81% of the variance in intention and subjective norm 7%. Self- identity (5%) and PCB (0.7%) were not found to make a significant contribution to the prediction of intention in LF.

Table 10.7: Hierarchical regression analyses predicting healthy eating intentions: LF

PREDICTOR OF INTENTION	R	R^2	INCREMENT TO R^2	F FOR CHANGE	FINAL β
Attitude	0.9	0.81	**0.91**	33.83***	0.46^{n}
Self-identity	0.93	0.86	**0.05**	2.561	0.21
Subjective norm	0.96	0.93	**0.069**	5.76*	0.36^{m}
PCB	0.97	0.94	**0.007**	0.584	0.13

*p<0.05, ***p<0.001, ^{n}=0.06, ^{m}=0.059

10.4.3.4 Intention towards a low fat diet – the High Fat (overweight) phenotype

Table 10.8 shows the regression analysis for the HF-O group alone. From the results it can be seen that 15% of the variance in intention can be accounted for by attitude, 32% for self-identity, 18% for subjective norm and 0.5% for PCB. However, none of the predictors were found to make a significant contribution in the prediction of intention.

Table 10.8: Hierarchical regression analyses predicting healthy eating intentions: HF-O

PREDICTOR OF INTENTION	R	R^2	INCREMENT TO R^2	F FOR CHANGE	FINAL β
Attitude	0.39	0.15	**0.15**	1.08	-0.104
Self-identity	0.69	0.47	**0.32**	3.02	0.72
Subjective norm	0.805	0.649	**0.18**	2.02	0.49
PCB	0.808	0.653	**0.005**	0.04	0.09

One-way ANOVA was carried out using the constructs of TPB as independent variables, in order to assess whether there were any between group differences. No significant differences were found. However it is worth mentioning the result for Subjective Norm ($F_{[2,27]}$=3.055, p=0.065). Post hoc test showed that there was a close to significant difference between LF and HF-O (p=0.074) indicating that HF-O feel greater social pressure to eat a low fat diet.

10.4.3.5 Factors Predicting Healthy Eating 'Behaviour'

TPB was used to predict healthy eating behaviour (eating a low fat diet) using multiple regression analyses (Table 10.9). A mean score for fat intake was calculated from results of the FFQ and 3 day food diary (r= 0.565, df= 26, p<0.01) which was used as the behaviour score.

Table 10.9: Hierarchical regression analyses predicting healthy eating behaviour: whole sample

PREDICTOR OF INTENTION	R	R^2	INCREMENT TO R^2	F FOR CHANGE	FINAL β
Intention	0.23	0.05	**0.053**	1.45	-0.52
Attitude	0.36	0.13	**0.08**	2.13	0.4
Self-identity	0.44	0.2	**0.07**	2.09	-0.01
Subjective norm	0.499	0.25	**0.051**	1.58	0.2
PCB	0.56	0.31	**0.06**	1.89	-0.35

From the sample as a whole, intention accounted for 5.3% of the variance in behaviour, attitude 7.5%, self identity 7%, subjective norm 5.1% and PCB contributed a further 5.9% of the variance, however none of these constructs was found to make a significant contribution to predicting behaviour (to eat a low fat diet).

10.4.3.6 A note on ambivalence

It is has been proposed that the greater an individual's ambivalence (mixed feelings) towards a topic the less likely attitude will predict behaviour (Gardner, 1987). Ambivalence scores were calculated using the 'Griffin' measure of ambivalence (Thompson *et al,* 1995) shown below. The measure involves taking the mean of separate positive and negative evaluations and subtracting from them the absolute difference between these evaluations:

$$\textbf{Ambivalence} = (P + N)/2 - | P - N |$$

The results for the whole group show no significant contribution for ambivalence in predicting behaviour. There was a negative relationship between attitude and ambivalence (att*ambiv: β=-0.112), which suggests that as ambivalence increases the relationship between attitude and intention/behaviour decreases. However, its effect was non-significant.

Table 10.10: Multiple regression of intentions to consume low fat diet: whole group

PREDICTOR OF INTENTION	R	R^2	INCREMENT TO R^2	F FOR CHANGE	FINAL β
Attitude	0.805	0.647	**0.65**	45.9***	0.802***
Ambivalence	0.806	0.649	**0.002**	0.117	0.12
Attitude*ambiv	0.809	0.66	**0.006**	0.377	-0.112

This analysis was broken down for the separate groups and is shown in Tables 10.11, 10.12 and 10.13. It might be worth noting that the influence of ambivalence for the overweight group was close to significance (p=0.08). This pattern not being shown in either of the lean groups. This suggests that an individual needs to be overweight in the first place before ambivalence effects the relationship between attitude and intention. Although all groups had similar levels of mixed feelings/beliefs about eating a low fat diet, this ambivalence only really effected intention towards eating a low fat diet in the overweight group (although n/s). A low ambivalence score results in a closer relationship between attitude and intention (as the relationship is negative).

Table 10.11: Multiple regression of intentions to consume low fat diet: HF-L

PREDICTOR OF INTENTION	R	R^2	INCREMENT TO R^2	F FOR CHANGE	FINAL β
Attitude	0.84	0.70	**0.70**	18.79***	0.962*
Ambivalence	0.84	0.70	**0.00**	0.00	0.05
Attitude*ambiv	0.88	0.78	**0.08**	2.06	**-0.3**

Table 10.12: Multiple regression of intentions to consume low fat diet: LF

PREDICTOR OF INTENTION	R	R^2	INCREMENT TO R^2	F FOR CHANGE	FINAL β
Attitude	0.899	0.809	**0.81**	33.83***	0.86*
Ambivalence	0.90	0.811	**0.002**	0.09	0.148
Attitude*ambiv	0.91	0.82	**0.01**	0.445	**-0.19**

Table 10.13: Multiple regression of intentions to consume low fat diet: HF-O

PREDICTOR OF INTENTION	R	R^2	INCREMENT TO R^2	F FOR CHANGE	FINAL β
Attitude	0.13	0.02	**0.02**	0.09	0.88
Ambivalence	0.34	0.12	**0.10**	0.459	4.87
Attitude*ambiv	0.85	0.72	**0.6**	6.37 (p=0.08)	**-4.22 (p=0.08)**

In summary then, from the previous hierarchical regression analyses both HF-L and LF were found to show a significant contribution of attitude to intention, but HF-O did not. It is possible that the influence of ambivalence is the reason for this result. However, neither attitudes held (about healthy eating) or intention (to eat a healthy diet) contributed in any significant way to the actual habitual diet selected. Therefore, at this stage it could be concluded that habitual diet selection is independent of both currently held attitudes and intentions. However, in order to explore further the possible role of conscious acts in food selection, a different experimental procedure was utilised.

10.4.4 Semi-structured interview (Qualitative Thematic Analysis)

Subjective perceptions associated with the causes and consequences of habitual food choice were examined in habitual high fat lean (HF-L) and overweight (HF-O) phenotypes along with habitual low fat lean (LF) phenotypes using a semi-structured qualitative interview technique. Across groups, a number of factors appear to be important. However the magnitude and influential power of these factors, in terms of food choice and energy balance, were found to differ. In the results section here, a summary of the major outcomes is described.

10.4.4.1 High fat phenotype (HF-lean)

Variety was highlighted as an important issue in the HF-L. Meal to meal variety was viewed as important in terms of enjoyment of food and eating. [NB. The identifiers at the start of each statement indicate the subject number assigned to each volunteer at recruitment.]

MJ/14 'I'd go for something like salami. Which I know is processed but it's a bit different.'

DB/15 'Sandwich and a piece of fruit....It usually varies every day for lunch. Then for evening, a cooked meal. Which changes every day. Generally potatoes or rice. One other vegetable or two.'

A number of individuals expressed boredom with rigid meal patterns and food selection.

NF/12 'I think it's a bit of the same old routines having a sandwich for lunch every day but it keeps you full.'

MJ/14 '...sometimes instead of rice I have pasta if I'm feeling bored with rice.'

The need for variety in the diet might be linked with enjoyment of (or pleasure from) eating. Nine out of ten HF-L stated clearly that they enjoyed eating.

NF/12 'Erm, certainly I enjoy the food. Dinner especially. Lots of spices and herbs.'

AR/8 'I enjoy most foods, but I've never been that bothered about foods to go out of my way to select particular types like low fat.'

MJ/14 'I really like tasty food and that would override...Em....As long as the food filled me then taste would be more important, because I really, really love my food.'

DB/15 'If I'm cooking for myself I do like to enjoy the food. But generally at the halls I don't enjoy the food (laughs). *It's not the greatest. But when I have been cooking, I think it's very important to enjoy it. Because if you don't you just feel 'hummph'* (slumps and pulls face).*'*

Health issues were also expressed as exerting a certain level of importance to some individuals. However an apparent conflict between the values of health and taste/enjoyment was evident.

OM/10 'I wouldn't eat chips everyday. I wouldn't....sometimes we'll buy a KFC bucket or something, but I wouldn't do that everyday even though I might like to!'

A summary of this group could be that the HF-L eats what he wants most of the time, but is conscious that the diet is considered unhealthy, so attempts to control the intake of fat at times. However enjoyment and tastiness of their food seems to be most influential in their selection process and health issues are often overridden in favour of enjoyment.

AR/8 ' Erm...yeah it [health] *is important, but I don't know...I can't really describe it. It's like, I know lots of people who think they do pick particular types of food, because they think that's good. Like really healthy or whatever. But I'm always like...I'm not really that fussed about the food either way. Just whatever's there. I enjoy most foods '*

CB/11 'Just taste is the most important thing. Health isn't a big factor with food.'

It seems therefore that the value of health is less important than taste along with satisfaction from the food. This seems to be one of the main factors influencing the habitual selection of high fat, energy dense food. This idea should also be discussed in terms of the 'desire to gain weight'. Six out of ten HF-L clearly stated that they believed they could eat what they wanted without gaining weight.

MJ/14 'I can eat whatever I want. Even if I eat really fatty foods I don't see a difference.'

Out of these six, most individuals also expressed a desire to gain weight. Their main method for trying to achieve this goal was to purposefully select high fat foods suggesting a conscious awareness in food selection. This is also an interesting point as it suggests that this group can eat what they want but cannot gain weight.

CB/11 'I'm not too particular about my food, because I'm trying to gain weight -.'

A further three HF-L stated they believed they could eat what they wanted without gaining weight as long as they maintained their physical activity levels.

NF/12 'Cos if I didn't play sport I'd be very careful with what I ate. But because you burn it off I don't mind going to the kebab house for example. Getting stuck in to some fat...fatty foods. If I don't go to the gym I'll get fat. I think I'd put on weight if I didn't. If I stopped sport then yeah I would have to change my diet.'

This idea, along with health awareness, may account for why many of the HF-L are able to remain lean. The HF-L enjoys eating, and more specifically enjoys eating high fat foods. Therefore, as these are the factors valued most by the HF-L, he participates in certain behaviours in an attempt to compensate for the habitual diet, such as increasing physical activity and controlling the intake of particularly high fat foods (whether for weight or health reasons). These two factors are both potentially under the conscious control of the individual. However these explanations are not sufficient to account for the reasons for not gaining weight in all HF-L. As previously mentioned six HF-L had stated that they were purposefully trying to gain weight unsuccessfully. Indeed below is a quote from one HF-L, which clearly illustrates this.

AR/8 'I've been static on my weight for the past 3 years and I can eat quite a lot and sometimes I won't eat very much. And my weight will just stay completely the same. So I reckon I can eat what I like // I'm not incredibly active. I don't do much sports. I do a little bit but not enough to explain anything like that. I don't know.'

A number of factors which might be termed 'unconscious' /physiological factors appear to play a key role in achieving energy balance. There is notably little reference to portion size when describing habitual meal patterns compared to the overweight volunteers. (This is supported by the previous study that found that the overweight volunteers ate significantly more compared to the lean HF, and this may indeed contribute to overall energy balance). It appears to be the case that these individuals (HF-L) eat high fat foods but consume smaller amounts compared to their overweight counterparts. Secondly an interesting issue to arise was that of hunger and how the HF-L deal with hunger. Most HF-L participants acknowledged experiencing hunger but did not express this as a particularly negative sensation, '*nothing major, just something to stop my stomach rumbling.*' or '*...but its keep you full. It's quick and it's easy and it fills a hole.*' Compared to the overweight subjects, there was no loss of control, they merely ate in order to prevent or reduce that hunger.

Also there were a number of references to only eating when they needed the energy requirements, that is feeling less hungry when they are less active or compensating the following day if their energy intake had been excessive.

'MJ/14 'So if I'm not going to the gym I don't feel that hungry and I don't feel I've done enough exercise during the day to warrant a big meal.'

OM/10 'I find if I eat something really high in fat then the next day I feel a bit groggy. So I won't feel healthy. It might taste good but.....'

The third factor to be highlighted is the effect of mood and stress. When asked if their mood ever effected what they chose to eat, five out of ten HF-L said that if they were in a dysphoric mood they would be more likely to eat less or stop eating all together,

PM/16 'If I get upset or anything I don't tend to eat I just tend to get sulky! (laughs)*'*

MJ/14 'If I'm feeling a bit depressed I probably couldn't be bothered to cook big amounts of food or put any effort into it. I might eat a little bit less.'

MR/9 'if I'm really stressed or upset than I'd probably stop eating almost.'

Four said that their mood would have no effect and one said they would probably select something 'a bit nicer'.

MD/5 'If I was in a foul mood I'd probably grab something nicer. Maybe a takeaway.'

This apparent behavioural response to a psychological state may also play an important role in overall energy balance.

The influence of family history should also be touched upon here. Many of those who said they could eat what they wanted without gaining weight mentioned some family connection; namely that one of their male relatives had the same experience.

AR/8 'I think my Dad, when he was my age, he was skinny as well and he couldn't put on weight. However, now he's old and fat! (laughs).*'*

CB/11 'Yeah, definitely [eat what I want]. *I think my Dad's the same. It's always been the same way.'*

DB/ 15 'I know I can [eat what I want]. *Because I don't seem to put on weight. I find it difficult. It's the same with my Dad. // and he's still dead skinny now. I don't think I'll ever be obese, maybe I'll put on weight in a few years, but at the same time you don't really know what's going on in there* (points to his chest) *inside you.'*

MJ/14 'I can eat whatever I want. Same with my family. Both my parents are very slim and my brother who's going to be 18 now. Cos I've know him since he was born, I know he eats whatever he wants and he's always had a six pack and you can see that and he doesn't do any exercise. But it's just the way.'

These observations may help to tie genetics and heritibility into the factors effecting both food choice and energy balance.

In summary: the desire for variety and enjoyment of food and eating appears to be the main important factor in food selection for the HF-L. Also the desire to gain weight is influential in certain HF-L. The main factors influencing energy balance, that is, the possible reasons why such individuals can maintain a diet high in fat yet remain lean, are under both voluntary (conscious) and physiological (unconscious) control. HF-L display an element of conflict between eating a diet they truly enjoy and eating healthily, so maintain a level of control over their intake of certain foods. As a compensation mechanism against weight gain, a number of HF-L stated they regularly exercise, simply in order to continue eating their desired diet without suffering the consequences of weight gain. The behavioural factors involved in the achievement of energy balance include a reduction in portion size (particularly in comparison to their overweight counterparts), more control over dietary intake in the presence of hunger and a reduction in food intake in response to mood and stress. These data suggest that HF-L are a heterogeneous group with differing mechanisms helping to maintain energy balance.

10.4.4.2 Low fat phenotype (LF- lean)

As with HF-L variety appears to play a role in getting enjoyment from the food selected but more importantly in relation to health. Some of the responses concerning variety and enjoyment are set out below.

LF/5sf 'I tend to eat things for a long period of time then I get bored of them. So I'll swap onto something else. I just get bored of crisps and go onto yogurts instead. Crisps are very nice day after day for a while and then I get bored of the taste.'

LF/1fj 'The only reason I wouldn't eat something I would usually eat is because I've eaten it a lot and I don't really want to eat it anymore. Just because of the variety. It's the taste. It doesn't taste the same after a while'.

LF/7aw 'Like if I haven't had pasta for a few days I'll have pasta, because I think it's important. And rice and potatoes. I try to eat all the food groups'

LF/4dh 'I'm trying to eat more varied foods now. I'm trying to get more vegetables and things as well cos I didn't tend to get a lot of them before.'

LF seem more influenced by long-term dietary variety (meal to meal; day by day). Enjoyment and tastiness of the food again feature as an influencing factor. Pleasure from food might be regarded as a universal influence in food choice.

LF/4dh 'With me I tend to eat pretty much all foods anyway. I suppose I'm not too much bothered about the taste because I enjoy eating most foods, so it's not a big issue with me. There's only a few things I won't eat.'

LF/1fj 'More often the enjoyment – eating it....tasty. The taste is important too. So if the food isn't tasting very good I'm not eating as much.'

LF/3af 'I like it to be tasty. But I'm usually eating something tasty and if it isn't I'm usually avoiding it.'

However the influence of enjoyment is less pronounced than the HF-L. LF express enjoyment as one of the reasons, but not primarily the main reason. Healthiness of the food is more often cited as a reason for food selection.

LF/7aw 'And I think I do eat quite a good diet, so maybe that contributes to me staying healthy. Because I've looked at what some other people are eating and I think it's a load of rubbish (laughs). *Some people will eat just rubbish after rubbish. To be honest, really, I would notice if I was eating stodgy foods and high saturated foods all the time. Because I would feel...I don't know...sort of funny....sluggish and bloated.'*

LF/5sf 'The majority of the time it's how healthy the food is. And then if something is really tasty then I'd just eat it anyway'

LF/8aw 'Healthiness. A lot of it comes from me playing a lot of sports, so I've always been taught how to eat properly at school. So I've got used to it.'

LF/12ps 'I do try to eat quite healthy. I try to avoid saturated fats. Since about secondary school and we started doing about it in Biology. About the dangers of unhealthy eating. And plus just the thought of eating unhealthy food.... (pulls face).*'*

LF/13jd 'if I was at uni I would have an apple or a banana. Now...I hardly ever eat crisps at all or chocolate bars.'

As with HF-L, a conflict between health and pleasure is evident. However in LF, health seems to override taste more frequently than HF-L with the quotation from one participant clearly illustrating this.

LF/13jd 'Firstly I'd probably look at it because I like the taste of it. And then once I've decided I'd quite like it, I'd probably look at the nutritional information at the back of it. Erm...I'd probably look for the option that is lower in fat. And if there wasn't one I'd probably think again about it.'

It should be pointed out here, however, that healthiness and enjoyment values are not necessarily conflicting in LF, as these individuals express a particular preference for low fat foods anyway as discussed below. When asked if they believed they could eat what they wanted without gaining weight six out of ten stated they could. However it might also be noted here that what they 'want' is probably not strongly weight inducing.

LF/2jc 'I usually get hungry around 10 o'clock. I know you shouldn't eat after a certain time but I don't know.... I can eat as much as I want to eat and I don't ever gain any weight. No matter what I eat I keep my weight no matter what. It's really strange.'

LF/3af 'Yes. I'm positive [I can eat what I want]// *Usually it happens that I cannot gain too much weight.'*

However, eating what they want is quite different to the HF-L. The LF show that what they want is to eat a low fat diet, thereby illustrating that their diet is not forced. They are not dieting or disordered eaters.

LF/4dh 'I always find I'm trying to gain weight a lot of the time anyway. And I seem to find, no matter what I eat, I don't tend to put any on. So I suppose, yeah...I would say that. I think I eat quite a healthy diet anyway. I don't eat a lot of fatty foods. But I find from what I do eat, it doesn't matter how much I actually do eat I don't seem to put the weight on. But of all the foods I chose to eat I think I can eat as much of them as I want without putting on any weight.'

LF/5sf 'You see....I've been trying [to gain weight]. *Well...I feel like I've been making a conscious effort to put on weight over Christmas and erm....I thought I had but I don't think I have. My weight seems to be round about the same. I've tried to eat more and more fatty things* *as well. Then again I haven't really been trying that hard. If I tried again I could start drinking full fat milk and things like that.'*

There might also be a conflict here between the desire to gain weight and the desire to maintain a healthy (low fat) diet. LF find it much more difficult to eat a high fat diet. Also it might be important to highlight here that one of the reasons for selecting a low fat over a high fat diet is a specific dislike of fatty foods. This is even expressed to the point of disgust in one volunteer.

LF/2jc 'Hall [of Residence] *food is disgusting, it's fried greasy stuff. // I do try not to eat chips. If I have a preference I hate greasy food. I always like...I'd rather eat rice or a salad. Or just chicken breast. // My family- we just hate greasy food. Or heavy foods, like cream. I'd much rather choose a tomato sauce than a cream sauce. I'm rarely in that mood to eat a cream sauce. Even, for example toast, I prefer not to put butter on.'*

LF/12ps 'I usually don't eat a lot of fat....I just find it unappetizing.'

So what they enjoy eating is food low in fat (high CHO) which is also considered to be healthy. Factors involved in food choice here are strong health values, enjoyment of food, which can be linked to a preference for low fat foods. The important factors involved in energy balance are their diet low in fat (considered to be less of a risk factor for obesity). They are regular exercisers which is more of a lifestyle factor rather than a compensation mechanism as found in the HF-L. These are the conscious factors (under the voluntary control of the individual). There are also a number of unconscious/physiological factors that appear to be important in influencing food intake and overall meal patterns. Firstly the role of hunger is referred to on a number of occasions, that is the lack of hunger in comparison to HF-L. This could reflect the effect of habitual carbohydrate intake on satiety and appetite control.

LF/3af 'Usually I don't want to eat very much. So...I'm not very hungry'

LF/7aw 'I mean, I don't sort of notice being hungry. It's like.... I'll just want something to eat. I think, 'oh, I've not had anything to eat for 4 hours', so when I get a cup of tea, I'll get something to eat and then I'll go and work.'

LF/8aw 'I tend to eat even if I'm not hungry but I know I should eat.'

Although it should be acknowledged that this might not be a universal factor.

LF/2jc 'If I'm really really hungry then I'll eat anything that comes my way. That's pretty much....that could be the deciding factor. Hunger. I can eat way more...all my friends ask 'how do you keep eating and stay so slim?'.'

However lower hunger might still contribute to the control of food intake in comparison to overweight individuals. Secondly, when asked whether their mood ever effected what they chose to eat one individual reported eating less, one reported eating more when in a dysphoric mood, however seven reported that mood had no influence at all.

LF/4dh 'Usually I don't really notice much of a difference in myself.'

This illustrates that, unlike the HF-L, there may be little influence of their current psychological state on their food choice and eating patterns; consequently food intake may in turn remain relatively constant, perhaps having metabolic advantages in the control of body weight. LF seem less influenced by mood and more disciplined in both their food choices and energy balance. Although there were no differences in nutritional knowledge between LF and the HF groups, these individuals are obviously *using* the knowledge much more. This influence of health related factors is important in understanding the aetiology of this phenotype.

10.4.4.3 High fat overweight phenotype (HF-O)

As with the lean HF variety in food selection is important for deriving enjoyment through eating.

TW/32 'It would be variety. Variety [most important factor when choosing food]*.'*

Enjoyment and more specifically tastiness of food is touched upon on a number of occasions and is expressed independently of health and hunger. The idea of getting positive reinforcement from food consumption is implied, through use of the term satisfaction.

CF/26 'I get enjoyment out of it [tasty food].//...the main reason I choose things is because I like the taste of them. As opposed to....cos sometimes I do think whether it's got less fat in, whether it's better for me.'

PM/22 'Taste. Taste is the priority for me.'

TW/32 '....I think the taste is more important.'

DM/30 'I'd have my pasta and tuna. Then if my friends are hungry, I'll probably go and eat as well - what they're getting. It's really bad. I'm not hungry and I'm just eating cos I like the taste.'

Unlike the other groups (HF-L and LF) who also express getting enjoyment from their food, the overweight volunteers were seen to use much stronger terminology in expressing this enjoyment. On a number of instances words used to describe their relationship with food might be more appropriate for describing an important or even intimate relationship - a love affair with food.

AS/28 'Erm....but I absolutely adore bacon. I eat loads of it.'

DM/30 'You just sit there and you just stuff your face and you just think...'oh, I love those biscuits, I love that, I love food'. I don't smoke, I don't really drink. I love cooking and I think I can cook well.// I love food (laughs). I love....I love chocolate.'

This idea might also be linked to cravings for food. Only the overweight volunteers in the sample mentioned experiencing food cravings and in some cases this was explained as being quite intense *'like a mission'*.

PM/22 'I tend to have cravings for Indian food. Even if I've eaten it yesterday I still will eat it today.'

DM/30 '- sometimes I get these cravings for foods I know I shouldn't eat. Just like I love chicken and chips and all I want is chicken and chips. It's like a mission. And sometimes I get this craving for chocolate- a <u>big</u> craving. It's like I've got to get this piece of chocolate and it has to be specific. It has to be Cadbury's'

Another factor, which appears to be dominant in the overweight individuals' food choice process, is that of mood. Unlike the HF-L who stated that they would reduce or stop eating in response to dysphoric moods (or the LF who expressed no effect of mood on food choice), the overweight clearly expressed that they are more likely to increase their food intake (particularly in terms of fat intake) in response to a negative mood. No volunteers stated that they would reduce their intake, two stated no effect of mood but six stated they would increase food intake.

DG/24 'I tend to like savoury foods more often.[But] *if I was feeling bad cos I got a bad mark in an essay for example occasionally I'll buy some biscuits or something like that. Chocolate biscuits normally!'*

AS/28 'I'll just eat and eat and eat (laughs). *Yeah, if I'm feeling fed up or if I'm tired actually, I like chocolate.'*

AD/27 'It depends on the feeling of the day. Sometimes you have a feeling when you just want something a bit more tasty.// If I'd had a really bad day, I'd probably not want to cook something. I'd want something a bit quicker to make. Something I can just get and eat it straight away. Like pizza or something like that.'

TW/32 'So if I'm in one particular mood, I might actually eat more. But I wouldn't go towards one particular food like chocolate.'

Generally the foods mentioned are high fat foods, such as pizza, chocolate and biscuits. So it might be proposed that mood has a direct effect in fat selection and which (indirectly) effects total food intake through increases in portion size *('I just eat and eat and eat')* and hunger.

The findings relating to mood can also be supported by the findings from the DEBQ and TFEQ administered to all volunteers prior to the interview (see Table 10.2). HF-O scored significantly higher than the other groups on emotional eating, external eating and disinhibition. Hunger too might be proposed as one of the important factors involved in their food selection process. Overweight volunteers tended to describe their experience of hunger as much more intense compared to the lean.

DM/30 'sometimes I get really hungry. I'm dead arrogant when I'm hungry. I just see your mouth moving and I can't hear what you're saying. All I can hear is 'I'm just hungry, I'm so hungry'.'

It might be proposed that hunger has a disinhibiting effect in overweight volunteers as they also expressed a need for immediacy in food selection. Foods chosen must be convenient and quickly prepared.

AW/31 'Like last night I came in from work and I actually ate a full packet of (pauses), *well a full packet of cookies. Erm, just because I, I felt like I wanted to. It wasn't for any particular...I just felt hungry. I was just hungry so I ate them.'*

AS/28 'So basically when I eat at lunch time it's got to be convenient. It's got to be either just bought like that (clicks fingers) *or in the fridge and all you have to do is heat it up what ever.'*

TW/32 'If I'm busy at home and I just haven't had time to prepare things for lunches at work, I end up eating a lot of junk and snacks. Toast is easy to do at work. I could just eat 8 slices of toast just as a meal because I haven't prepared anything the day before. I suppose that does happen quite often.'

Interestingly the overweight volunteers also tended to emphasise a lack of awareness at times when selecting their food. Although there were occasional references made to this in the lean sample, it was much more pronounced in the overweight group.

CF/26 'I don't think it [food diary] *made me change what I was going to eat. It just made me more conscious of what I was eating. If I was eating quite often without really realising it.'*

AD/27 'Yeah. I mean, I'm usually pretty much in a routine anyway. With that [food diary] *though, I had to actually sit down and write it, whereas otherwise I was oblivious to it. So it made me more aware.'*

This might suggest the influence of habit in their food selection process. Coupled with the lower priority of importance of health issues, this might also provide support for an unconscious reward system in operation in overweight individuals.

The overweight group mentioned portion size itself on a number of occasions when explaining their habitual meal patterns. Several volunteers used the word 'big' when referring to the size of the portions selected to eat. This may be a more significant factor, compared to actual 'food choice' per se, involved in energy balance with these volunteers; that is a main factor contributing to their much larger BMI.

CF/26 'I have a <u>big</u> bowl of pasta and sauce [or] *I'll just whack a <u>big</u> curry on or something.'*

AS/28 '-lunch time. And that can be quite <u>large</u>. Lunch is normally my first meal of the day.'

AW/31 'A bowl of cereal with dried fruit or chopped banana something like that. It's a ***large*** *bowl.'*

No overweight volunteers believed they could eat what they wanted without gaining weight, which is what might be expected. However one individual did explain that he believed he could when he was younger, although now had put on a lot of weight.

DM/30 'Cos I was always a skinny kid. I was really thin…16…17 [years old]. *But you think 'oh I'm just fit and skinny then. I can just eat what I want.' I could I just ate loads of things. But I think one of my problems is that I didn't do enough exercise.'*

Although they did not believe they could eat what they wanted without gaining weight, they did suggest they still ate what they wanted. However what these individuals wanted to eat was very different to what the LF wanted to eat for example.

AS/28 'I know exactly what I should eat and then I don't do it. Because I just give in. I haven't got the will power. Erm….but I absolutely adore bacon. I eat loads of it. And yet it's really unhealthy. And sometimes sausages and stuff like that. So what I eat, I know it's unhealthy but I just eat it.'

DM/30 'It's really like,…I just stuff my face. But my friends are really bad, they say 'shall we get a pizza?' and it's like…..I don't really want one because I know how fattening and bad it is. And then they'll be like 'Oh, ok then we'll share' and I'll have 2 slices. Or sometimes we'll have Chinese. I really like Chinese food. I can't say 'No'. I like my chicken wings and it's like 'I've got to get them!' They're really bad.'

There are elements of conflict here. These individuals are aware of what is healthy and contrast this with what they actually want to eat. It appears that in most cases their enjoyment of the food overrides their health concerns. The experience of guilt is implied with the use of phrases such as '*it's really bad*' and '*I know exactly what I should eat and then I don't do it.*' It might be postulated that this guilt might arise from this unresolved conflict between eating what they enjoy and eating what they think they should. A similar conflict is seen in the HF-L however the guilty undertones are absent. This might be due to the fact that the HF-L participate in behaviours which might relieve this conflict and achieve a balance (such as going to the gym). Interestingly few overweight volunteers reported taking any sort of exercise. This should be taken into account when discussing the factors effecting energy balance.

To summarize then, the important factors for food choice in overweight volunteers seem to be enjoyment (even love) of food and eating, along with mood. These factors directly influence fat and overall food intake. A lack of awareness was also expressed suggesting an almost passive role in their own food selection (at times). Other factors contributing to overall energy balance, include increased hunger sensations, which might contribute through increased portion sizes and meal size. These parameters result in a high energy intake with little or no extra energy expenditure through active participation in physical activity. Taking these factors into account suggests the operation of a (food) system that will inevitably lead to weight gain and obesity.

10.5 Discussion

The findings from the attitudes survey showed some interesting results. From the group as a whole it might be concluded that although attitude is a predictor of intention, intention towards eating a healthy diet does not predict whether someone actually will eat a low fat diet. This may mean that although someone intends to eat a diet low in fat, some other variables actually dictate whether or not this occurs. It might also mean that the individual who intends to eat a diet low in fat thinks they are eating a healthy diet but in reality is not achieving this. This could be due to lack of nutritional knowledge or awareness of specifically the fat content of different food types. However no significant difference between groups were found from analysis of the nutritional knowledge questionnaire. These results suggest that some further factor(s) (other than socio-cognitive factors) may be determining habitual food choice.

A common set of food choice values have been highlighted that are important to all participants in this study. In today's Western society we are faced with an abundance of eating situations and a wide variety of foods from which to select. It has previously been established that the most frequent food related values include health (physical well being), taste (sensory perception), convenience (time and effort) and cost (Conners *et al*, 2001). This set of criteria has been applied to a sample of 30 male volunteers (although the importance of cost has been kept to a minimum as many volunteers were students). However the importance of these values not only change over time and situations (within the individual) but also between individuals. It would be naïve to assume that all people possess an identical belief system or set of criteria in the same way and with equal influence. Three phenotypes have been identified (HF-L, HF-O and LF) who share the same values of enjoyment, health, variety and convenience but who clearly regard these values with varying importance.

Variety was seen to be important in all three groups. In a study by Meiselman *et al* (2000) it was found that acceptance and intake of meals declined in the week in which subjects were presented with the same food (monotony week) but did not decline in the variety week. It was proposed that *'within-meal', 'across-meal'* and *'dietary'* variety are all important in contributing to or maintaining food acceptability. Raynor and Epstein (2001) proposed that an increase in variety in the food supply may contribute to the development and maintenance of obesity. Food consumption increases when there is more variety in a meal or diet and greater dietary variety is associated with an increase in body weight and fat. Perhaps the underlying motives relating to the desire for variety should also be taken into account here. Both the HF-L and HF-O participants discuss variety in terms of enjoyment. This can be contrasted with the LF who suggest the quest for dietary variety is closely linked to health and well being, that is the desire to ensure consumption of a balanced diet rather than one eaten for enjoyment. However, this is not to say that enjoyment does not feature as a predominant value in the LF along with the other two groups. Indeed this factor is highlighted as one of the master themes from the discussion of food choice. Rozin (1998) stated that a psychology of food choice, like other aspects of motivation, cannot avoid the powerful role of affect. Consumption (ingestion) of food is found to be rewarding and enjoyable in most individuals (as it should).

In all three groups a conflict between enjoyment and health can be identified. In a qualitative study by Conners *at el* (2001) it was found that values often conflicted in food choice contexts when satisfying one value would prevent meeting another and people were found to struggle to find foods that fit two or more preferred categories. In particular they highlighted that tasty, favourite foods did not fit in the healthy food category. It was concluded that value conflict made it necessary to prioritise values. Value prioritisation for some individuals seemed to involve elimination of one or more values from consideration in many situations. The top few values needed to be considered are used, thus simplifying food choice decisions (Conners *et al*, 2001). In the case of the HF-L and HF-O with the conflict between health and enjoyment, the value of enjoyment is given priority, whereas with LF health is the dominant category. Health concerns everyone and it can be seen from the interviews and the nutritional information questionnaire that all three groups share a similar level of nutritional knowledge. It is the priority of health concern as a category within food choice systems that varies. The idea of enjoyment conflicting with health concerns might be proposed as less of a conflict with the LF. It is clearly stated by a number of individuals within this group that they enjoy high fat much less. It is implied then that the low fat foods selected are their preferred choice for taste preference, enjoyment and health reasons. Whereas the HF-L and HF-O this conflict is more pronounced (even to the point of guilt for the overweight subjects) as their taste preferences contrast health concerns. However each group is believed to select what they like on a habitual basis. Taste preference might be linked to the findings from the previous chapter (Ch. 9) which found that HF-L showed no particular taste preference (liked all food), LF preferred low fat foods, and HF-O preferred high fat foods (see also Le Noury *et al,* 2002).

Awareness is highlighted on a number of levels. The HF-L illustrate a conscious awareness in their food selection through their motivation to gain weight. Many display a specific intention to consume a high fat diet for this reason which suggests they find it difficult to gain weight. LF also show awareness in their food selection in an attempt to satisfy their desire to eat healthily. The HF-O on the other hand demonstrate a lack of awareness at times. They profess to eating without realising; 'being oblivious' for example. This may suggest that their food choice decisions have become so ingrained that they are now 'habit' (no longer under the conscious control of the individual) which might have implications for dietary intervention programs. There may be an underlying reward mechanism that is in place, established through positive reinforcement and could be linked to the findings of the influence of mood. Berridge (1996) argues that wanting and liking can exist without subjective awareness and that conscious experience can distort or blur the underlying reward process.

Therefore the important factors involved in food choice have been highlighted as enjoyment (pleasure from eating), health concern (physical well being), and variety. It can be seen that this simplified set of value systems operate differently within different people. Having considered the factors effecting food choice it seems appropriate to also take into account how these choices in turn effect overall energy balance. HF-L and HF-O are seen to select quite similar foods on a habitual basis, yet the HF-L remain lean whereas the HF-O appear susceptible to weight gain and obesity. What are the important mechanisms involved here? How is energy balance achieved on such a high risk, high fat diet and why is it achieved in some individuals and not in others?

One important factor, which can be seen to influence both food choice and energy balance, is that of mood. (On previous occasions mood has been an identifying factor in food choice- see chapter 8 FCQ data). Both HF-L and HF-O reported being effected by mood in terms of their food choice (compared to LF who revealed no effect). However this effect is quite contrasting. HF-L reported eating less, HF-O reported eating more when in a dysphoric (negative) mood. Overeating when in a negative mood is more pronounced in the overweight group. Cooper and Bowskill (1986) found that a dysphoric mood preceded a food craving. The overweight participants were also the only group to mention cravings in the present study. It might be implied that the overweight individuals are eating in an attempt to increase their mood; that is making themselves feel better (self reward) by doing something they enjoy. Cools *et al* (1992) concluded that emotional arousal (regardless of valence; positive or negative) may trigger overeating among restrained eaters. Polivy *et al* (1994) proposed that the pattern of overeating in response to an anxiety producing threat to self esteem in restrained eaters, may temporarily counteract (mask) dysphoria. HF-O volunteers in this study were more restrained than the lean, however the three groups did not differ significantly on levels of dietary restraint.

The effect of mood is believed to be a factor involved in food choice as well as energy balance. The serotonin hypothesis has been used to explain eating in response to mood. An increase in carbohydrate consumption is believed to increase serotonin release, acting via insulin secretion and the 'plasma tryptophan to LNAA' ratio. It has been proposed that many people learn to eat carbohydrate to make themselves feel better and have a tendency to use certain foods as drugs (see Wurtman, 1993; Wurtman and Wurtman, 1995). In this study it appears that as mood decreases, the consumption of high fat (sweet and savoury) food increases in HF-O. Oliver *et al* (2000) found that stressed emotional eaters ate more sweet high fat foods and more energy dense meals than unstressed and unemotional eaters; and that dietary restraint did not significantly effect appetitive responses to stress. These stress-related changes in food choice may, therefore, have a negative effect on the health of the individual. This can be seen to influence factors relating to energy balance in HF-O, which has implications for weight gain and the health threats which come with the development of obesity. The foods selected are high fat, energy dense and portion sizes are also increased. These are both important factors involved in inducing a positive energy balance and promoting weight gain. This is a process that does not appear to occur so frequently in the HF-L.

The conflict between health and enjoyment from food is evident in the HF-O (and too in the HF-L). Enjoyment as a category in the food choice system is given priority over health in these groups. Conners *et al* (2001) identified that in an attempt to overcome these conflicts in values individuals applied balancing strategies. As an example, they suggest that some of their participants ate one way on weekdays and relaxed their rules at weekends in an attempt to balance health values and taste preferences across the week. This idea can be seen in some of the HF-L who state a liking for one food but at times control, to a certain extent, the intake of the foods particularly high in fat. A more conscious compensation mechanism at play is the active participation in exercise to counteract the possible consequences of eating a high fat/ energy dense diet (weight gain). They specifically cite exercising – a physical activity (behaviour)- which might fulfil their health values, whilst not compromising their taste preference (enjoyment) through eating behaviour. A balance is achieved. In the study by Conner *et al* people expressed feeling a reduction of guilt about value conflicts in food choices and seemed to feel better with the use of these balancing strategies. Perhaps it is the case that these conflicts are not resolved or balanced in the overweight group and this might account for the guilt experienced in their food choices. It might be postulated that this in turn could lead to a reduction in mood and have a knock on (cyclic) effect. A negative mood increases food intake (in particular fat). An increase in fat intake (minus exercise or compensation) increases conflict, which in turn promotes a negative mood (see Figure 10.1). What can then be seen is the development of a pernicious cycle between internal conflict, mood and food/fat intake, which becomes self-maintaining. The consequence of which are weight gain.

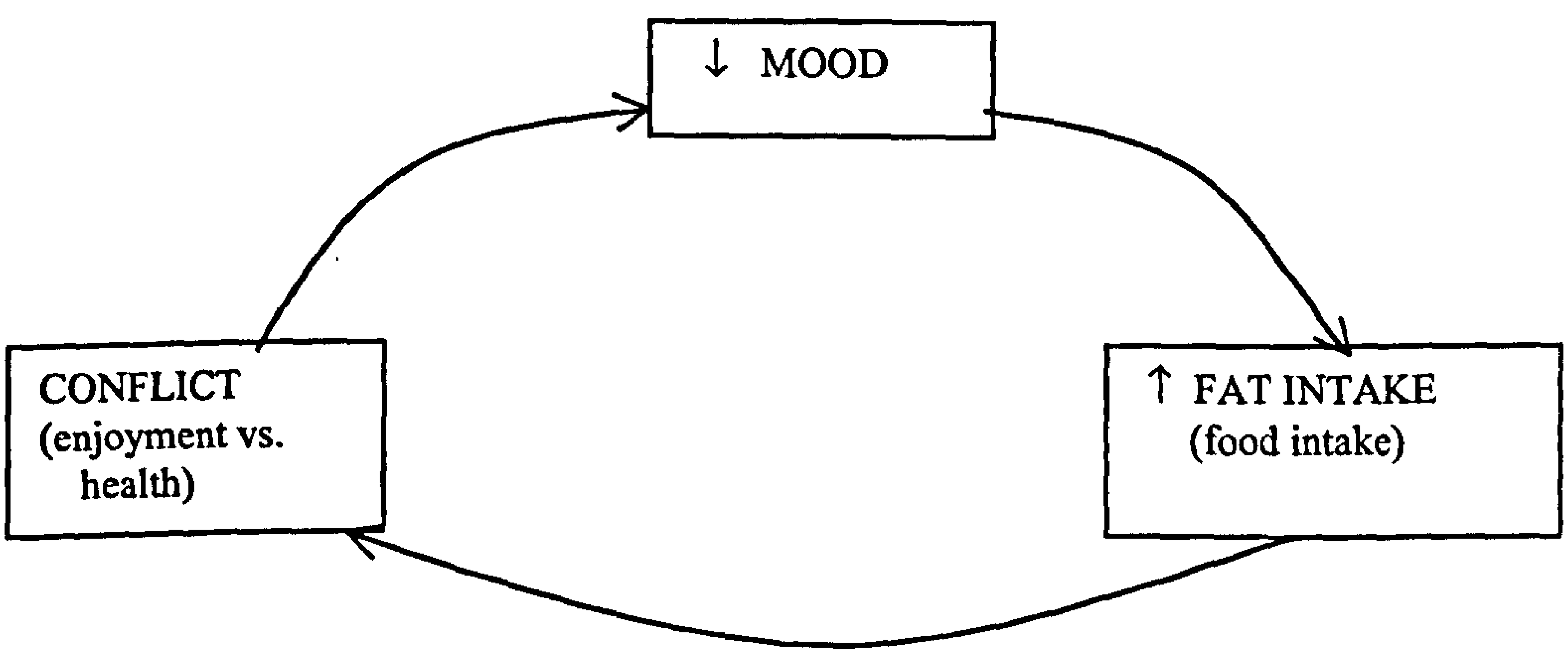

Figure 10.1 Proposed self-maintaining cycle influencing food choice in HF-O

LF on the other hand show a contrasting system. Health is the most important factor in food choice. They are believed to exercise for health reasons rather than as a compensation strategy. Conflicts with the desire to gain weight and enjoyment are seen, however this is often overridden by health concerns, and healthy food choices are enjoyed anyway. Their overall eating pattern and food intake is relatively stable and not effected by mood. These factors might help to maintain a normal body weight as well as having metabolic advantages.

8.6 Summary

Attitudes and intentions are poor predictors of eating behaviour. However a common set of food choice values has been identified across all three phenotype groups. All groups used the factors health, enjoyment, variety and convenience when describing their food selection. However, it is proposed that these values are prioritised in different ways between the groups.

- LF-L prioritise health over enjoyment, whereas HF-L and HF-O prioritise enjoyment.

- HF-L reported exercising more frequently than HF-O in order to avoid having to compromise their taste preferences.

- HF-O experience guilt due to lack of compensating behaviours (such as partaking in regular physical activity), possibly leading to a self-medicated increase in food intake.

- HF-O reported eating more in response to a dysphoric mood. This was supported by the results from the DEBQ. HF-L reported eating less in response to dysphoria. LF reported no change in food intake in response to mood.

- All three groups had a similar level of nutritional knowledge, however LF appear to be <u>using</u> this knowledge more than the HF groups.

- HF-O show more mixed feelings (ambivalence) toward their diet compared to HF-L and LF (although n/s).

The use of qualitative interviews has resulted in gaining a different perspective on the food choice process. This methodology is useful particularly when used in support of quantitative data.

Chapter 11

HEDONIC RESPONSE & PREFERENCES IN HF and LF PHENOTYPES

11.1 Introduction

One of the important questions posed in this thesis is whether the habitually consumed diet (reflecting the operation of food choices) arises from a physiological drive for specific foods (mediated via sensory preferences) or a response to the impact of environmental forces. Although environmental influences should not be entirely overlooked, the results from the previous chapters suggest an influence of sensory hedonic response on habitual food choice. Behavioural characteristics, such as a high food induced pleasure response and strong oro-sensory preferences, coupled with a preference for fatty foods and a binge potential (high disinhibition) constitute potent risk factors for weight gain and in turn obesity. Chapter 9 showed that the HF-O display a greater preference for high fat foods compared to low fat foods and a higher preference for these foods even compared to HF-L. HF-O reported a modestly increased hedonic response to food in terms of satisfaction, pleasantness and tastiness following consumption of a high fat meal. It was also found that HF-O consumed more food (in weight) compared to the lean phenotypes (HF-L and LF). It has been proposed that these may be important factors involved in the achievement of energy balance and overall body weight in these individuals. When these phenotypes were asked directly (in the qualitative interview situation) both HF-L and HF-O reported a greater importance of receiving enjoyment from food when describing their food choices. This can be contrasted with the response of the LF who reported prioritised health concern over taste and enjoyment.

From these results a number of interim conclusions have been made. Although people display similar potential weight inducing habitual dietary patterns (e.g. consumption of high fat foods), some people gain weight because they show stronger preferences for these foods in choice situations, eat greater amounts of these foods, receive greater reward from consumption (feelings of pleasantness, satisfaction and taste), and state that enjoyment is a major factor in their eating. These last two issues suggest that the hedonic dimension could be important in overconsumption.

This present study aims to investigate the issue of hedonic response to food in more detail. The previous chapter (Ch. 9) found that hedonic sensations which accompanied (and/or followed) eating may have particular importance in the establishment of overall energy balance. This study will look at the potential influence of sensory and hedonic events in guiding (eating) behaviour- an equally important aspect relating to food choice and energy balance. It may be hypothesised that there is evidence for a biological reward mechanism involved in the aetiology of obesity. An enhanced anticipatory hedonic response to food (particularly fatty foods) may be found to be more pronounced in HF phenotypes, particularly the overweight. This coupled with a heightened response to food *actually* consumed may be a potent contributor to overall energy intake and body weight. It may also be proposed that LF have a dampened reward mechanism and therefore find it easier to override desire for pleasure and satisfaction in favour of health concerns.

11.2 Objective

This study aims to provide further quantitative data to support the hypothesis of a enhanced reward mechanism in HF (particularly in overweight) as one of the risk factors for becoming obese. The study also aims to investigate differences in taste evaluation between groups (do these groups respond differently to high and low fat, sweet and savoury foods?), and to provide further support for overconsumption in HF-O (via increased portion or meal size) compared to the lean.

11.3 Method

11.3.1 Recruitment process & Subjects

Volunteers were recruited via poster advertisements on university notice boards, distribution of flyers and advertisements in the student paper. All volunteers were members of the staff-student population at the University of Leeds. Each volunteer was given the initial screening questionnaire pack consisting of the recruitment information sheet (including demographic details), food frequency questionnaire (FFQ), DINE and the short fat questionnaire (SFQ) (see chapter 4). From the initial screening process, 16 HF-L (high fat- lean), 16 LF and 16 HF-O (high fat- overweight) males were selected to take part. The HF-L were defined as consuming >120g/d of fat and >43% energy from fat and have a BMI of between 20-25 kg/m^2. The LF were defined as eating <70g/d and <33% energy from fat and a BMI of between 20-25 kg/m^2. HF-O were defined as consuming approximately 120g/d of fat and >43% energy from fat and a BMI of >27 kg/m^2, therefore making this group the highest fat consumers of the overweight/obese cohort. All volunteers were aged between 18 and 30 years and self reported non-smokers. Each subject was required to read and sign a participant information sheet and consent form as required by the School Psychology, University of Leeds Ethical Committee, following ethical approval of this study.

11.3.2 Experimental Design

The study took a 3 x 4 repeated measures design *(IV-1: 3 levels- HF-L, HF-OW and LF-L & IV-2: 4 levels- Hfsav, HFswt, LFsav, LFswt foods)*. A Latin square was used as a method of counterbalancing the order that the photos were presented to the volunteers in an attempt to eliminate any order effects.

11.3.3 Materials

11.3.3.1 Hedonic/taste questionnaire

The hedonic questionnaire involved presenting volunteers with a photo album containing photographs of 20 different food types: 5 high fat/savoury foods; 5 high fat/sweet foods; 5 low fat/savoury foods and 5 low fat/sweet foods (see Table 11.1). Volunteers were asked to answer 11 VAS questions for each food item. Questions were designed to address three variables – 'taste hedonics' (4 items), 'taste evaluation' (5 items) and 'prospective eating' (2 items) (see Table 11.2 for a summary of items included within each variable).

Table 11.1 Summary of foods presented in the hedonic questionnaire

Food Types			
High Fat		**Low Fat**	
Savoury	**Sweet**	**Savoury**	**Sweet**
Cheddar cheese	Ring Doughnut	White bread rolls	Jelly
French fries	Vanilla slice	Ham slices	Marshmallows
Pork pie	Shortbread	Spaghetti in tom sauce	Jelly babies
Cheese filled crackers	Blueberry muffin	Chicken breast	Rich tea biscuits
Pork sausages	Cream doughnut	Boiled new potatoes	Mixed fruit cocktail

Table 11.2 Summary of items within each variable in the hedonic questionnaire (e.g. 'how '*tasty*' do you find this food).

	Variable		
	Taste hedonics	**Taste evaluation**	**Prospective eating**
Items	*Tasty* *Pleasant* *Satisfying* *Liking*	*Fatty* *Starchy* *Sweet* *Salty* *Filling*	*Could* *Want*

11.3.4 Procedure

Following initial recruitment, volunteers who met the criteria for inclusion were asked to come into HARU having not eaten in the last 2 hours (in order to prevent the state effects of hunger and fullness). They were then asked to complete the hedonics/taste questionnaire. This was a series of 20 photographs of different foods- 5 high fat savoury, 5 high fat sweet, 5 low fat savoury and 5 low fat sweet. Volunteers were asked 11 VAS questions for each food item administered using the EARS/PSION. These VAS were used to give a measure of how accurately the volunteers could identify taste (sweet and salty) and nutrient (fatty, healthy). (N.B. The variable 'healthy' was a composite score calculated from the variables 'filling' and 'starchy'). Also a measure of the hedonic response relating to that food type (pleasant, satisfying, tasty and liking), and prospective measure of how much they could eat and how much they would want to eat were taken. These items were used to calculate a composite score for each dimension in order to identify any significant differences in responses.

11.3.5 Data Analysis

Screening data were analysed using one-way ANOVAs to assess any significant differences in anthropometry and habitual dietary consumption.

Hedonic questionnaire data were analysed by measuring each of the three dimensions of the questionnaire individually- 'taste hedonics', 'taste evaluation' (in terms of high fat and low fat foods and also savoury and sweet foods) and 'prospective eating'. Mean scored were calculated for each food type (i.e. HFsav/HFswt/Lfsav/LFswt) and eight 2 by 3 mixed ANOVAs were carried out on the data (see Table 11.3 for summary). In all statistical tests performed p-values < 0.05 were considered significant and the data are presented as means +/- SDs. Bonferroni post-hoc tests were applied where a significant main effect was found.

Table 11.3 Summary of 2 x 3 repeated measures ANOVAs carried out on the data.

ANOVA	To measure:	IVs	DV
1	Differences in hedonic response to high fat and low fat foods	1)FOOD TYPE (high fat v low fat) 2)GROUP (HF-L, HF-O, LF)	VAS ratings of hedonic response to high fat and low fat foods
2	Differences in hedonic response to savoury and sweet foods	1) FOOD TASTE (savoury v sweet) 2) GROUP (HF-L, HF-O, LF)	VAS ratings of hedonic response to savoury and sweet foods
3	Differences in ability to identify high fat foods.	1)FOOD TYPE (high fat v low fat) 2)GROUP (HF-L, HF-O, LF)	Subjective ratings of 'FATTINESS' of food
4	Differences in ability to identify low fat foods.	1)FOOD TYPE (high fat v low fat) 2)GROUP (HF-L, HF-O, LF)	Subjective assessment of how 'HEALTHY' the food was.
5	Differences in ability to identify savoury and sweet foods.	1) FOOD TASTE (savoury v sweet) 2) GROUP (HF-L, HF-O, LF)	Subjective ratings of 'SAVOURINESS' of food
6	Differences in ability to identify savoury and sweet foods	1) FOOD TASTE (savoury v sweet) 2) GROUP (HF-L, HF-O, LF)	Subjective ratings of 'SWEETNESS' of food
7	Differences in amount of high fat and low fat foods groups potentially COULD consume	1)FOOD TYPE (high fat v low fat) 2)GROUP (HF-L, HF-O, LF)	Prospective ratings of how much COULD be eaten
8	Differences in the amount of high fat and low fat foods groups potentially would WANT to consume	1)FOOD TYPE (high fat v low fat) 2)GROUP (HF-L, HF-O, LF)	Prospective ratings of how much would WANT to eat.

11.4 Results

11.4.1 Subject demographics

From the analysis of the screening data a number of significant differences were found (see Table 11.4). No significant differences were found for age. A significant main effect of weight ($F_{[2,47]}$=27.48, p<0.0001) and BMI ($F_{[2,47]}$= 75.903, p<0.0001) was found, with the overweight group weighing significantly more than both lean groups (p<0.0001 in both cases). A significant main effect of group on energy intake was found ($F_{[2,47]}$=19.503, p<0.0001). HF-L reported consuming significantly more energy per day compared to LF (p<0.0001). HF-O also reported to consume more energy compared to LF (p<0.001). A significant main effect was found for fat intake in grams ($F_{[2,47]}$=53.15, p<0.0001). As expected, by definition, LF reported consuming significantly less fat (g) compared to HF-L (p<0.0001) and HF-O (p<0.0001). According to the FFQ, when expressed as percent energy from fat ($F_{[2,47]}$=125.74, p<0.0001) HF-L reported consuming significantly more fat than LF (p<0.0001) and HF-O reported to consume more fat % than LF (p<0.0001). This finding was reinforced by the data from the DINE ($F_{[2,47]}$= 35.652, p<0.0001) whereby no significant difference in fat intake was reported between HF-L or HF-O. LF reported to consume significantly less fat than HF-L (p<0.0001) and HF-O (p<0.0001). The same pattern was observed from the SFQ data ($F_{[2,47]}$= 30.87, p<0.0001). HF-L reported a higher fat intake compared to LF (p<0.0001) and HF-O also reported a higher fat intake compared to LF (p<0.0001). All groups reported to consume a similar amount of carbohydrate (in grams). However when expressed as percent energy from CHO a significant effect was found ($F_{[4,47]}$=61.04, p<0.0001). LF consumed more CHO% compared to both HF-L (p<0.001) and HF-O (p<0.001). A significant main effect of group was found for protein intake in grams ($F_{[2,47]}$= 14.15, p<0.0001). LF reported consuming significantly less protein compared to HF-L (p<0.0001) and HF-O (p<0.001). When expressed as a percentage of total energy intake (PRO %) no significant differences were found between groups.

Table 11.4 Screening data collected from the FFQ, DINE, SFQ and BMI [mean (+/- SD)] (Key: a- significant from HF-L; b- significant from HF-O; c- significant from LF; FE= food energy)

	HF-L	HF-O	LF
AGE	20.7 (2.2)	21.7 (2.2)	22.4 (3.9)
HEIGHT (m)	1.81 (0.08)	1.76 (0.05)	1.78 (0.05)
WEIGHT (kg)	69.8 (11.5)^{b}	91.9 (8.0)^{a,c}	72.0 (8.1)^{b} *
BMI (kg/m^2)	21.3 (2.01)^{b}	29.6 (2.21)^{a,c}	22.7 (1.89)^{b} *
ENERGY INTAKE (kcal)	3054.6 (477.1)^{c}	2710.1 (507.3)^{c}	2056.5 (384.2)^{a,b} *
FAT (%FE)	46.2 (2.6)^{c}	43.0 (3.9)^{c}	28.4 (3.6)^{a,b} *
FAT (g)	141.3 (26.7)^{c}	124.5 (29.2)^{c}	59.2 (11.9)^{a,b} *
CHO (%FE)	40.7 (4.6)^{c}	42.1 (5.2)^{c}	57.6 (4.6)^{a,b} *
CHO (g)	296.4 (43.4)	291.4 (55.5)	289.5 (55.3)
PRO %	16.0 (1.5)	15.8 (1.9)	16.1 (2.2)
PRO (g)	110.4 (22.9)^{c}	102.2 (19.9)^{c}	75.2 (15.0)^{a,b} *
SUGAR (g)	121.4 (22.8)	113.3 (38.4)	124.1 (28.8)
STARCH (g)	173.4 (29.5)	176.1 (34.9)	164.6 (39.5)
DINE	43.4 (9.7)^{c}	37.2 (7.6)^{c}	20.8 (5.8)^{a,b} *
SFQ	32.6 (4.7)^{c}	28.5 (4.5)^{c}	17.3 (7.4)^{a,b} *

*p <0.0001

11.4.2 Hedonic response

Average hedonic responses were calculated from ratings of tastiness , pleasantness , satisfying and liking ratings for each food type (high fat and low fat foods/ savoury and sweet foods). Figure 11.1 shows the average hedonic ratings across all food types. Overall hedonic response (not taking account of food type) showed that the mean response to all foods was lower in LF (HF-L: 57.0+/-8.01; HF-O: 58.9+/-6.41; LF: 50.0+/-10.53).

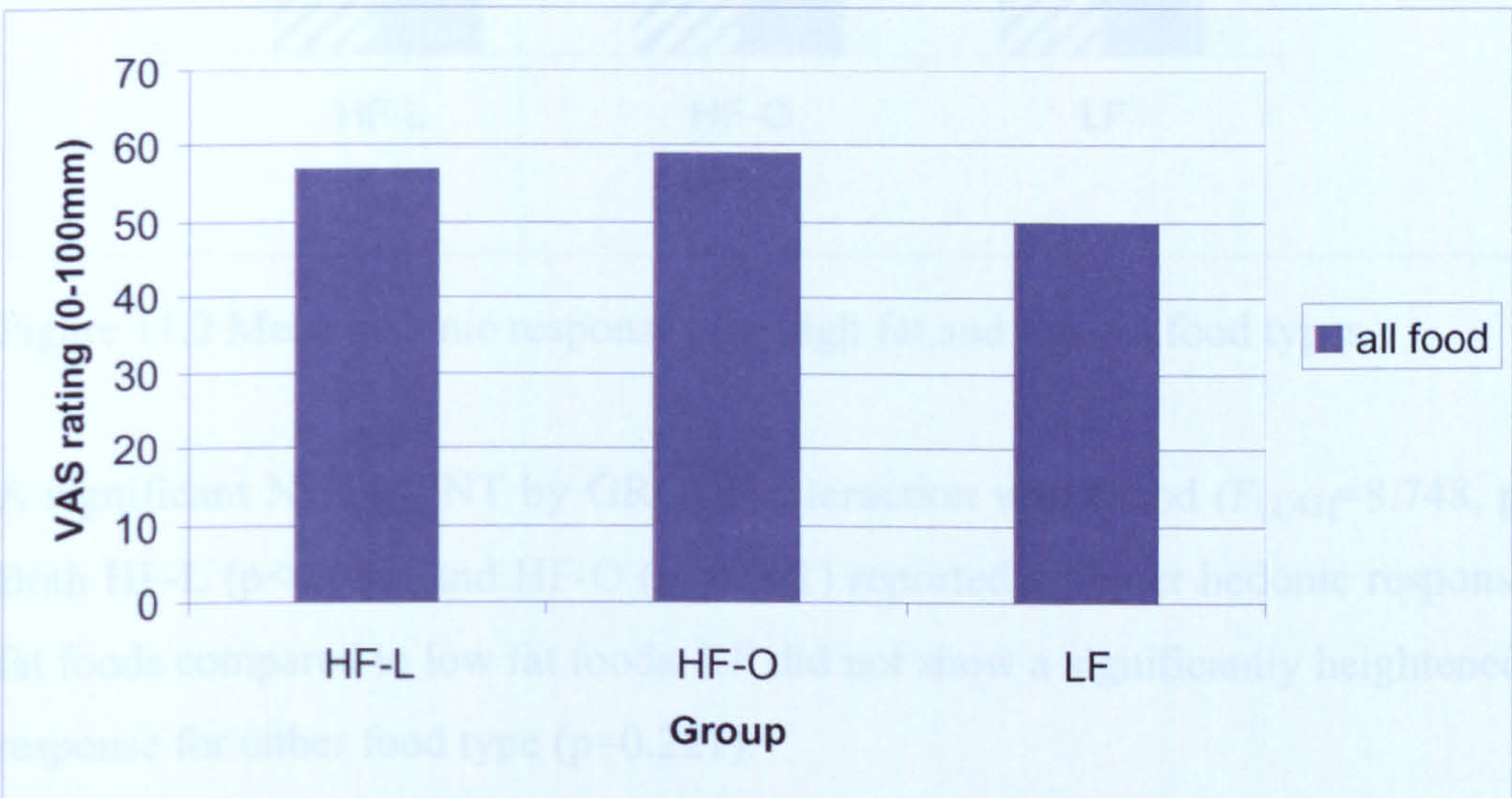

Figure 11.1 Average hedonic responses across all food types for each group

11.4.2.1 Hedonic response to high fat and low fat foods

Figure 11.2 shows the mean hedonic response given in response to high fat and low fat foods by each phenotype. HF-L and HF-O can be seen to give higher hedonic responses for high fat foods. LF gave a slightly higher response for low fat foods.

Results from the 2 by 3 repeated measure ANOVA revealed a significant main effect for NUTRIENT ($F_{[1,45]}$=9.672, $p<0.01$). Regardless of any group effect, high fat foods (mean: 59.19+/- 14.45) were rated higher than low fat foods (mean: 51.34 +/- 12.73). Also a significant main effect of GROUP was found ($F_{[2, 45]}$= 4.876, $p<0.05$) (see above). Post-hoc Bonferroni tests showed that regardless of the type of food, hedonic responses given by LF were significantly lower than HF-O ($p<0.05$) and lower than HF-L although not significant ($p=0.074$). No significant difference was found between HF-L and HF-O ($p=0.99$).

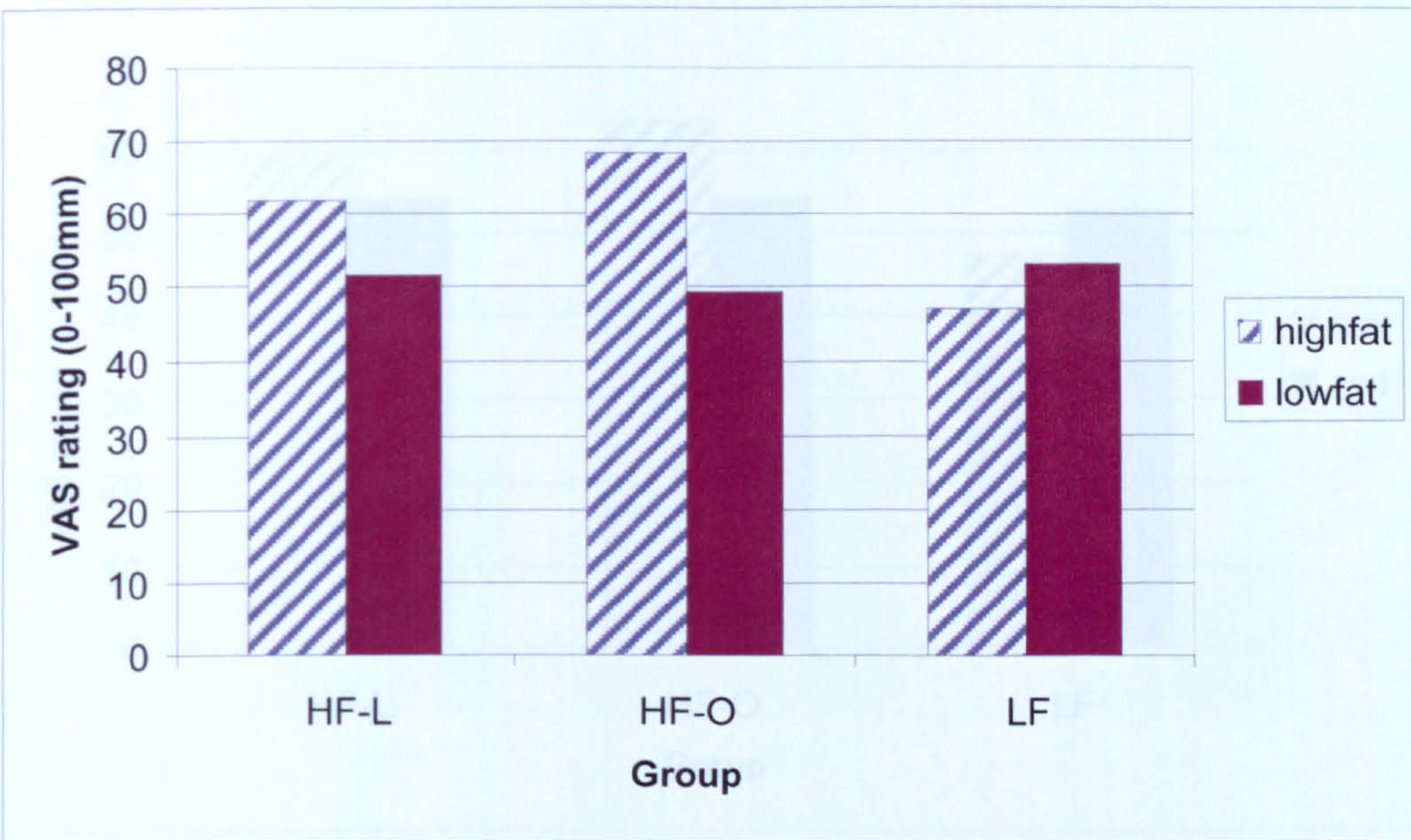

Figure 11.2 Mean hedonic responses for high fat and low fat food types

A significant NUTRIENT by GROUP interaction was found ($F_{[2,45]}$=8.748, p<0.001). Both HF-L (p<0.001) and HF-O (p<0.001) reported a higher hedonic response to high fat foods compared to low fat foods. LF did not show a significantly heightened hedonic response for either food type (p=0.221).

11.4.2.2 Hedonic response to savoury and sweet foods

Figure 11.3 gives a breakdown of the mean hedonic responses given for savoury and sweet foods by each phenotype. HF-L and HF-O gave slightly higher hedonic responses for savoury foods. LF gave slightly higher responses for sweet foods.
Results from the 2 by 3 repeated measure ANOVA revealed no main effect for TASTE ($F_{[1,45]}$= 1.83, p=0.183). However a significant main effect of GROUP was found ($F_{[2, 45]}$= 4.876, p<0.05). Post hoc Bonferroni tests showed that regardless of the taste of the food (savoury or sweet), hedonic responses given by LF were significantly lower than HF-O (p<0.05) and lower than HF-L although not significant (p=0.074). No significant difference was found between HF-L and HF-O (p=0.99).

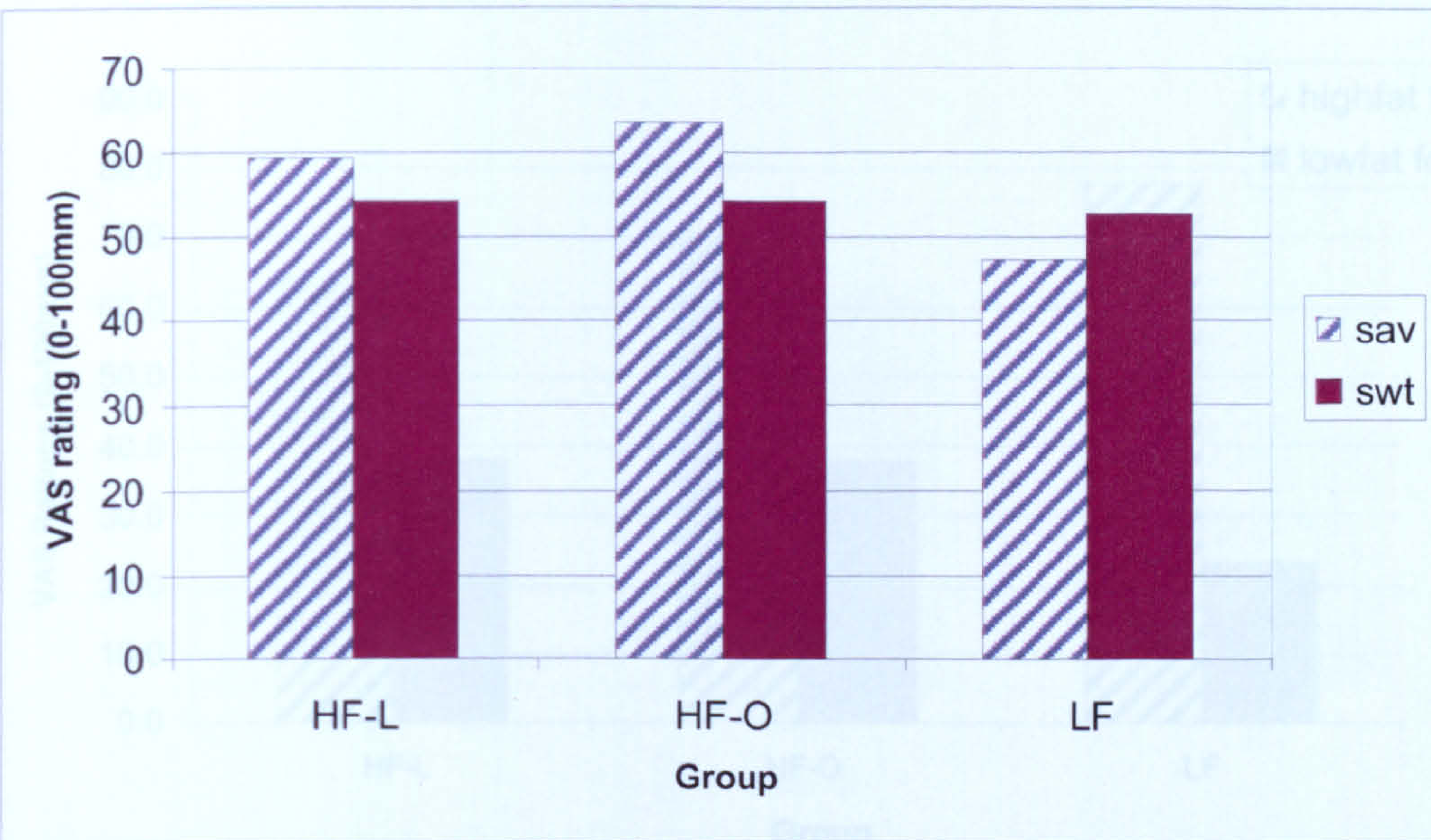

Figure 11.3 Mean hedonic responses for savoury and sweet food types

A significant TASTE by GROUP interaction was found ($F_{[2,45]}$=3.82, p<0.05). HF-O reported a higher hedonic response to savoury foods compared to sweet foods (p<0.01). Neither HF-L (p=0.30) nor LF (p=0.189) reported heightened hedonic response for either food taste.

11.4.3 Taste evaluation

11.4.3.1 Identification of high fat and low fat foods

Volunteers were asked a series of VAS questions to assess how well they could identify whether the foods (presented to them as a photograph) were high or low in fat content. Questions included (for example): How fatty do you find this food? vs How healthy (filling/starchy) do you find this food? Figure 11.4 shows the subjects responses for the high fat and low fat foods on how fatty they were believed to be. As can be seen, all three groups reported the high fat foods to be more fatty than low fat foods. This pattern is particularly evident in the LF group.

A 2 by 3 repeated measures ANOVAs were carried out on the data. The ANOVA tested whether there were any significant differences between ratings of FATTINESS for high fat and low fat foods between HF-L, HF-O and LF. A significant main effect was found for FOOD ($F_{[1,45]}$= 231.46, p<0.0001). This indicates that overall (regardless of group) higher ratings of FATTINESS were given for the high fat foods (mean: 71.2+/- 14.5) compared to the low fat foods (mean: 33.2+/- 12.2).

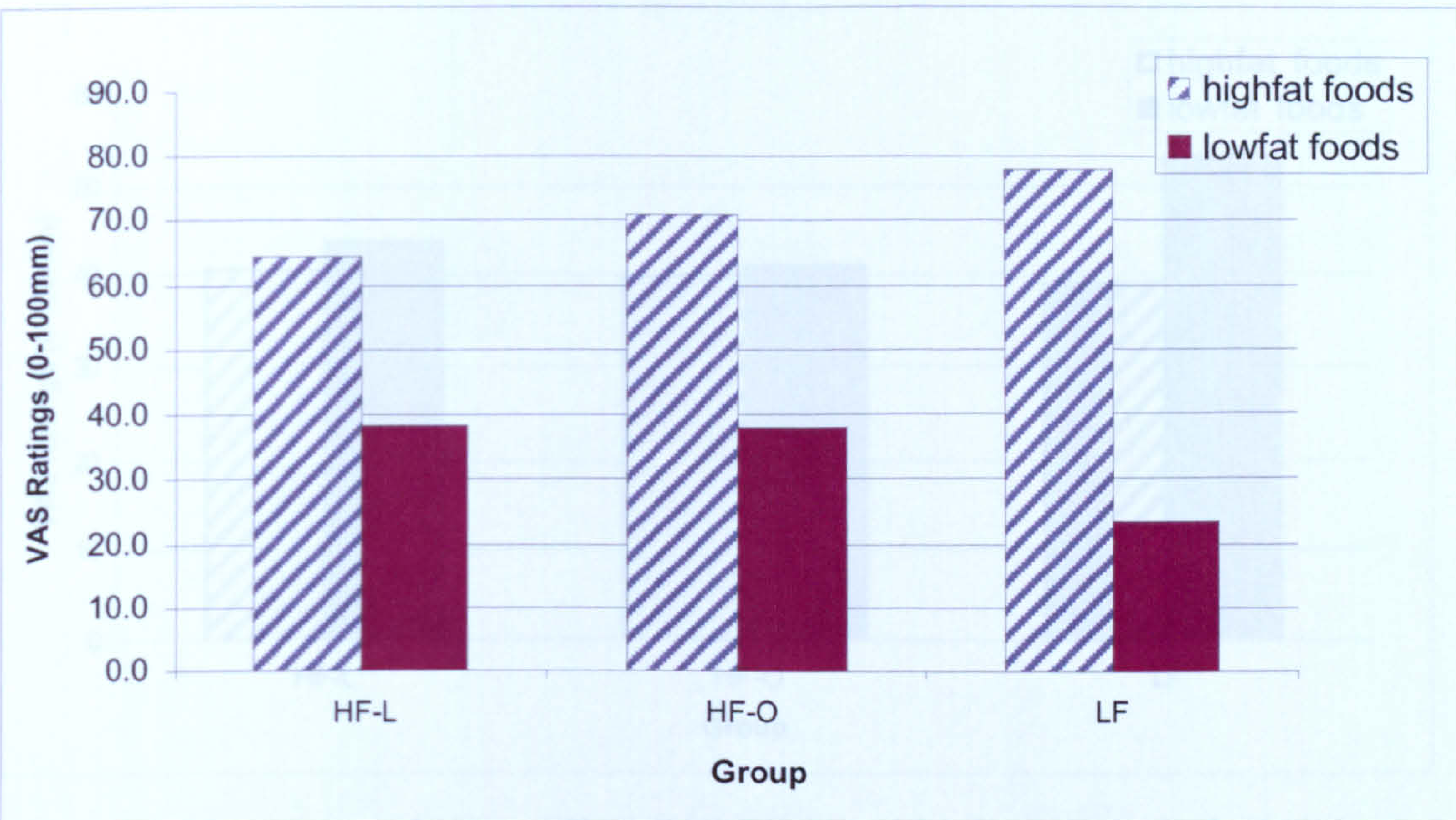

Figure 11.4 Mean taste evaluation (FATTY) given for high fat and low fat foods.

No significant main effect of GROUP was found ($F_{[2,45]}$= 0.852, p<0.433). Overall (regardless of food type) there was no significant difference in ratings of fattiness were given by HF-L (mean: 51.37+/- se:2.13), HF-O (mean: 54.48+/- se: 2.13) and LF (mean: 50.9+/- se: 2.13). However a significant FOOD by GROUP interaction was found ($F_{[2,45]}$=11.604, p<0.0001). Post hoc tests revealed that HF-O did not significantly differ from HF-L (p=0.518) or LF (p=0.476) on ratings of fattiness for high fat foods. However HF-L did give significantly lower ratings of fattiness for high fat foods compared to LF (p<0.05). No significant difference was found for ratings of fattiness for low fat foods between HF-L and HF-O. However LF did report the low fat foods to be significantly less fatty compared to HF-L (p<0.001) and HF-O (p<0.001).

However, for ratings of how healthy the foods were believed to be, the pattern of response was not as might be expected. Both HF-L and HF-O gave similar ratings of how healthy the foods were believed to be for both high fat <u>and</u> low fat foods. LF on the other hand gave higher healthy ratings for low fat foods compared to high fat foods (see Figure 11.5). This ANOVA tested whether there were any significant differences between ratings of how HEALTHY the foods were believed to be, for high fat and low fat foods between HF-L, HF-O, and LF. A significant main effect of FOOD was found ($F_{[1,45]}$=10.54, p<0.01). Regardless of group, low fat foods (mean: 46.33+/- 10.6) were rated as significantly more healthy than high fat foods (mean: 40.0+/- 10.5).

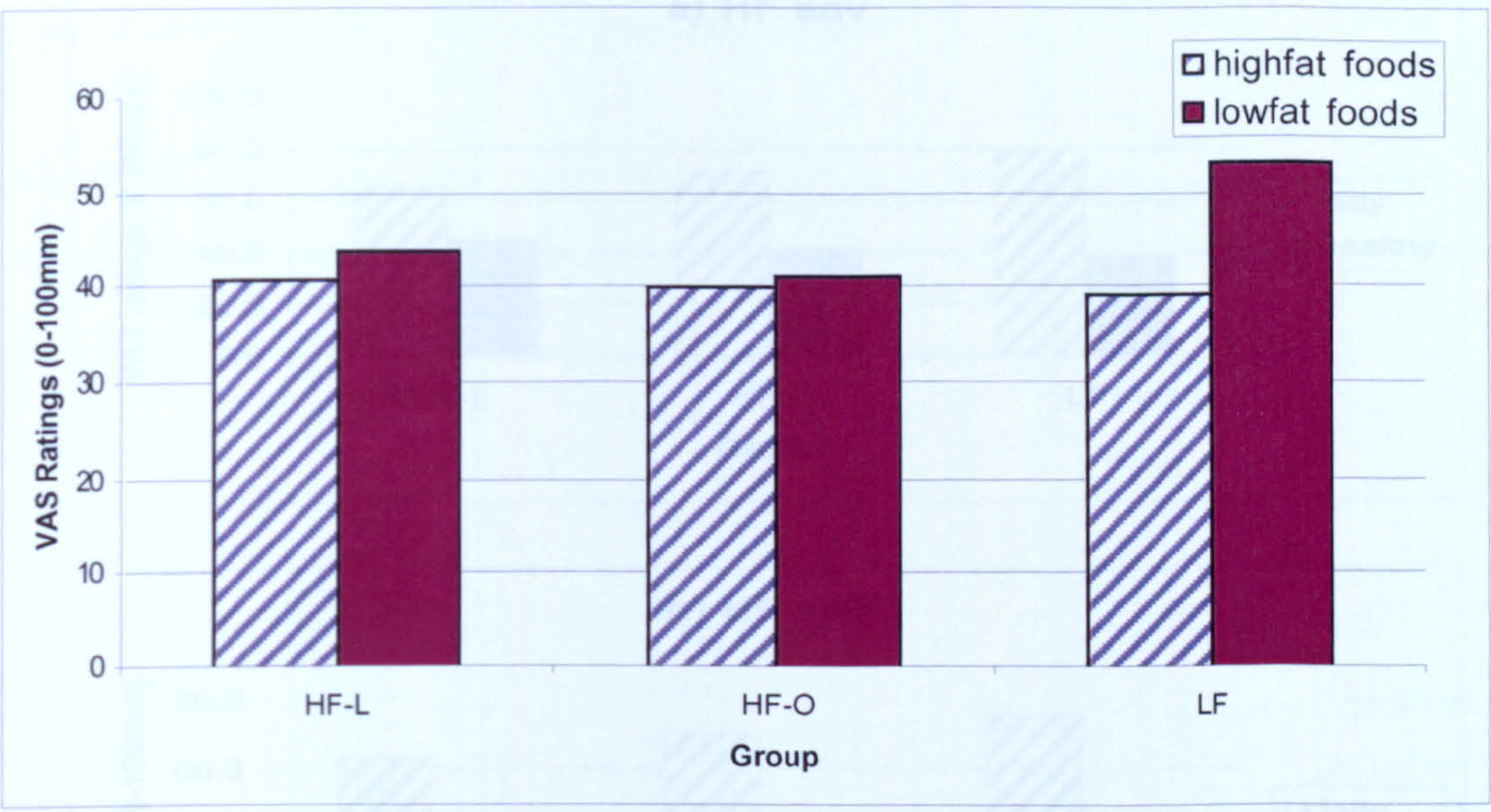

Figure 11.5- Mean taste evaluation (HEALTHY) given for high fat and low fat foods.

No significant main effect of GROUP was found ($F_{[2,45]}$= 2.398, p=0.102).That is, regardless of food type no significant difference in ratings of healthiness was found between HF-L (mean: 42.5+/- 1.88se), HF-O (mean: 40.7+/- se: 1.88) or LF (mean: 46.4+/- se: 1.88). However a significant FOOD by GROUP interaction was found ($F_{[2,45]}$= 4.414, p<0.05). Post hoc tests revealed that within group comparisons show no significant difference between ratings of healthiness for high fat and low fat foods by HF-L (p=0.305) or HF-O (p=0.781). However LF did report low fat foods to be significantly healthier than high fat foods (p<0.001). Between groups comparisons revealed that no significant difference in ratings of healthiness for high fat foods was given between groups (p=0.99 all cases). Also no significant difference for ratings of healthiness for low fat foods was found between HF-L and HF-O (p=0.99). However LF did report low fat foods to be significantly healthier compared to the HF-L (p<0.05) and HF-O (p<0.01).

Figure 11.6 (a-d) shows a breakdown of the ratings given for the four different food types (highfat/savoury; highfat/sweet; lowfat/savoury; lowfat/sweet). Each group was asked how FATTY and how HEALTHY each food type was. It can be seen that high fat savoury and sweet foods were rated as more FATTY than HEALTHY (see Figure 11.6 a & b). Low fat savoury foods were rated as more HEALTHY than FATTY (see Figure 11.6c). However the ratings given for the low fat sweet foods showed some interesting patterns. LF reported low fat sweet foods to be more HEALTHY than FATTY. Both HF-L and HF-O reported low fat sweet foods to be more FATTY than HEALTHY, although not fattier compared to the high fat sweet foods (see Figure 11.6d).

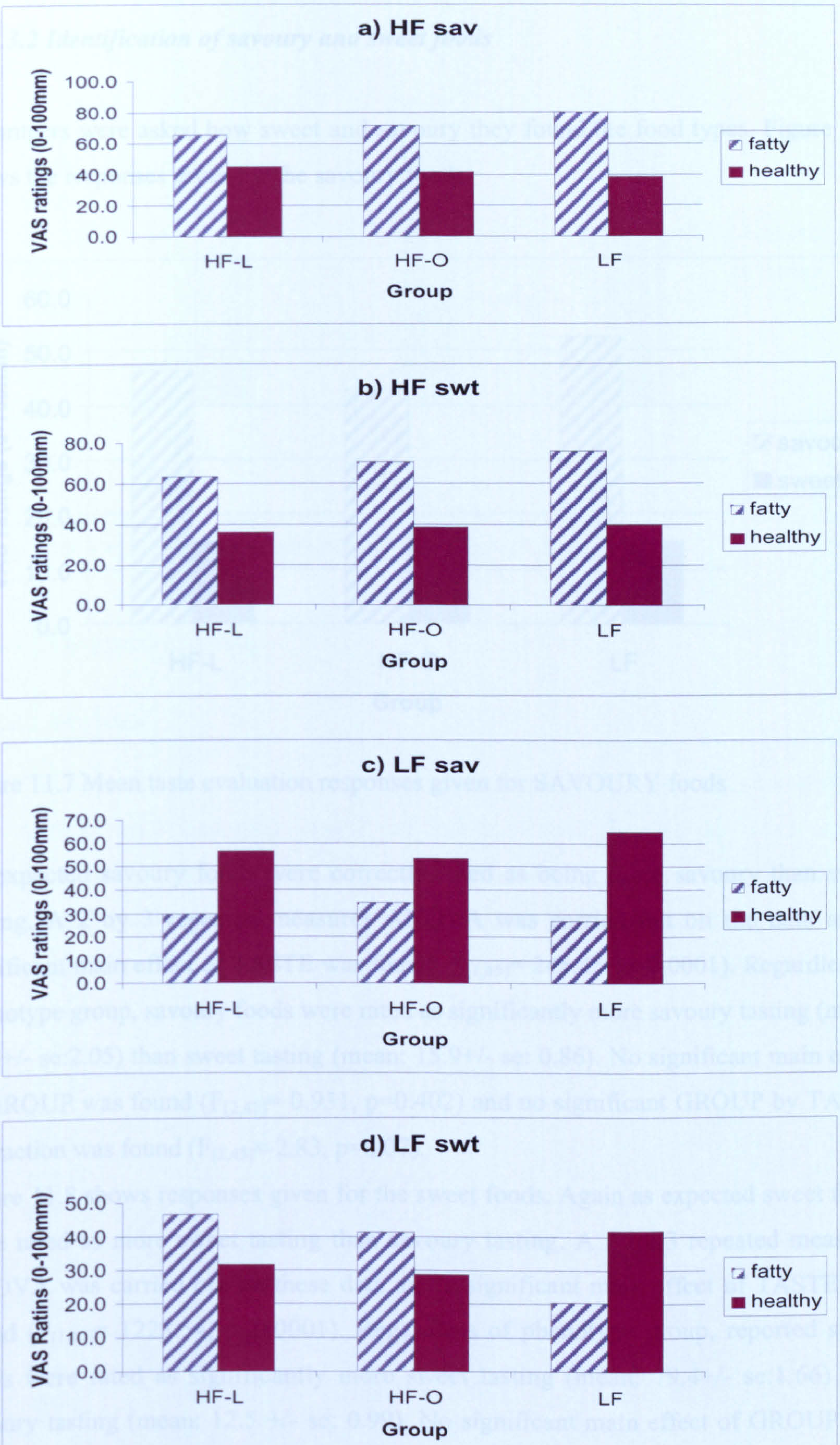

Figure 11.6- Mean taste evaluation (FATTY/ HEALTHY) given for a) HFsav b) HFswt c) LFsav d) LFswt food types

11.4.3.2 Identification of savoury and sweet foods

Volunteers were asked how sweet and savoury they found the food types. Figure 11.7 shows the responses given for the savoury foods.

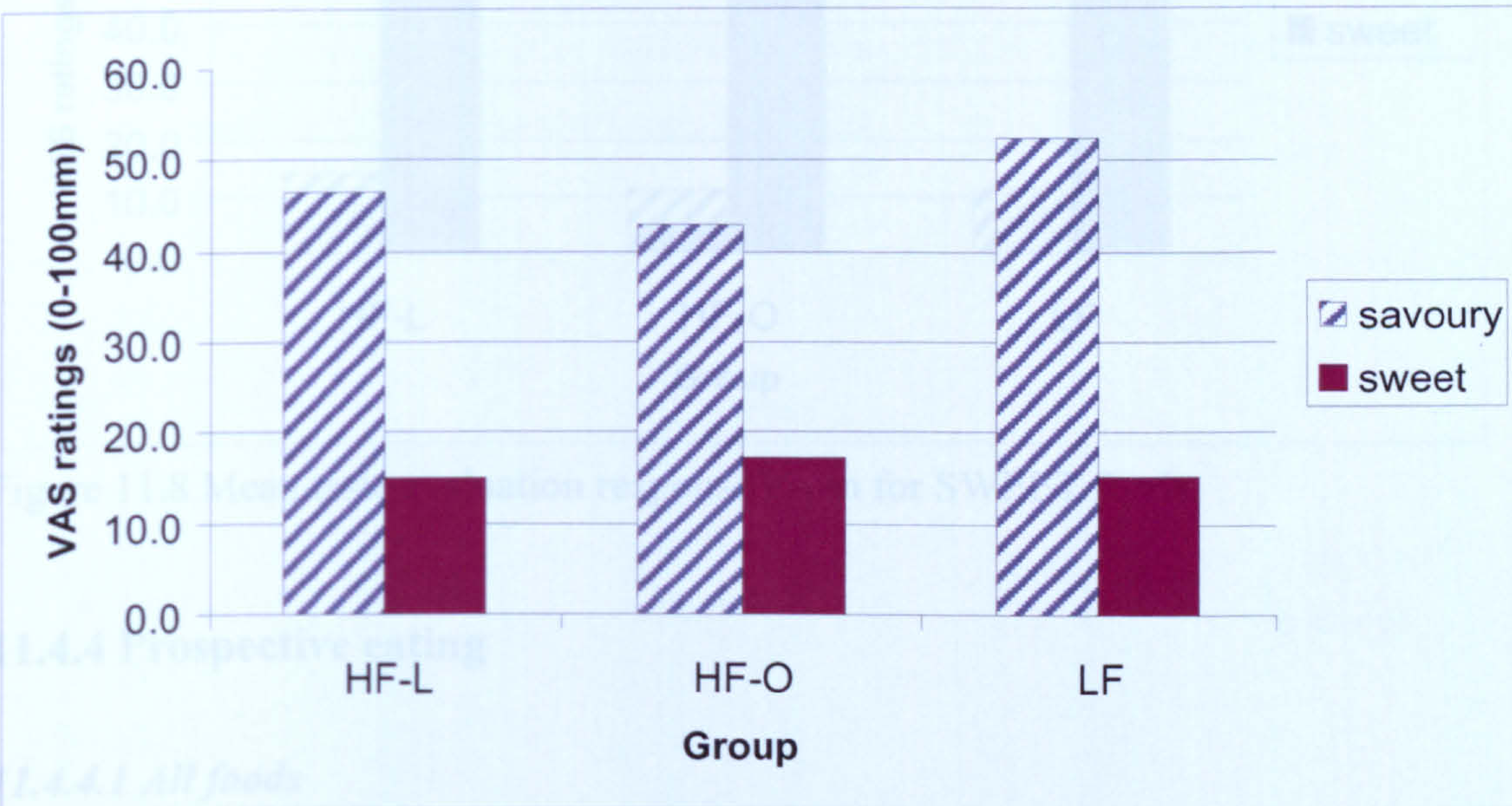

Figure 11.7 Mean taste evaluation responses given for SAVOURY foods

As expected savoury foods were correctly rated as being more savoury than sweet tasting. A 2 by 3 repeated measures ANOVA was carried out on the data and a significant main effect of TASTE was found ($F_{[1,45]}$= 245.45, p<0.0001). Regardless of phenotype group, savoury foods were rated as significantly more savoury tasting (mean: 47.3+/- se:2.05) than sweet tasting (mean: 15.9+/- se: 0.86). No significant main effect of GROUP was found ($F_{[2,45]}$= 0.931, p=0.402) and no significant GROUP by TASTE interaction was found ($F_{[2,45]}$= 2.83, p=0.07).

Figure 11.8 shows responses given for the sweet foods. Again as expected sweet foods were rated as more sweet tasting than savoury tasting. A 2 by 3 repeated measures ANOVA was carried out on these data and a significant main effect of TASTE was found ($F_{[1,45]}$= 1228.54, p<0.0001). Regardless of phenotype group, reported sweet foods were rated as significantly more sweet tasting (mean: 79.4+/- se:1.66) than savoury tasting (mean: 12.5 +/- se: 0.99). No significant main effect of GROUP was found ($F_{[2,45]}$= 0.043, p=0.958) and no significant GROUP by TASTE interaction was found ($F_{[2,45]}$= 0.684, p=0.958).

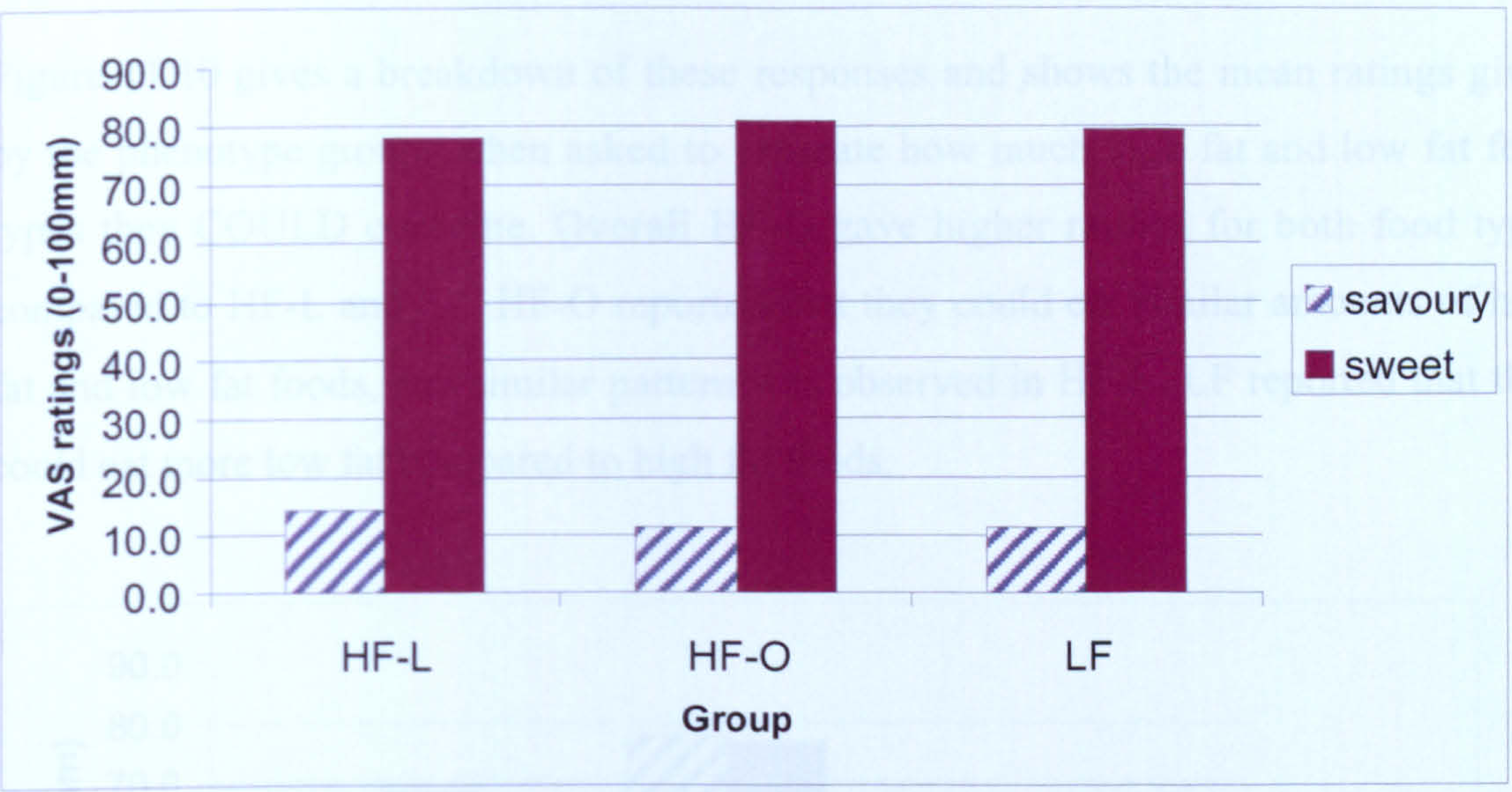

Figure 11.8 Mean taste evaluation response given for SWEET foods

11.4.4 Prospective eating

11.4.4.1 All foods

Figure 11.9 gives the mean scores for each phenotype group when asked to evaluate how much of each food they *could* eat and how much they would *want* to eat. Subjects reported that they COULD eat more of the foods presented to them (in photographs) than they would actually WANT to eat. HF-O reported that they COULD eat more of the foods compared to the lean groups, however reported to WANT to eat a similar amount as the leans.

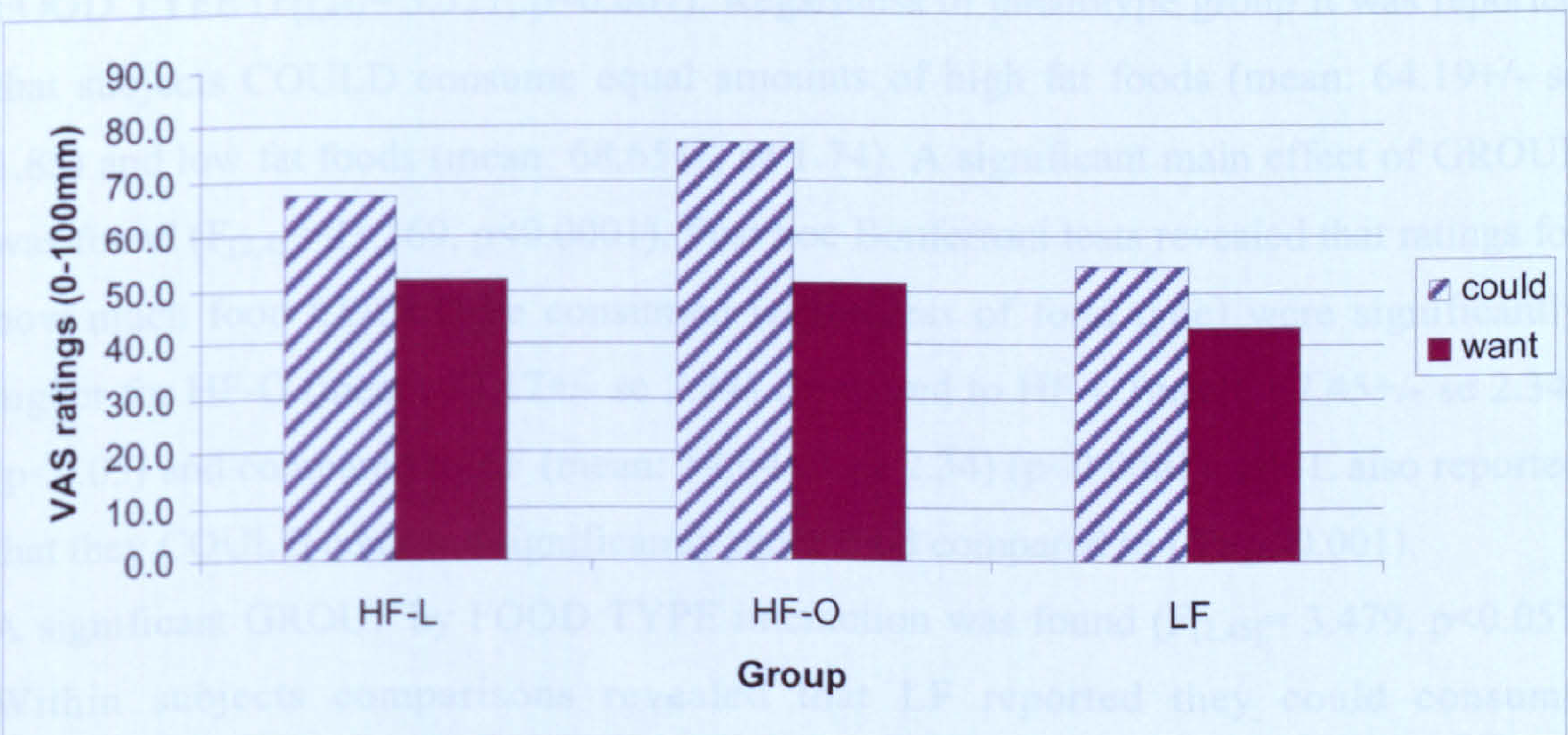

Figure 11.9 Mean prospective eating (could eat & want to eat) responses for all foods

11.4.4.2 High fat and low fat foods

Figure 11.10 gives a breakdown of these responses and shows the mean ratings given by the phenotype groups when asked to estimate how much high fat and low fat food types they COULD consume. Overall HF-O gave higher ratings for both food types compared to HF-L and LF. HF-O reported that they could eat similar amounts of high fat and low fat foods, and similar pattern was observed in HF-L. LF reported that they could eat more low fat compared to high fat foods.

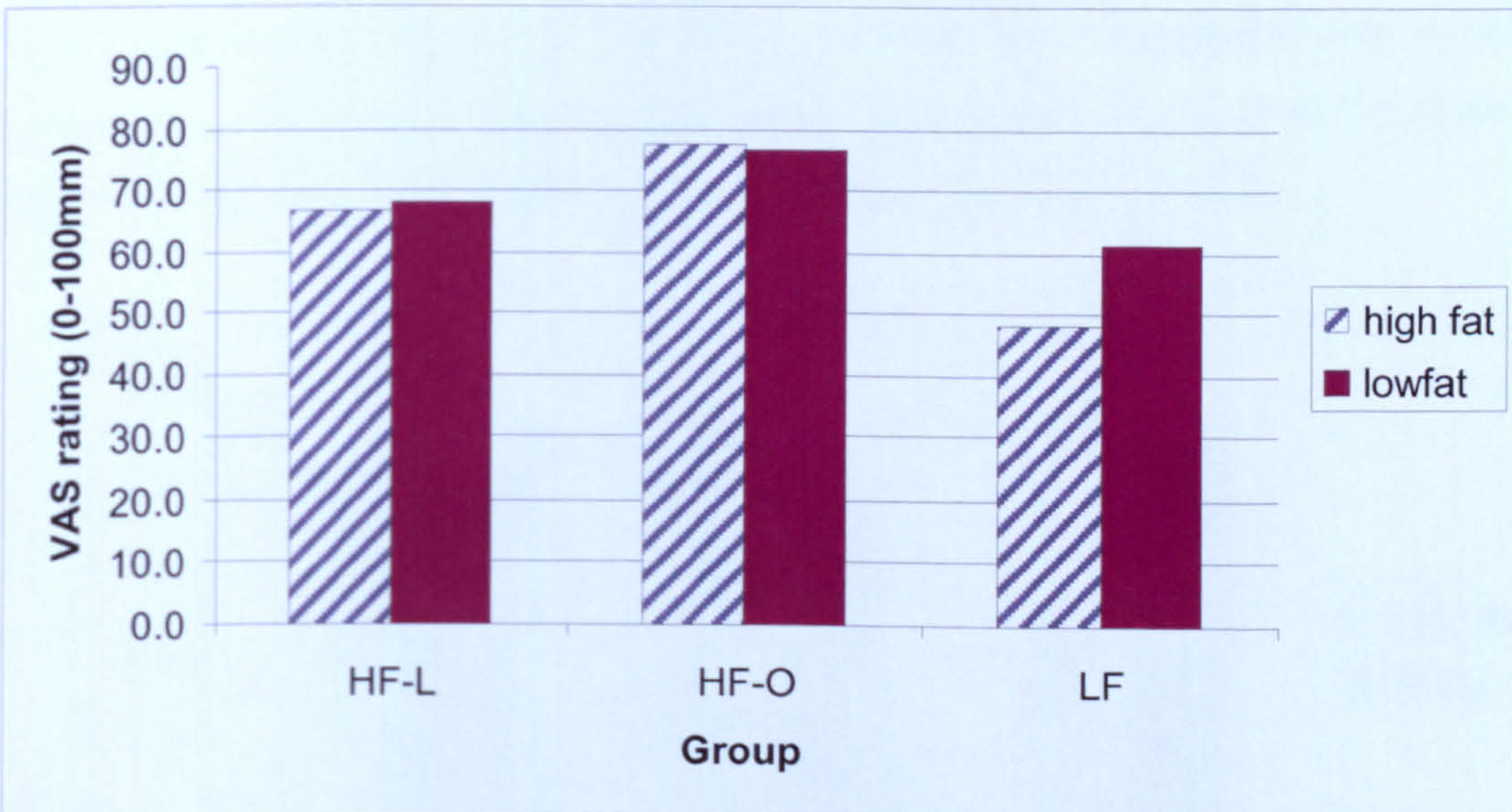

Figure 11.10 — Mean responses given for amount of high fat & low fat foods that COULD be eaten.

Results from the 2 by 3 repeated measure ANOVA showed no significant main effect of FOOD TYPE ($F_{[1,45]}$= 3.527, p=0.067). Regardless of phenotype group it was reported that subjects COULD consume equal amounts of high fat foods (mean: 64.19+/- se 1.85) and low fat foods (mean: 68.65+/- se 1.74). A significant main effect of GROUP was found ($F_{[2,45]}$=23.369, $p<0.0001$). Post hoc Bonferroni tests revealed that ratings for how much food COULD be consumed (regardless of food type) were significantly higher for HF-O (mean: 77.17+/- se 2.34) compared to HF-L (mean: 67.45+/- se 2.34) ($p<0.05$) and compared to LF (mean: 54.64+/- se 2.34) ($p<0.0001$). HF-L also reported that they COULD consume significantly more food compared to LF ($p<0.001$).
A significant GROUP by FOOD TYPE interaction was found ($F_{[2,45]}$= 3.479, $p<0.05$). Within subjects comparisons revealed that LF reported they could consume significantly more low fat foods compared to high fat foods ($p<0.01$). Both HF-L (p=0.776) and HF-O (p=0.796) reported being able to consume equal amounts of both

food types. Between subject comparisons revealed that LF could consume significantly less high fat foods compared to HF-L (p<0.001) and HF-O (p<0.0001). No significant difference was found between HF-L and HF-O for the amount of high fat foods that could be consumed. HF-O reported that they could consume significantly more low fat foods compared to the LF (p<0.01). No significant difference between the amount of low fat foods that COULD be consumed by the HF-L and HF-O (p=0.146) or LF (p=0.357) was found.

Figure 11.11 shows the mean response given for the amount of high fat and low fat foods the phenotype groups WANTED to consume. HF-L reported to want to eat equal amounts of the high fat and low fat foods. HF-O reported to want to eat more of the high fat foods whereas LF reported to want to eat more low fat foods.

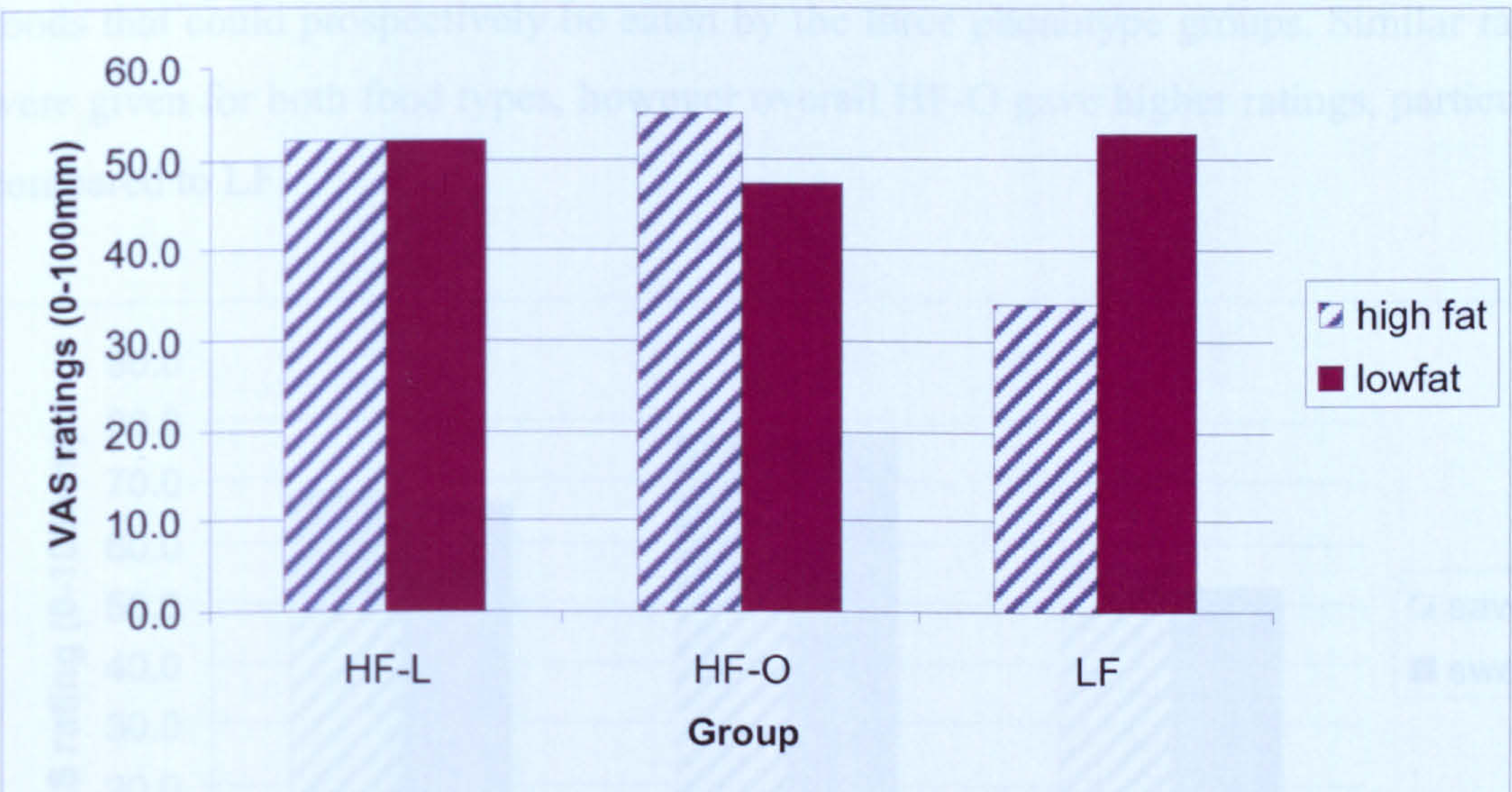

Figure 11.11- Mean response given for how much WANTed to eaten for high fat & low fat foods

Results from the 2 by 3 repeated measures ANOVA revealed no significant main effect of FOOD TYPE ($F_{[1,45]}$= 2.14, p<0.15). That is all volunteers reported to WANT to consume equal amounts of high fat (mean: 47.07+/- 2.091) and low fat foods (mean: 50.74+/- se 1.92) overall. Also no significant main effect for GROUP was found ($F_{[2,45]}$= 3.154, p=0.052). However both HF-L (mean: 52.16+/- se: 2.72) and HF-O (mean: 51.2+/- se: 2.715) reported to want to consume a higher amount of food compared to LF (mean: 43.4+/- se: 2.72).

A significant GROUP by FOOD TYPE interaction was found ($F_{[2,45]}$= 9.823, p<0.001). Within subjects comparisons revealed that LF reported to want to consume a significantly higher amount of low fat food compared to high fat food ($p<0.0001$). HF-L reported to want to consume equal amounts of high and low fat foods ($p=0.985$). HF-O reported to want to consume significantly more high fat foods compared to low fat ($p<0.05$). Between subjects comparisons revealed that LF reported to want to consume a significantly smaller amount of high fat foods compared to HF-L ($p<0.01$) and HF-O ($p<0.0001$). No significant difference between HF-L and HF-O was found for the amount of high fat foods they wanted to eat ($p=0.99$). Also no significant differences in the amount of low fat foods the volunteers wanted to consume was found (HF-L and LF: $p=0.99$; HF-L and HF-O: $p=0.06$; HF-O and LF: $p=0.77$).

11.4.4.3 Savoury and sweet foods

Figure 11.12 shows the mean responses given for the amount of savoury and sweet foods that could prospectively be eaten by the three phenotype groups. Similar ratings were given for both food types, however overall HF-O gave higher ratings, particularly compared to LF.

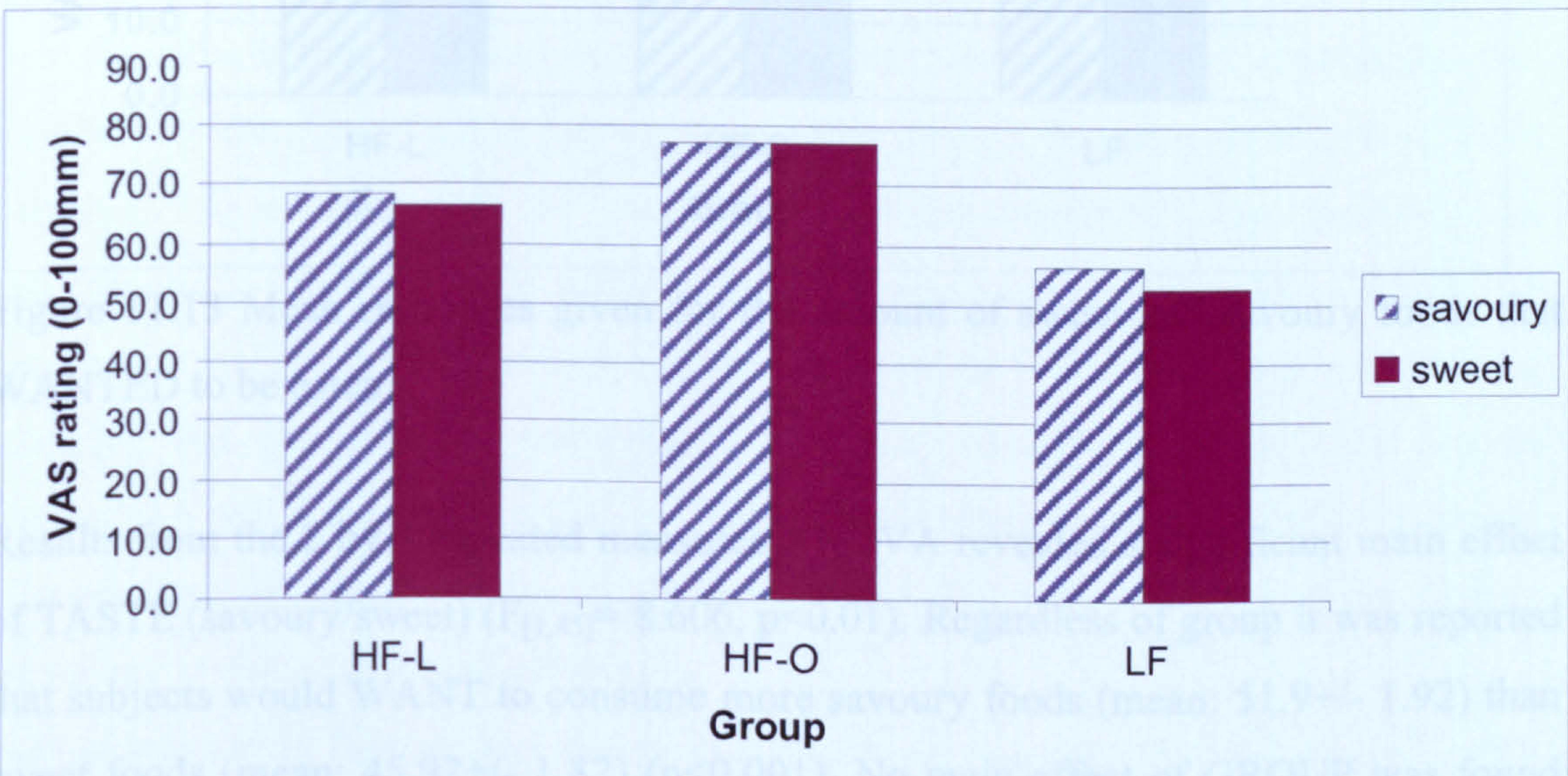

Figure 11.12 Mean responses given for the amount of savoury and sweet foods that COULD be eaten

Results from the 2 by 3 repeated measures ANOVA showed no main effect of TASTE ($F_{[1,45]}= 1.287$, $p=0.263$). Regardless of group, subjects rated that they COULD eat equal amounts of savoury (mean: 67.43 +/- se: 1.417) and sweet (mean: 65.41 +/- se: 1.796) foods. However a significant main effect of GROUP was found ($F_{[2,45]}= 23.37$, $p<0.0001$). Post hoc Bonferroni revealed that regardless of TASTE (savoury or sweet)

HF-O reported that they COULD consume significantly more food (mean: 77.17+/- 2.34) than HF-L (mean: 67.45+/- 2.34) ($p<0.05$) and compared to LF (mean: 54.64+/- 2.34) ($p<0.0001$). HF-L also reported that they COULD consume significantly more food than LF ($p<0.001$). No significant GROUP by TASTE interaction was found ($F_{[2,45]}= 0.385$, $p=0.682$).

Figure 11.13 gives the mean ratings for the amount of savoury and sweet foods each group would WANT to consume. All groups reported WANTING to consume more savoury than sweet foods and this was particularly evident in the HF-O group.

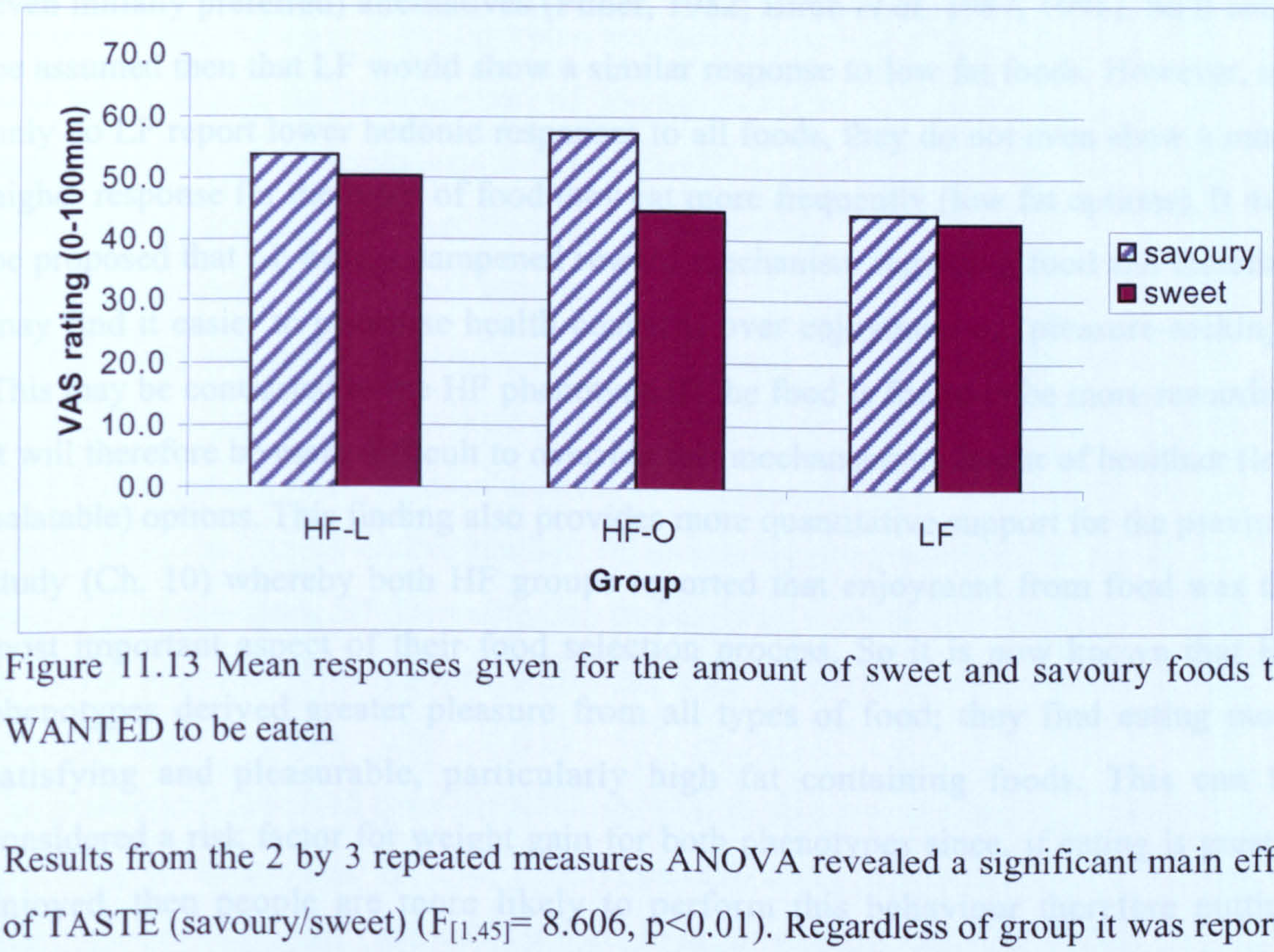

Figure 11.13 Mean responses given for the amount of sweet and savoury foods that WANTED to be eaten

Results from the 2 by 3 repeated measures ANOVA revealed a significant main effect of TASTE (savoury/sweet) ($F_{[1,45]}= 8.606$, $p<0.01$). Regardless of group it was reported that subjects would WANT to consume more savoury foods (mean: 51.9+/- 1.92) than sweet foods (mean: 45.92+/- 1.82) ($p<0.001$). No main effect of GROUP was found ($F_{[2, 45]}=3.154$, $p=0.052$) and no significant TASTE by GROUP interaction ($F_{[2,45]}= 2.97$, $p=0.061$).

11.5 Discussion

The results from this study show support for the hypothesis that the HF phenotype may have an enhanced hedonic response to food and that this may be an important factor in the development of the habitual diet.

Both HF-L and HF-O reported a higher hedonic response to food compared to LF; in particular they reported a higher hedonic response to high fat compared to low fat food types. This may be an understandable finding in light of what is know regarding taste preferences and habitual consumption. It has been found that repeated (increased) exposure to certain food types may come to be liked and preferred over equivalent (or even initially preferred) alternatives (Pliner, 1982; Birch *et al,* 1987, 1998). So it could be assumed then that LF would show a similar response to low fat foods. However, not only do LF report lower hedonic responses to all foods, they do not even show a much higher response for the types of food they eat more frequently (low fat options). It may be proposed that LF have a dampened reward mechanism regarding food and therefore may find it easier to prioritise health concerns over enjoyment or 'pleasure-seeking'. This may be contrasted to the HF phenotype. If the food is found to be more rewarding it will therefore be more difficult to override this mechanism in favour of healthier (less palatable) options. This finding also provides more quantitative support for the previous study (Ch. 10) whereby both HF groups reported that enjoyment from food was the most important aspect of their food selection process. So it is now known that HF phenotypes derived greater pleasure from all types of food; they find eating more satisfying and pleasurable, particularly high fat containing foods. This can be considered a risk factor for weight gain for both phenotypes since, if eating is greatly enjoyed, then people are more likely to perform this behaviour therefore putting themselves at risk of overconsumption.

Another interesting finding here concerns the hedonic responses to savoury and sweet foods. Only HF-O showed a heightened hedonic response to savoury foods (not observed in either lean group). Meiselman *et al* (1974) found that in a large study of US Army personnel the overweight recruits reported preferring red meat dishes rather than desserts. Cox *et al* (1999) found that obese individuals reported consuming significantly more dietary energy from savoury (salty) foods, and that the saltiness of foods (in the obese group only) correlated with energy density. However in the same study the authors found that there was no clear association between any particular taste (savoury or sweet) and hedonic ratings for obese groups. They concluded that obese and lean subjects do not self-select diets with markedly different perceived sensory or hedonic attributes. However the habitual diets of those particular subjects were not considered. Overall (as a group mean) the energy and fat intake of the volunteers in the Cox *et al* study was average (35.5% FE), and it is therefore likely that the effect of different habitual intakes (and therefore differing behavioural responses) were masked as a consequence. This is a good example of the heterogeneity of the subject sample concealing group differences (Kosslyn *et al,* 2002).

HF-O also reported that they could consume significantly more food (overall) compared to both lean phenotypes and HF-L reported that they could consume more than the LF. This finding may be related to previous chapters that found that HF-O reported higher levels of disinhibition and demonstrated increased test meal intake. This will obviously be a key factor in the development of obesity in HF-O (and a risk factor in HF-L if larger amounts of food are *actually* consumed) by simply increasing food intake and raising energy intake above that of energy requirements.

Therefore, both HF phenotypes showed a higher hedonic response toward fatty foods but HF-L reported to *want* to consume equal amounts of all foods (high fat and low fat) whilst HF-O reported to *want* to consume more high fat food. So are HF-O different to HF-L? This pattern of motivation towards the consumption of certain foods mirrors the results from the forced choice method of measuring food preferences as reported in chapter 9. In this study HF-L reported no particular preference between high fat and low fat foods, whereas HF-O reported preferring high fat foods and LF reported preferring low fat foods.

The differences observed between HF-L and HF-O may reveal some of the keys factors necessary to understanding what influences resistance and susceptibility to obesity. Although an individual may have a high hedonic response to (fatty) food, this only becomes a risk factor if coupled with heightened taste preferences and motivations (wanting) towards that food. If these (fatty) foods are found to be more rewarding, more preferred and the individual displays higher motivation toward them then it may follow that these foods are likely to be selected more frequently and perhaps in greater amounts, particularly if coupled with the trait of disinhibition.

This may be contrasted with the LF who wanted to consume significantly more low fat foods even though they reported no elevated hedonic response to these foods. This suggests then that there must be another mechanism (physiological or behavioural) other than 'pleasure response to food' influencing food choices in LF.

At the beginning of this chapter the question of whether the habitually consumed diet arose from physiological drives for specific foods (i.e. mediated via sensory preferences) or a response to the impact of the environmental forces was posed. From these and previous results it might be proposed that hedonic response to specific foods is related to the development (and maintenance) of the habitual diet. This in turn impacts upon body weight if coupled with heightened preferences and motivation. It can be supposed that an enhanced hedonic response implies a physiological mechanism at the level of sensory receptors, or brain reward circuitry.

There are a number of behavioural processes which constitute risk factors leading to hyperphagia (overconsumption). These processes may include patterns of eating behaviour, events that guide behaviour (such as anticipatory hedonic responses) and sensations which accompany or follow eating (i.e. fullness, satisfaction, pleasure). It has been shown that both HF-L and HF-O show a high food induced pleasure response for fatty foods and, in the overweight phenotype, higher preference (liking) and motivation (wanting) for fat coupled with a high score on the disinhibition trait. These are all specific features that together may increase the risk of overconsumption. These behavioural risk factors may be regarded as psychobiological dispositions which create a vulnerability for weight gain. The influence of environmental factors should not be overlooked as in most Western societies the food environment exploits these dispositions and promotes the achievement of a high-energy intake.

11.6 Summary

The results of this study have been successful in extending the current knowledge regarding food choice phenotypes and traits of vulnerability and susceptibility to obesity.

- HF-L and HF-O report higher hedonic response to all foods but particularly high fat items.

- HF-O show a heightened hedonic response for savoury foods compared to sweet.

- HF-O reported that they could consume significantly more food compared to the lean phenotypes.

- HF-O reported to want to consume more high fat foods; LF wanted to consume more low fat foods; HF-L showed no heightened motivation towards either food type.

Risk factors associated with weight gain on a high fat diet include a positive hedonic response to fatty foods, however it is proposed that vulnerability is greater when this trait is coupled with heightened preferences (increased liking) and higher motivation (increased wanting) towards fatty foods. Although it is not implied that the ratings reported in this study are necessarily continually reflected in conscious awareness, they are quite consistent with the described relationship with food set out in Chapter 10.

Chapter 12

GENERAL DISCUSSION

12.1 Causes and consequences of habitual food choice

The primary aim of this thesis was to further investigate the causes of habitual food choice (specifically dietary fat intake) and how these choices relate to body weight control. As set out in the introduction, the importance of focusing on habitual fat consumption for weight gain lies in the capacity of fat to increase energy intake above energy requirements. Obesity is a multifaceted problem whereby physiological, behavioural and environmental influences all play a role. By identifying individuals at risk from obesity (e.g. high fat consumers) it has been possible to investigate important factors involved in the food selection process along with the consequences of these food choices.

From previous studies carried out, using the lean HF and LF phenotypes as an investigative tool, a number of behavioural (i.e. habitual choices, preferences, physical activity patterns) and physiological differences (i.e. increased plasma leptin, resting metabolic rate and heart rate in HF-L) have been found. This thesis has added to these findings. The first study aimed to investigate further the achievement of energy balance in lean HF and LF phenotypes in their free-living environment. Even with such contrasting habitual dietary patterns in terms of fat intake both these groups remain lean. The study specifically looked at the behavioural (i.e. sleep quality and eating patterns) effects of the habitual diet.

The phenotypes differed in the patterns of heart rate particularly during the period of sleep. As previously mentioned, although these heart rates cannot be used to estimate energy expenditure, they may be a useful biomarker for sleeping behaviour. HF-L had higher heart rates during the night which might be associated with more sleep problems. This finding may be a direct consequence of the 'free living' eating patterns in that HF-L were found to consume much higher amounts of fat (and energy) during the latter part of the evening. HF-L have to deal with this metabolic load late on in the day and during sleep. This may be the reason for the increased heart rate (reflecting metabolic activity) and a somewhat inferior sleep quality. This supports (and extends) the proposal that HF-L may be physiologically protected from obesity (Blundell and Cooling, 2000). This may also tell us something about the antecedents to food choice. The findings regarding the interaction of eating patterns and increases in heart rate during the night is an example of behavioural and physiological interactions and their relationship with energy balance.

Regarding the question of the antecedents to food choice, it has been previously suggested that biological differences concerning the control of appetite may underlay the development of habitual dietary patterns. Alternatively the habitual consumption of a high fat or low fat diet may entrain different patterns of physiological satiety signals (pre- and post-absorptive) which will mediate the expression of appetite and the pattern of eating. The second study aimed to investigate whether HF-L and LF have different patterns of physiological satiety signals (and therefore a different modulation of appetite control) and also to examine the impact of short-term changes to the habitual diet on hunger and satiety. It was found that HF-L and LF were both less hungry following consumption of the meal most dissimilar to their habitual diet. This may indicate an up-regulation of satiety signals related to nutrients least often consumed.

It has been proposed by numerous authors that the hedonic value of food or a heightened reward response to food are involved in the development of the habitual diet. Therefore it might be hypothesised that HF-L select high fat foods because they are more rewarding than lower fat foods, a response possibly absent (or dampened) in the LF. However no significant difference between groups was found. This may be linked to the achievement of energy balance in HF (at least the lean HF). Although HF-L are selecting a diet that puts them at risk, they may be less prone to overeating if they do not have an enhanced hedonic response to the food consumed. This hypothesis will be discussed in more detail below. It was also found that there was no significant difference in food preferences between lean groups. This may indicate then that the development of the habitual diet (and day to day choices) may be independent of current taste and preference at least for normal weight individuals. This introduces the idea that dietary selection may have become 'habit'. Habit has previously been defined as a behaviour that is automatic or out of awareness (Saba *et al,* 1999). It may therefore be the case that these individuals are not consciously aware of the diet they are choosing. The causes behind particular food choices may have occurred many years earlier so that the eating behaviour becomes habitual.

This study also highlighted a potential risk factor for obesity in the HF group. HF-L were shown to significantly increase energy and fat intake following a high fat preload, indicating a tendency toward overconsumption under certain conditions (independent of hedonic response).

In chapter 8 a third phenotype was introduced in order to further investigate how energy balance might be achieved on a high fat diet. The aim was to define a cluster of characteristics that might ultimately diagnose susceptibility and resistance to dietary induced obesity. It has been argued that the development of obesity is a result of the consumption of a 'normal' Western diet under sedentary conditions (Prentice and Jebb, 1995). However the findings from this thesis suggest that it is more likely to be a result of maladaptive food choice and eating behaviours as suggested by Blundell and Stubbs (2002).

From the results of the free living study, which aimed to investigate a number of psychological, behavioural and physiological differences between the phenotypes, it was found (from FFQ and food diary data) that both overweight and lean high fat phenotypes appear to be making similar habitual dietary choices in terms of energy and macronutrient intakes, yet these two groups have (by definition) very different body compositions. One possibility is that HF-O may have been underreporting and that this may be a result of the use of the FFQ as a dietary assessment tool. It is acknowledged that the FFQ does not take into account portion sizes in the analysis (but uses only frequency of consumption). Therefore if an individual eats small portions of a wide variety of foods then the dietary analysis will be accurate. However if an individual habitually consumes a limited variety of foods but in large amounts the FFQ is likely to underestimate energy intake. This idea of the selection of larger portion sizes in the overweight group is given support by the findings that HF-O score more highly on the TFEQ disinhibition factor. This can be interpreted as the HF-O being more likely to over eat in the presence of strong cues or stimuli.

This was given support by the findings of studies in a more controlled lab-based environment. Here it was found that HF-O ate greater amounts of food compared to HF-L (by weight) when given a high fat test meal. HF-L and HF-O are known to select similar types of foods but HF-O are simply eating more of them. This may be a parsimonious explanation for their contrasting body weights. However the question still remains as to why HF-O are over eating? We know they have higher disinhibition score and in chapter 9 it was reported that HF-O showed a greater preference for high fat foods compared to low fat foods (in response to the question: which food would you like to eat now?). They also showed a greater preference for fatty foods in comparison to the HF-L who demonstrated no particular preference between these food types. HF-O were also found to show a slightly increased hedonic response to high fat foods (satisfaction, tastiness and pleasantness) following *actual* consumption of food and also showed a heightened anticipatory hedonic response to *all* foods, but particularly high fat savoury food. These features could play a significant role in promoting over consumption of certain foods in these individuals. It may be assumed that the pleasure yielded by food influences the expression of food preferences and that these factors are important in influencing (directly or indirectly) food choices (confirmed by descriptive reports in ch.10).

HF-O appear to have an enhanced response to food. (This could be termed a supersensitive response). If they find food more pleasant then this would stimulate more eating through an increased sensation of hunger and a consequent weakening of satiety. Indeed this action has been demonstrated by Yeomans (1996) who found that more palatable foods gave rise to an increase in hunger during a meal therefore resulting in a prolongation of intake during the eating episode. This potential link between hedonic response to food, increased intake and overweight could be important. Negative gustatory alliesthesia has been defined as the decline in pleasantness between the start and the end of a meal (Cabanac, 1971; 1992), and it has been proposed that the decision to end a meal may be hedonically driven (Cabanac, 1989). It may be possible that this mechanism (decline in pleasantness) is weakened in HF-O, resulting in continued intake and over consumption. This issue warrants further exploration.

It might be proposed that the overweight (at least one group of overweight individuals) have a disposition to perceive foods as more satisfying. Given the capability to obtain higher levels of pleasure from food and eating it is not surprising that overweight people show a tendency to self select highly palatable foods (which for these individuals are high fatty foods). This is in part supported by other findings. Hajnal *et al* (1997) found that increases in dopamine (implicated in hedonic processes) availability initiated feeding behaviour even in satiated rats. In addition, Wang *et al* (2001) found that in obese individuals the dopamine D2 receptor was altered. Mela and Sacchetti (1991) found a positive relationship between pleasantness of fat content of food and measures of body fatness. Moreover, Rissanen *et al* (2002) found that in monozygotic twins, discordant for body weight, the heavier twin showed a higher preference for fatty foods indicating that fat preference may be entrained from environmental influences rather than from a biological predisposition or genetic susceptibility. This idea was explored in more depth during the investigation into attitudes, intentions and values/beliefs and the relationship to habitual food choices (ch.10). This study revealed that although HF (lean and overweight) and LF have contrasting values/beliefs when asked to contemplate their own food choices, attitudes and intentions were poor predictors of their actual behaviour. If differences in the power of attitudes had been evident between groups then this would imply that food choice would be a socio-cognitive phenomenon. However, it was disclosed (ch.10) that phenotypes vary in their values (and prioritisation of values) relating to the food choice process. HF (lean and overweight) prioritised enjoyment and pleasure from eating compared to LF who prioritised health issues. It was concluded that attitudes and intentions were weakly associated with behaviour, leading to the assumption the food choice is not under the control of conscious socio-cognitive reasoning. Therefore a more unconscious or psychobiological explanation of human food selection, emphasising the interaction between biology and behaviour, may be appropriate.

However it should be noted that when ambivalence (towards a low fat diet) was investigated, it was the HF-O who were found to display greater ambivalence, that is more mixed attitudes towards their diet. Ambivalence has been defined in a number of ways. Gardner (1987) stated that ambivalence in this context is a psychological state in which a person holds mixed feelings (positive and negative) towards some psychological object. Emmons (1996) proposed that it is an approach-avoidance conflict, that is wanting but at the same time not wanting the same goal object. Food consumption has been associated with ambivalence (Beardsworth, 1995; Fischler, 1988) and with conflicting motives (Herrnstein, 1990) at least in overweight/obese individuals. That is a wanting to eat preferred foods yet conflicted with elements of social desirability (for example). This seems a plausible way of understanding the <u>consequences</u> of food choices (which are determined by other mechanisms).

To give an interim summary then, it can be surmised that HF-L and HF-O make similar food choices, however HF-O, due to heightened hedonic response to food (and therefore increased food preferences towards fatty foods), over consume on particularly fatty foods, resulting in the promotion of a positive energy balance and therefore ultimately an increased body weight. HF-L on the other hand, although show an increased preference and hedonic response to <u>all</u> foods in comparison to LF, do not appear to have a 'super' sensitivity directed towards fatty foods in the same way as their overweight counterparts. Neither do they display high scores on disinhibition. Therefore, HF-L are less likely to overeat on the foods they preferentially select. This finding, in conjunction with the physiological protective mechanisms, which may also exist (i.e. slightly raised BMR, higher leptin levels and fat oxidation; see Cooling and Blundell, 2000), may account for their ability to remain lean on a high fat diet. A supersensitive hedonic response should be added to the list of behavioural risk factors associated with obesity, along with patterns of eating, food selection and drive to eat set out by Blundell and Cooling (2000). However it is proposed that vulnerability is more profound when this trait is coupled with heightened preferences and higher motivations towards fatty foods. It is also important to consider physiological factors associated with HF-O, as it might be the case that these individuals are physiologically as well as behaviourally vulnerable to weight gain, thereby indicating further psychobiological interactions influencing energy balance. HF-L will remain protected if they do not overconsume the foods (that is, they maintain lower portion sizes) whilst maintaining their actual food choices. It is possible that this situation may change with the ageing process. Further research is necessary which addresses the question of whether HF-L do remain physiologically protected into middle age. As HF-L have shown equal preferences for all types of food (both high fat and low fat) it may be easier for this group to change their eating habits to counteract the onset of physiological changes associated with age. This may prove to be more difficult for the HF-O who show a stronger specific preference for fat, particularly in a climate where the food industry has the main aim of producing highly palatable foods to promote acceptance and consumption, which in turn are likely to increase the willingness to consume and overconsume (Blundell and Le Noury, 2002). Increasing awareness in this group may be a necessary precursor for weight loss through encouragement and education about portion sizes. These findings indeed have implications for nutritional strategies to deal with obesity.

12.2 Methodological issues

This thesis has highlighted a number of methodological issues concerning research in the area of appetite control and energy balance. The major theme to emerge is that of the importance of acknowledging individual differences. It was stated by Cabanac (1989) that the physiological state of the subjects, and the environment in which the food and subject interact, may have an important contributing effect to experimental outcomes. A particular manipulation may have equivalent quantitative effects but in opposite directions in particular subgroups of any given sample. This would therefore give an average response showing only small and often non-significant effects for the sample.

The results reported in chapter 6 showed that fat and CHO foods differ in their post ingestive actions independently of weight, energy value and taste characteristic. However it was evident that these macronutrients did not exert similar effects on all volunteers. It is proposed that this has methodological implications for (past and) future research involving dietary manipulations using unselected samples of subjects. Since the habitual diet appears to modulate the control of appetite, the outcome of a particular manipulation could indeed depend on the habitual diet of the subjects taking part. Failure to take account of an individual's habitual diet during recruitment would lead to the absence of any positive results if the group were heterogeneous or, in the case of inadvertent selective recruitment, could result in very misleading extreme responses. This reasoning provides increased support for the use of the food choice phenotypes as an investigative tool. By researching individual differences in eating behaviour (and other behaviours) it is possible to provide a deeper insight that will help the understanding of disorders (such as obesity) and could possibly inform the development of more successful interventions and prevention programmes.

Research strategies focusing on specific behavioural phenotypes can be said to help in the understanding of the factors leading to weight gain by drawing attention to the interaction between individual differences in physiological features and behaviour variables and their relationship to energy balance. Kosslyn *et al* (2002) argue that group data should be used in conjunction with individual differences research, and combining the two methods provides a powerful tool for linking psychology and biology.

In this thesis, the diagnosis of susceptibility and resistance to weight gain has been advanced through the identification of key factors such as heart rate food preference, hedonic response and eating itself. A link between psychology and biology, in a way that respects individual differences, in this way may have considerable implications for treatment programmes (Kosslyn *et al,* 2002). This draws attention to the fact that different treatment programmes will be more or less appropriate for different types of people. Ultimately it would be a more beneficial option to customise dietary interventions to treat obesity. This has the advantage of giving the individual the opportunity to gain control over behaviours and situations where weakness has been demonstrated.

Another methodological issue to be highlighted, which is often a problem in research of this nature, is the issue of underreporting. This appears to be a problem particularly in the dietary assessment of overweight people. It was found in this thesis that this might be a problem if the method of assessment is the FFQ. As the FFQ does not take into account portion sizes it is likely that energy intake will be underestimated in certain groups (i.e. overweight). If this problem is acknowledged from the outset, the FFQ might still be valuable as a quick and convenient method to provide an approximate measure of the direction of food choice and of habitual eating patterns, without specifying total energy intake. However if it is to be used in the identification of food choice phenotypes it is important that these data are further supported with (at the very least) three-day food diaries, the DINE and SFQ. Selection criteria for inclusion in the phenotype groups should be based on a consistent outcome across all measures.

Any arguments regarding the control of body weight must involve measures of both energy intake and energy expenditure. There is the possibility of measurement error in all components of the energy balance equation. In addition, it is very difficult to accurately measure such components, and arguably, impossible under free-living conditions. Therefore all explanations regarding aspects of energy balance should be modestly proposed, recognising that measurements are subject to a degree of error and any unmeasured components could alter the picture proposed.

12.3 Conclusions

What factors effect food choice? Why do some individuals consume contrasting diets given the same cultural and economic environments and what are some consequences of these choices? It has been demonstrated that LF have a lower (dampened) hedonic response to food and also prioritise health aspects over enjoyment from eating. They apparently find it easier to override the hedonic power of fatty foods in favour of health concerns due to a reduced pleasure response. HF on the other hand prioritise enjoyment over health when making food choice and they show increased pleasure from food (in general). They enjoy and get more enjoyment from eating compared to LF and fatty foods appear to be intrinsically more rewarding.

What factors determine susceptibility and resistance to dietary induced obesity? It appears that HF-L get pleasure from eating (in general) and show no particular taste preference toward high or low fat foods (that is they like all foods). It also appears that these individuals have a low disinhibition score, low restrained eating and are therefore less vulnerable to counter-regulation and over eating. These psychological findings together with what is already known with regard to the physiological mechanisms at play in these individuals provide a possible indication for how HF-L are able to remain lean when consuming a potential weight inducing diet. It also appears that some HF-L are conscious of not being able to gain weight.

HF-O also receive pleasure from eating but in comparison to their lean counterparts this might be termed a 'super' sensitive hedonic response to food and particularly to high fat (savoury) foods. They show a directed preference for high fat foods coupled with increased levels of disinhibition. This susceptibility to overeating along with the hedonic response to food may be responsible for the increase in meal size demonstrated in experimental situations. Small but consistent overeating is probably one of the main reasons why some individuals are overweight. Whether someone becomes obese under a given set of environmental and nutritional circumstances will be determined by the interaction between the behavioural response to the circumstances and the metabolic responses to the behaviour (Pagliassotti *et al,* 1997). This interaction determines how much and what type of energy enters the body and the fate of the energy within the body. It indeed appears to be the case that psychological and physiological dispositions of the subject will effect preferences and responses to the qualities of foods (Stubbs *et al,* 2002).

Epilogue

Classification & definition of the phenotypes

Classification of the phenotypes through the use of the FFQ and food diaries may mean that there are errors in the identification of true, clean habitual HF and LF consumers. The importance of accurate dietary assessments can not be overemphasized since much of our understanding of the relationship between diet and, in this instance, weight gain/obesity, depends on the validity of the dietary data. It has long been established that food intake records may not give a reliable estimate of the food actually consumed due to under-eating and under-reporting (see section 4.5). Alternatives to food diaries and FFQs for use in the detection of the phenotypes might be proposed, such as 24-hour recall, duplicate portion analysis, or the use of feeding cubicles and calorimeters in the laboratory. However most methods will cause subjects to alter their behaviour and there is always likely to be a trade off between accuracy and validity (Hill *et al,* 1995).

In the case of nutrition, unlike other disciplines, there is the advantage of having physiological parameters that provide a guide to the plausibility of the self report, that is the use of the EI:BMR ratio. Physiological measurements used in conjunction with psychological parameters will provide a much greater understanding and will increase confidence in the dietary data. However dependence on these parameters should not be over stated as studies have shown that they do not guarantee detections of inaccurate data (Blundell and Macdiarmid, 1997). There is a possibility of measurement error in all components of the energy balance equation (measurements of RQ, for example, can be substantially distorted by hyperventilation; severe exercise and after exercise). As mentioned in the previous chapter, it should be acknowledged that when explanations regarding aspects of energy balance are made, they should be done modestly, recognizing that *all* measurements are subject to a degree of error and any unmeasured component could alter the proposed picture.

In order to improve the reliability of conclusions that have been made in this way, studies using the phenotypes need to ensure that identification of true and accurate dietary data and accurate measures of energy requirements (for EI:BMR calculations) is achieved; that studies are repeated and under a variety of experimental conditions, with larger samples to minimise any reduction in the sensitivity of measurements and the likelihood of Type II errors. This may help to improve the generalisability of the conclusions made in light of the fact that the perfect experimental protocol to the study of human feeding behavior does not exist (Blundell and Stubbs, 2002). In addition, the generalisability of findings could be improved by assessing the phenotypes over time using i) shorter-term prospective studies to monitor the body weight of HF (and LF) (i.e. are HF-L slowly gaining weight despite protective mechanisms without which they may already have become obese?); ii) longer-term studies to assess the ability of these individuals to maintain in energy balance into middle age.

Despite these limitations in methodology used to identify the phenotypes, significant (and consistent) differences have been found between these groups, in this and previous research. This suggests that they are different and distinct in their physiological and behavioural makeup. HF and LF phenotypes do constitute a useful investigative approach for examining the relationship between energy intake and energy utilization. The problem appears to lie with the terms used to define these subgroups of individuals. This thesis has highlighted a cluster of behavioural characteristics that may render an individual susceptible or resistant to weight gain and in turn obesity. Vulnerability has been associated with a high intake of fat (a risk factor associated with increasing energy intake), higher hedonic response to food (fat), higher preferences for fat and higher disinhibition to food. This thesis has therefore mainly focused on the psychological aspects involved in the achievement of energy balance. However it is acknowledged that there may in deed be a number of different 'routes' to obesity and that these factors are just one possible 'route'. As pointed out in the introduction, in order to fully understand these issues both sides of the energy balance equation should be addressed simultaneously; energy intake and energy expenditure, since a positive energy balance occurs when energy intake is above that of energy requirements. Although some of the physiological parameters were touched upon it is proposed that further investigations of these variables is necessary in order to achieve a fuller understanding of how energy balance is achieved by these phenotypes.

Resting metabolic rate (RMR) and respiratory quotient (RQ) were measured in lean HF-L and LF (see Chapter 5) and no significant differences in RMR or RQ were found. It may be the case that there are no differences in metabolic rate between phenotypes in which case it may be inferred that HF-L are slowly gaining weight due to their higher energy intake (from food diaries not FFQ). However, in light of previous findings it is argued that this result is more likely a cohort effect and due to the small sample sizes used in this study. The results achieved were in the expected direction (HF-L=1844 kcal/d; LF=1816kcal/d) to support those of previous studies. Cooling and Blundell (1998b) found that HF-L had significantly higher RMR and significantly lower resting RQ compared to LF. In addition HF had a significantly lower RQ response to a high fat (low CHO) than high CHO (low fat) challenge. This effect was not observed in the LF. It was concluded that a high-energy intake characterised by a large fat component is associated with metabolic adaptations, which could offset the weight inducing properties of a high fat diet. However the authors also pointed out that although the major differences between HF and LF consumers concerns their fat consumption (large differences in absolute and fat % energy), the two groups also differed in total energy intake and the amount of protein consumed (as seen in the phenotypes in this thesis; see Table 5.4, for example). Therefore it is possible that the measured increases in energy expenditure reflected the overall energy intake or turnover of protein (Cooling and Blundell, 1998). The same argument can be applied to the interpretation of the data in this thesis. The observed differences in hedonic response, preferences, attitudes and values may reflect patterns of overall energy intake rather than specifically to the intake of dietary fat per se. It may be argued, then, that a better definition would be to term this subgroup of individuals 'High Energy' consumers.

It is important to acknowledge that how the research question is posed will in part influence the interpretation of the results (Blundell and Stubbs, 2002). For example, some previous studies have found that high fat, high energy diets promote a higher energy intake compared to low fat, low energy dense diet (Lissner *et al,* 1987; Stubbs *et al,* 1995) whereas others have not shown this effect (Van Stratum *et al,* 1978; Stubbs *et al,* 1996). The answer to these conflicting results, and also the argument concerning the definition of the phenotypes, lays in the fact that macronutrient composition (including dietary fat), energy density and their effect on energy intake are *all* important and interrelated (Stubbs *et al,* 2000). That is, any model that examines the effects of macronutrients on satiety, should include the effects of all three macronutrients. In animal studies it has been shown that when oxidation of either fat or CHO has been blocked, the use of the other energy providing nutrient has been displayed. However when the oxidation of both fat and CHO has been inhibited, the animal is then observed to seek metabolic fuels from the environment (Friedman and Tordoff, 1986; Thompson and Campbell, 1977). These kinds of results suggest that the central nervous system is responsive to the combined effects of the macronutrients rather than being driven by the negative feedback from a single nutrient. Models using this approach have explained a greater proportion of the variance in energy intake in the laboratory and free-living environment with subjects self-recording their own intakes (Stubbs *et al,* 2000; Stubbs, 1998; Blundell and Stubbs, 2002). It could therefore be argued that a more accurate definition and description of the phenotypes would be 'dietary-induced obesity: resistant' (DIO-R) and 'dietary-induced obesity: vulnerable' (DIO-S) individuals.

However as set out in the introduction, there are a number of important reasons why the focus has been on fat, not only in this thesis but also in the field of obesity research, in general. The development of obesity occurs due to a high-energy intake brought about by an obesigenic environment in the face of a permissive physiological system (Blundell and King, 1996). One characteristic of the food supply that has been identified as a likely promoter of a high energy intake and positive energy balance is the prevalence of high fat foods (Blundell *et al,* 1996), and the consumption of a high fat diet poses a risk factor for obesity through its ability to substantially increase energy intake. This is achieved through a number of mechanisms such as increasing the palatability of foods, the low satiating efficiency and high energy density of fat. In addition, fat ingestion is accompanied by a low rate of fat oxidation in the presence of an unlimited storage capacity. Total energy intake is the most important issue, however it is the role of fat in influencing energy intake that makes this macronutrient significant. In contrast it is argued that CHO diets are more beneficial to appetite control, and therefore provide greater protection against weight gain, through a number of mechanisms such as their limited storage capacity, their high oxidative hierarchy and the poor conversion of CHO to fat. These factors make the habitual consumption of a high CHO, low fat diet the most plausible way to maintain energy balance thereby preventing weight gain and the associated health risk (Blundell and Le Noury, 2001). However, it is acknowledged that it is possible (although less likely) to overconsume on a high CHO diet. An individual could, potentially, override these physiological signals and reach a high-energy intake on CHO foods (and beverages), and also through the interaction of both CHO and fat. For instance in the short term, sweet high fat foods have a potent effect at stimulating energy intake.

In order to further the work carried out in this thesis, future studies may also focus on how the findings from this thesis may be used as potential treatments for those individuals susceptible to weight gain. For example, interventions could be developed which address portion size control and changes to food-values and the emotional response associated with certain foods. In addition, the use of fat mimetics (e.g. olestra-based foods) could prove to be particularly effective in those individuals with a sensory preference for dietary fat by continuing to provide the hedonic response and sensory qualities of real fats.

This thesis has highlighted a number of factors associated with human food choice behaviour and susceptibility to obesity. The cluster of risk factors that have been identified can be regarded as just one potential 'route' to obesity. The methodological and theoretical implications raised here need to be both acknowledged and addressed in future studies in order to further enhance our understanding of this complex, and fascinating, arena.

References

Ajzen, I. (1991) The theory of planned behaviour. *Organisational Behaviour and Human Decision Processes*, 50, 179-211.

Ajzen, I. and Fishbein, M. (1980) *Understanding Attitudes and Predicting Social Behaviour.* Englewood Cliffs: Prentice-Hall.

Ambler, C., Eliakim, A., Brasel, J. A., Lee, W.N., Burke, G. and Cooper, D.M. (1998) Fitness and the effect of exercise training on the dietary intake of healthy adolescents. *International Journal of Obesity*, 22, 354-362.

Allied Dunbar National Fitness Survey (1992) *A Report on Activity Patterns and Fitness Levels.* London: Sports Council And Health Education Authority.

Appleton, D.B. and De Vino, D.C. (1974) An animal model for the ketogenic diet. *Epilepsia*, 15, 211-227.

Armitage, C.J. and Conner, M. (1999) Predictive validity of the theory of planned behaviour: the role of questionnaire format and social desirability. *Journal of Community and Applied Social Psychology*, 9, 261-272.

Astrup, A. (2001) Healthy lifestyles in Europe: prevention of obesity and type 2 diabetes by diet and physical activity. *Public Health Nutrition*, 4, 499-515.

Astrup, A., Buemann, B., Toubro, S. and Raben, A. (1996) Defects in substrate oxidation involved in the predisposition to obesity. *Proceedings of the Nutrition Society*, 55, 817-828.

Baecke, J.A.H., Burema, J. and Frijters, J.E.R. (1982) A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *Amèrican Journal of Clinical Nutrition*, 36, 936-942.

Baghurst, K.I., Baghurst, P.A. and Record, S.J. (1994) Demographic and dietary profiles of high and low fat consumers in Australia. *Journal of Epidemiology and Community Health,* 48, 26-32.

Balcioglu, A. and Wurtman, R.J. (1998) Effects of phentermine on striatal dopamine and serotonin release in conscious rats: in vivo microdialysis study. *International Journal of Obesity Related Metabolic Disorders,* 22, 325-328.

Barkeling, B., Rössner, S. and Sjöberg, A. (1995) Methodological studies on single meal food intake characteristics in normal weight and obese men and women. *International Journal of Obesity,* 19, 284-290.

Barker, M. E., Thompson, K.A. and McClean, S.I. (1995) Attitudinal dimensions of food choice and nutrient intake. *British Journal of Nutrition,* 74, 649-659.

Beardsworth, A. (1995) The management of food ambivalence: Erosion and reconstruction. In D. Maurer and J. Sobal (eds) *Eating Agendas: Food and Nutrition as Social Problems. Social Problems and Social Issues.* Hawthorne: New York. pp. 117-142.

Beaton, S.A. (1994) Approaches to analysis of dietary data: relationship between planned analyses and choices of methodology. *American Journal of Clinical Nutrition,* 59(suppl), 253S-261S.

Benton, D. (1997) Dietary fat and cognitive functioning. In M. Hillbrand and R.T. Spitz (eds) *Lipids, Health and Behaviour,* APA: Washington DC. pp227-243.

Bergstrom, A *et al,* (2001) Obesity and renal cell cancer- a quantitative review. *British Journal of Cancer,* 85, 984-990.

Berridge, K.C. (1996) Food reward: brain substrates of wanting and liking. *Neuroscience and Biobehavioural Reviews,* 20 (1), 1-25.

Berridge, K.C. and Robinson, T.E. (1998) What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? *Brain Research Brain Research Reviews,* 28, 309-369.

Birch, L.L., McPhee, L., Shoba, B.C., Pirok, E. and Steinberg, L. (1987) What kind of exposure reduces childrens food neophobia? Looking vs. tasting. *Appetite,* 9, 171-178.

Birch, L.L., McPhee, L., Steinberg, L. and Sullivan, S. (1990) Conditioned flavour preferences in young children. *Physiology and Behaviour,* 47, 501-505.

Birch, L.L., Gunder, L. Grimm-Thomas, K and Laing, D.G. (1998) Infants' consumption of a new food enhances acceptance of similar foods. *Appetite,* 30, 283-295.

Black, A.E. (1997) Under-reporting of energy intake at all levels of energy expenditure: evidence from doubly labelled water studies. *Proceedings from the Nutrition Society,* 56, 121A.

Black, A.E. (1999) Small eaters or under-reporters? In *Progress in Obesity Research,* pp 223-228, ed. G. Ailhaud & B. Guy-Grand, Paris: John Libbney/ 8th International Congress on Obesity.

Black, A.E., Jebb, S.A., Bingham, A., Runswick, S.A. and Poppitt, S.D. (1993) The validation of energy and protein intakes by doubly labelled water and 24-hour urinary nitrogen excretion in post-obese subjects. *Journal of Human Nutrition and Dietetics,* 8, 51-64.

Black, A.E., Prentice, A.M. and Coward, W.A. (1985) Validation of the 7-day weighed diet record by comparison against total energy expenditure. *Proceedings of the BDA Study Conference, 1985,* British Dietetic Association: Birmingham, p.25.

Blackburn, G.L. (2001) Dietary patterns for weight management. *Obesity Research,* 9 (suppl 4), S217-S218.

Block, E. E. (1999) Characterisation of female high fat and low fat consumers. *MSc Thesis*, School of Psychology, University of Leeds.

Block, G., Hartman, A.M., Dresser, C.M., Carroll, M.D., Gannon, J. and Gardner, L. (1986) A data-based approach to dietary questionnaire design and testing. *American Journal of Epidemiology*, 124, 453-469.

Blundell, J.E. (1991) The biology of appetite. *Clinical Applied Nutrition*, 1, 21-31.

Blundell, J.E. (1997) Food intake and body weight regulation. In C. Bouchard and G.A. Bray (eds) *Regulation of body weight, biological and behavioural mechanisms*, Dahlem Workshop Reports. Life sciences research report, 57, John Wiley and Sons. pp 85-110.

Blundell, J.E., Burley, V.J., Cotton, J.R., Lawton, C.L. (1993) Dietary fat and the control of energy intake: evaluating the effects of fat on meal size and post meal satiety. *American Journal of Clinical Nutrition*, 57, 772S-778S.

Blundell, J.E. and Cooling, J. (1999) High- fat and low-fat (behavioural) phenotypes: biology or environment? *Proceedings of the Nutrition Society*, 58, 1-5.

Blundell, J.E. and Cooling, J. (2000) Routes to obesity: phenotypes, food choices and activity. *British Journal of Nutrition*, 83 (suppl), 33-38.

Blundell, J.E., Cooling, J. and King, N. (2002) Differences in postprandial responses to fat and carbohydrate loads in habitual high and low fat consumers (phenotypes). *British Journal of Nutrition*, 88 (2): 125-132.

Blundell, J.E. and Gillett, A. (2001) Control of food intake in the obese. *Obesity Research*, 9 (suppl 4), 263S-270S

Blundell, J.E. and Green, S. (1994) Nutrition and appetite control: implications for the regulation of body weight. *International Journal of Risk & Safety in Medicine*, 7, 135-145.

Blundell, J.E. and King, N.A. (1996) Overconsumption as a cause of weight gain: behavioural-physiological interactions in the control of food intake (appetite). *The Origins and Consequences of Obesity. Ciba Foundation Symposium* no. 201, pp. 138-158. Chichester, West Sussex: John Wiley & Sons.

Blundell, J.E. and Le Noury, J.C. (2001) Carbohydrates and appetite control. *Australian Journal of Nutrition and Dietetics,* 58 (suppl 1), S13-S18.

Blundell, J.E. and Le Noury (2002) Appetite. In *Encyclopaedia of Food and Culture.*

Blundell, J.E. and Macdiarmid, J.I. (1997) Fat as a risk factor for overconsumption: Satiation, satiety and patterns of eating. *Journal of the American Dietetic Association,* 97 (suppl), S63-S69.

Blundell, J.E. and Rogers, P.J. (1991) Satiating power of food. *Encyclopaedia of Human Biology,* 6, 723-733.

Blundell, J.E. and Stubbs, J. (2002) Diet composition and the control of food intake in humans. In D.G. Bray, C. Bouchard and W. P. T James (eds). *Handbook of Obesity.* New York, Marcel Dekker.

Bolton-Smith, C. and Woodward, M. (1994) Dietary composition and fat to sugar ratios in relation to obesity. *International Journal of Obesity,* 18, 820- 828.

Borah-Giddens, J. and Falciglia, G.A. (1993) A meta-analysis of the relationship in food preferences between parents and children. *Journal of Nutrition Education,* 25, 102-107.

Bouchard, C. (1994) Individual differences in energy intake and food preferences: are they inherited. *International Monitor on Eating Patterns and Weight Control,* first quarter, 2-7.

Bouchard, C. (1996) Can obesity be prevented? *Nutrition Reviews,* 54, S125-S130.

Bouchard, C., Tremblay, C., Le Blanc, G., Lortie, R., Savard, R. and Theriault, G. (1983) A method to assess energy expenditure in children and adults. *American Journal of Clinical Nutrition*, 37, 461-467.

Bray, G.A. and Popkin, B.M. (1998) Dietary fat does affect obesity rate. *American Journal of Clinical Nutrition*, 68, 1157-1173.

Briefel, R.R. (1994) Assessment of the US diet in national nutrition surveys: national collaborative efforts and NHANES. *American Journal of Clinical Nutrition*, 59 (1S), 164S-167S.

Briefel, R.R., Sempos, C.T., McDowell, M.A., Chein, S. and Alaimo, K. (1997) Dietary methods research in the third National Health and Nutrition Examination Survey: under-reporting of energy intake. *American Journal of Clinical Nutrition*, 65(suppl), 1203S-1209S.

Cabanac, M. (1971) Physiological role of pleasure. *Science*, 173, 1103-1107.

Cabanac, M. (1989) Palatability of food and the ponderstat. *Annuals of the New York Academy*, 575, 340-352.

Cabanac, M. (1992) Pleasure: the common currency. *Journal of Theoretical Biology*, 155, 173-200.

Ceesay, S.M., Prentice, A.M., Day, K.C., Murgatroyd, P.R., Goldberg, G.R. and Scott, W. (1989) The use of heart rate monitoring in the estimation of energy expenditure; a validation study using indirect whole-body calorimetry. *British Journal of Nutrition*, 61, 175-186.

Champagne, C.M., Baker, N.B., DeLany, J.P., Harsha, D.W. and Bray, G.A. (1998) Assessment of energy intake under-reporting by doubly labelled water and observations on reported nutrient intakes in children. *Journal of American Dietetic Association*, 98, 426-433.

Chapman, I.M., Goble, E.A., Wittert, G.A. and Horowitz, M. (1999) Effects of small-intestinal fat and carbohydrate infusions on appetite and food intake in obese and non-obese men. *American Journal of Clinical Nutrition,* 69, 6-12.

Conners, M., Bisogni, C.A., Bobal, J. and Devine, C.M. (2001) Managing values in personal food systems. *Appetite,* 36, 189-200.

Cooling, J. (1998) Behavioural and physiological differences between high fat and low fat consumers. *PhD thesis, Department of Psychology, University of Leeds.*

Cooling, J. and Blundell, J.E. (1998a) Are high fat and low fat consumers distinct phenotypes? Differences in the subjective and behavioural response to energy and nutrient challenges. *European Journal of Clinical Nutrition,* 52, 193-201.

Cooling. J. and Blundell, J.E. (1998b) Differences in energy expenditure and substrate oxidation between habitual high fat and low fat consumers (phenotypes). *International Journal of Obesity* 22, 612-618.

Cooling, J. and Blundell, J.E. (2000) Lean male high- and low-fat phenotypes - different routes for achieving energy balance. *International Journal of Obesity,* 24 (12), 1561-1566.

Cooling. J. and Blundell, J.E. (2001) High-fat and low-fat phenotypes: habitual eating of high and low fat foods not related to taste preference for fat. *European Journal of Clinical Nutrition,* 55, 1016-1021.

Cooling, J., Barth, J. and Blundell, J.E. (1998) The high fat phenotypes: is leptin involved in the adaptive response to a high fat (high energy) diet? *International Journal of Obesity,* 22, 1132-1135.

Cools, J., Schotte, D.E. and McNally, R.J. (1992) Emotional arousal and overeating in restrained eaters. *Journal of Abnormal Psychology,* 101 (2), 348-351.

Cooper, P.J. and Bowskill (1986) Dysphoric mood and overeating. *British Journal of Clinical Psychology,* 25, 155-156.

Cotton, J.R., Burley, V.J., Westrate, J.A. and Blundell, J.E. (1994) Dietary fat and appetite: similarities and differences in the satiating effect of meals supplemented with either fat or carbohydrate. *Journal of Human Nutrition and Dietetics,* 7, 11-24.

Cox, D.N., Perry, L., Moore, P.B., Vallid, L. and Mela, D.J. (1999) Sensory and hedonic association with macronutrient and energy intakes of lean and obese consumers. *International Journal of Obesity,* 23, 403-410.

de Castro, J.M. (1987) Macronutrient relationships with meal patterns and mood in the spontaneous feeding behaviour of humans. *Physiology and Behaviour,* 39, 561-569.

de Castro, J.M. (1993) Independence of genetic influences on body size, daily intake and meal patterns of humans. *Physiology and Behaviour,* 54, 633-639.

de Castro, J.M. (1994) Methodology, correctional analysis, and interpretation of diet diary records of the food and fluid intake of free living humans. *Appetite,* 23, 179-192.

de Castro, J.M. (1998) Prior day's intake has macronutrient-specific delayed negative feedback effects on the spontaneous food intake of free-living humans. *Journal of Nutrition,* 128 (1), 61-67.

de Graaf, C. (1993) The validity of appetite ratings. *Appetite* 21, 156-160.

de Graaf, C., Drijvers, J.J.M.M., Zimmermanns, N.J.H., van het Hof, K.H., Weststrate, J.A., van den Berg, H., Velthuis-te Wierik, E.J.M., Westerterp, K.R., Verboeket-van de Venne, W.P.H.G., Westerterp-Plantenga, M.S. (1997) Energy and fat compensation during long term consumption of reduced fat products. *Appetite.* 29(3), 305-323.

Delargy, H.J., Lawton, C.L., Smith, F.C., King, N.A. and Blundell, J.E. (1996) Electronic appetite rating system (EARS): validation of continuous automated monitoring of motivation to eat. *International Journal of Obesity,* 20 (suppl4), 104.

De Onis, M. and Blössner, M. (2000) Prevalence and trends of overweight among preschool children in developing countries. *American Journal of Clinical Nutrition,* 72, 1032-1039.

Department of Health (1999) Joint health surveys Unit on behalf of the Department of Health -1999. *Health Survey for England: Cardiovascular Disease '98.* The Stationary Office.

de Vries, J.H.M, Zock, P.L., Mensink, R.P. and Katan, M.B. (1994) Underestimation of energy intake by 3-d records compared with energy intake to maintain body weight in 269 non-obese adults. *American Journal of Clinical Nutrition,* 60, 855-860.

Dobson, A.J., Blijlevens, R., Alexander, H.M., Croce, N., Heller, R.F., Higginbotham, N., Pike, G., Plotnikoff, R., Russell, A. and Walker, R. (1993) Short fat questionnaire: a self administered measure of fat-intake behaviour. *Australian Journal of Public Health,* 17 (2), 144-149.

Dreon, D.M., Frey-Hewitt, B., Ellsworth, N., Williams, P.T., Terry, R.B. and Wood, P.D. (1988) Dietary fat: carbohydrate ratio and obesity in middle aged men. *American Journal of Clinical Nutrition,* 47, 995-1000.

Drewnowski, A. (1997) Why do we like fat? *Journal of the American Dietetic Association,* 97, S58-S62.

Drewnowski, A., Krahn, D.D., Demitrack, M.A., Nairn, K. and Gosnell, B.A. (1992) Taste responses and preferences for sweet high-fat foods: evidence for opioid involvement. *Physiology and Behaviour,* 51, 371-379.

Driver, H.S., Shulman, I., Baker, F.C. and Buffenstein, R. (1999) Energy content of the evening meal alters nocturnal body temperature but not sleep. *Physiology and Behaviour,* 68, 17-23.

Eck, L.H., Klesges, L.M. and Klesges, R.C. (1996) Precision and estimated accuracy of two short-term food frequency questionnaires compared with recalls and records. *Journal of Clinical Epidemiology,* 49 (10), 1195-1200.

Egger, G. and Swinburn, B.A. (1997) An ecological approach to the obesity pandenic. *British Medical Journal,* 315, 477-480.

Emmons, R.A. (1996) Strivings and feelings: Personal goals and subjective wellbeing. In P.M. Gollwitzer and J.A. Bargh (eds) *The Psychology of Action: Linking Cognition and Motivation to Behaviour.* New York: Guilford. pp.313-337.

Enzi, E. (1994) Socio-economic consequences of obesity. *PharmacoEconomics,* 5 (suppl 1), 54-57.

Fischler, C. (1988) Food, self and identity. *Social Science Information,* 27, 225-292.

Fisher, J.O. and Birch, L.L. (1995) Fat preferences and fat consumption of 3 to 5 year old children are related to parental adiposity. *Journal of the American Dietetic Association,* 95, 759-764.

Flegal, K. (1999) The obesity epidemic in children and adults: current evidence and research issues. *Medicine and Science in Sports and Exercise,* 31 (suppl 11) S509-S514.

Flint, A., Raben, A., Blundell, J.E. and Astrup, A. (2000) Reproducibility, power and validity of visual analogue scales in assessment of appetite sensations in single test meal studies. *International Journal of Obesity,* 24, 38-48.

Foltin, R.W., Fischman, M.W., Moran, T.H., Rolls, B.J. and Kelly, T.H. (1990) Caloric compensation for lunches varying in fat and carbohydrate content by humans in a residential laboratory. *American Journal of Obesity,* 52, 969-980.

French, S.J., Murray, B., Rumsey, R.D.E., Fadzlin, R. and Read, N.W. (1995) Adaptation to high-fat diets- effects on eating behaviour and plasma cholecystokinin. *British Journal of Nutrition,* 73 (2), 179-189.

Friedman, M.I. and Tordoff, M.G. (1986) Fatty acid oxidation and glucose utilisation interact to control food intake in rats. *American Journal of Physiology,* 251, R840-845.

Furst, T., Conners, M., Bisogni, C., Sobal, J. and Falk, L. (1996) Food choice: a conceptual model of the process. *Appetite,* 26, 247-265.

Gardner. P.L. (1987) Measuring ambivalence to science. *Journal of Research in Science Teaching,* 24, 241-247.

Garner, D.M. and Garfinkel, P.E. (1979) The Eating Attitude Test: an index of the symptoms of anorexia nervosa. *Psychological Medicine,* 9, 1-7.

Garner, D.M., Olmsted, M.P., Bohr, Y and Garfinkel, P.E. (1982) The Eating Attitude Test: psychometric features and clinical correlates. *Psychological Medicine,* 12, 871-878.

Garner, D.M., Olmsted, M.P. and Polivy, J. (1983) Development and validation of a multidimensional eating disorder inventory for anorexia nervosa and bulimia. *International Journal of Eating Disorders,* 2 (2), 15-34.

Garrow, J.S. (1974) *Energy balance and obesity in man.* North-Holland Publishing Company, Amsterdam.

Garrow, J. (1988) *Obesity and related diseases.* London, Churchill Livingston.

Glotzbach, S.F. and Heller, H.C. (1994) Temperature regulation. In M.H. Kryger, T. Roth, W.C. Dement (eds) *Principles and Practice of Sleep Medicine.* Philadelphia: W.B. Saunders, 1994. pp. 260-275.

Goldberg, G.R., Black, A.E., Jebb, S.A., Cole, T.J., Murgatroyd, P.R., Coward, W.A. and Prentice, A.E. (1991) Critical evaluation of energy intake using fundamental principles of energy physiology. Deviation of cut-off values to identify under-reporting. *European Journal of Clinical Nutrition,* 45, 569-581.

Goris, A.H.C., Westerterp-Plantenga, M.S. and Westerterp, K.R. (2000) Undereating and underrecording of habitual food intake in obese men: selective underreporting of fat intake. *American Journal of Clinical Nutrition,* 71, 130-134.

Green, S.M., Burley, V.J. and Blundell, J.E. (1994) Effect of fat and sucrose containing foods on the size of eating episodes and energy intake in lean males: potential for overconsumption. *European Journal of Clinical Nutrition,* 8, 547-555.

Gregory, J., Foster, K., Tyler, H. and Wiseman, M. (1990) *The Dietary and Nutritional Survey of British Adults,* London, HMSO.

Gretebeck, R.J., Montoye, H.J., Ballor, D. and Montoye, A.P. (1991) Comment on heart rate recording in field studies. *Journal of Sports Medicine and Physical Fitness,* 31, 629-631.

Hajnal, A., Mark, G.P. Rada, P.V., Lenard, L. and Hoebel, B.G. (1997) Norephinephrine microinjections in the hypothalamic paraventricular nucleus increase extracellular dopamine and decrease acetylcholine in the nucleus accumbens: Relevance for feeding reinforcement. *Journal of Neurochemistry,* 68, 667-674.

Haskell, W.L., Yee, M.C., Evans, A. and Irby, P.J. (1993) Simultaneous measurement of heart rate and body motion to quantitate physical activity. *Medical Science of Sports and Exercise,* 25, 109-115.

Health and Lifestyle Survey (1987) London: Health Promotion Research Trust.

Herrnstein, R.J. (1990) Rational choice and theory: Necessary but not sufficient. *American Psychologist,* 45, 356-367.

Hill, A.J. and Blundell, J.E. (1990) Sensitivity of the appetite control system in obese subjects to nutritional and serotoninergic challenges. *International .Journal of Obesity,* 14, 219-233.

Hill, A.J., Leathwood, P.D. and Blundell, J.E. (1987) Some evidence for short term caloric compensation in normal weight human subjects: The effects of high- and low-energy meals on hunger, food preference and food intake. *Human Nutrition,* 41A, 244-257.

Hill, A.J., Rodgers, P.J. and Blundell, J.E. (1995) Techniques for the experimental measurement of human eating behaviour and food intake: A practical guide. *International Journal of Obesity,* 19, 361-375.

Hill, J.O., Melby, C., Johnson, S.L. and Peters, J.C. (1995b) Physical activity and energy requirements. *American Journal of Clinical Nutrition,* 62 (suppl), S1059-S1066.

Hindmarch, I. and Parrott, A.C. (1979) The effects of repeated nocturnal doses of clobazam, dipotassium clorazepate and placebo, on subjective ratings of sleep and early morning behaviour and objective measures of arousal, psychomotor performance and anxiety. *British Journal of Clinical Pharmacology,* 7, 325-329.

Hu, F.B., Rimm, E., Smith-Warner, S.A., Feskanich, D., Stampfer, M.J., Ascherio, A., Sampson, L. and Willett, W.C. (1999) Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. *American Journal of Clinical Nutrition,* 69, 243-249.

Hulshof, K.F.A.M., Wedel, M., Lowik, M.R.H., Hermus, R.J.J., tn Hoor, F. and Ockhuizen, T.H. (1992) Clustering of dietary variables and other lifestyle factors (Dutch Nutritional Surveillance System). *Journal of Epidemiology and Community Health,* 46, 417-424.

Hulshof, T., de Graff, C. and Weststrate, J.A.(1993) The effects of preloads varying in physical state and fat content on satiety and energy intake. *Appetite,* 21, 273-286.

James, P.T., Leach, R., Kalamara, E. and Shayeghi, M. (2001) The worldwide obesity epidemic. *Obesity Research,* 9 (suppl 4), S228-S233.

Johnson, S.L., McPhee, L. and Birch, L.L. (1991) Conditioned preferences: Children prefer flavours associated with high dietary fat. *Physiology and Behaviour,* 50, 1245-1251.

Karhunen, L.J., Lappalainen, R.I., Vanninen, E.J., Kuikka, J.T. and Uusitupa, M.I.J. (1997) Regional blood flow during food exposure in obese and normal weight women. *Brain,* 120, 1675-1684.

Kelly, T.H., Foltin, R.W., Rolls, B.J. and Fischman, M.W. (1994) Effect of meal macronutrient and energy content on human performance. *Appetite,* 23, 97-111.

Kissileff, H.R. (1984) Satiating efficiency and a strategy for conducting food loading experiments. *Neuroscience and Behavioural Reviews,* 8, 129-135.

Kosslyn, S.M., Cacioppo, J.T., Davidson, R.J., Hugdahl, K., Lovallo, W.R., Spiegel, D. and Rose, R. (2002) Bridging Psychology and Biology. *American Psychologist,* 57 (5), 341-351.

Kuczmarski, R.J., Flegal, K.M., Campbell, S.M. and Johnson, C.L. (1994) Increasing prevalence of overweight among US adults: The national health and nutrition examination surveys 1960 to 1991. *Journal of the American Medical Association,* 272 (3), 205-211.

Lappalainen, R., Mennen, L., van Weert, L. and Mykkänen, H. (1993) Drinking water with a meal: a simple method of coping with feelings of hunger, satiety and desire to eat. *European Journal of Clinical Nutrition,* 47, 815-819.

Larson, D.E., Tataranni, P.A., Ferraro, R.T. and Ravussin, E. (1995) Ad libitum food intake on a 'cafeteria diet' in Native American women: relations with body composition and 24-h energy expenditure. *American Journal of Clinical Nutrition,* 62 (5), 911-917.

Lawton, C.L., Burley, V.J., Wales, J.K. and Blundell, J.E. (1993) Dietary fat and appetite control in obese subjects: weak effects on satiation and satiety. *International Journal of Obesity,* 17, 409-416.

Le Noury, J.C., Cooling, J and Blundell, J.E. (2000) Relationships between eating and sleeping: comparison of high fat and low fat (behavioural) phenotypes. *Appetite,* 35, 202.

Le Noury, J.C., Lawton, C. and Blundell, J.E. (2002) Food choice and hedonic responses: differences between overweight and lean high fat phenotypes.

Levine, J.A., Eberhardt, N.L. and Jenson, M.D. (1999) Role of nonexercise activity thermogenesis in resistance to fat gain in humans. *Science,* 283, 212-214.

Lissner, L and Heitmann, B.L. (1995) Dietary fat and obesity: evidence from epidemiology. *European Journal of Clinical Nutrition,* 49, 79-90.

Lissner, L., Levitsky, D.A., Struup, B.J., Kalkwarf, H.J. and Roe, D.A. (1987) Dietary fat and the regulation of energy intake in human subjects. *American Journal of Clinical Nutrition,* 46, 886-892.

Livingstone, M.B.E., Prentice, A.M., Coward, W.A., Ceesay, W.A., Strain, J.J., McKenna, P.G., Nevin, G.B., Barker, M.E. and Hickey, R.J. (1990) Simultaneous measurement of free-living energy expenditure by doubly labelled water method and heart rate monitoring. *American Journal of Clinical Nutrition,* 52, 59-65.

Lloyd, H.M., Green, M.W., and Rogers, P.J. (1994) Mood and cognitive performance effects of iso-caloric lunches differing in fat and carbohydrate content. *Physiology and Behaviour,* 56, 51-57.

Lloyd, H., Paisley, C. and Mela, D.J. (1993) Changing to a reduced fat diet: attitudes and beliefs of UK consumers. *European Journal of Clinical Nutrition,* 47, 361-373.

Lovelady, C., Meredith, C., McCrory, M., Nommsen, L., Joseph, L. and Dewey, K. (1993) Energy expenditure in lactating women: a comparison of doubly labelled water and heart rate monitoring methods. *American Journal of Clinical Nutrition,* 57, 512-518.

Macdiarmid, J.I. (1997) The characterisation and eating patterns of high and low fat consumers. *PhD Thesis, Department of Psychology, University of Leeds.*

Macdiarmid, J.I. and Blundell, J.E. (1998) Assessing dietary intake: who, what and why of under-reporting. *Nutrition Research Reviews.* 11, 231-253.

Macdiarmid, J.I., Cade, J.E. and Blundell, J.E. (1996a) High and low fat consumers, their macronutrient intake and body mass index: further analysis of the national diet and nutrition survey of British adults. *European Journal of Clinical Nutrition,* 50, 505-512.

Macdiarmid, J.I., Cade, J.E., Hamilton, K.V. and Blundell, J.E. (1996b) Leeds High Fat Study: Factors associated with high fat consumption. *International Journal of Obesity,* 20 (suppl 4), 48.

Mandenoff, A., Fumeron, F., Apfelbaum, M. and Margules, D.L. (1982) Endogenous opiates and energy balance. *Science,* 215, 1536-1538.

Margetts, B.M., Cade, J.E. and Osmond, C. (1989) Comparison of a food frequency questionnaire with a diet record. *International Journal of Epidemiology,* 18, 868-873.

Martel, P. and Fantino, M. (1996) Mesolimbic dopaminergic system activity as a function of food reward: a microdialysis study. *Pharmacological and Biochemical Behaviour,* 53, 221-226.

Martin, L.J., Lockwood, G.A., Kristal, A.R., Kriukov, V., Greenberg, C., Shatuck, A.L. and Boyd, N.F. (1997) Assessment of a food frequency questionnaire as a screening tool for low fat intakes. *Controlled Clinical Trials,* 18, 241-250.

Martin, L.J., Su, W., Jones, P.J., Lockwood, G.A., Tritchler, D.L. and Boyd, N.F. (1996) Comparison of energy intakes determined by food records and doubly labelled water in women participating in a dietary intervention trial. *American Journal of Clinical Nutrition*, 63, 483-490.

Mason, J. (1996) *Qualitative Research.* Sage Publishing Ltd. p.35-59 and p.135-163.
Mattes, R. (1990) Hunger ratings are not a valid proxy measure of reported food intake in humans. *Appetite*, 15, 103-113.

Mcardle, W.D., Katch, F.I., Katch, V.L. (1991) Individual differences and measurement of energy capacities. In *Exercise Physiology, Energy, Nutrition and Human Performance.* Lea & Febiger. Philadelphia.

Meiselman, H.L., Waterman, D. and Symington, T.E.(1974) *Technical Report 75-63-FSL.* US Army Natick Development Center: Natick.

Meiselman, H.L., de Graaf, C. and Lesher, L.L. (2000) The effects of variety and monotony on food acceptance and intake at a midday meal. *Physiology and Behaviour*, 70, 119-125.

Mela, D.J. (1999) Food choice and intake: the human factor. *Proceedings of the Nutrition Society*, 58, 513-521.

Mela, D.J. and Rogers, P.J. (1998) *Food, Eating and Obesity: The Psychobiological Basis of Appetite and Weight Control.* London: Chapman and Hall.

Mela, D. J. and Sacchetti, D.A. (1991) Sensory preferences for fats: relationship with diet and body composition. *American Journal of Clinical Nutrition*, 53, 908-915.

National Audit Office (2001) *Tacking Obesity in England.* The Stationary Office.

Oliver, G., Wardle, J. and Gibson, E.L. (2000) Stress and food choice: a laboratory study. *Psychometric Medicine*, 62 (6), 853-865.

O, Reilly, L.M. (2001) Mis-reporting of Food Intake by UK Adults. *PhD Thesis, University of Ulster.*

Oswald, I. (1980) Sleep as a restorative function: human clues. *Programme Brain Research,* 53, 275-288.

Pagliassotti, M.J., Gayles, E.C. and Hill, J.O. (1997) Fat and energy balance. *Annuals of the New York Academy of Sciences,* 827, 431-448.

Parrott, A.C. and Hindmarch, I. (1980) The Leeds sleep evaluation questionnaire in psychopharmacological investigations: A review. *Psychopharmacology,* 71, 173-179.

Patton, D., Barnes, G.E. and Murray, R.P.(1993) Personality characteristics of smokers and ex-smokers. *Personality and Individual Differences,* 15 (6), 653-664.

Paz, A. and Berry, E.M. (1997) Effect of meal composition on alertness and performance of hospital night-shift workers - do mood and performance have different determinants? *Annals of Nutrition and Metabolism,* 41 (5), 291-298.

Pearcey, S.M. and de Castro, J.M. (2002) Food intake and meal patterns of weight-stable and weight gaining persons. *American Journal of Clinical Nutrition,* 76 (1), 107-112.

Pliner, P. (1982) The effects of mere exposure on liking for edible substances. *Appetite,* 3, 283-290.

Polivy, J., Herman, C.P. and McFarlance, T. (1994) Effects of anxiety on eating: does palatability moderate distress-induced overeating in dieters. *Journal of Abnormal Psychology,* 103 (3), 505-510.

Porrini, M., Crovetti, R., Testolin, G., and Silva, S. (1995) Evaluation of satiety sensation and food intake after different preloads. *Appetite,* 25, 17-30.

Prentice, A.M. and Jebb, S.A. (1995) Obesity in Britain: gluttony or sloth? *British Medical Journal,* 311, 437-439.

Prentice, A.M., Black, A.E., Coward, W.A., Davies, H.L. Golberg, G.R., Murgatroyd, P.R., Ashford, J., Sawyer, M. and Whitehead, R.G. (1986) High levels of energy expenditure in obese women. *British Medical Journal,* 292, 983-987.

Ravussin, E. and Bogardus, C. (1989) Relationship of genetics, age and physical fitness to daily energy expenditure and fuel utilisation. *American Journal of Clinical Nutrition,* 49, Suppl 5, S968-S975.

Ravussin, E. and Gautier, J.F. (1999) Metabolic predictors of weight gain. *International Journal of Obesity,* 23 (suppl 1), 37-41.

Ravussin, E., Lillioja, S., Anderson, T.E., Christin, I. and Bogardus, C. (1986) Determinants of 24-hour energy expenditure in man. Methods and results using a respiratory chamber. *Journal of Clinical Investigation,* 78, 1568-1578.

Ravussin, E. and Swinburn, B.A. (1992) Pathophysiology of obesity. *The Lancet,* 340, 404-408.

Raynor, H.A. and Epstein, L.H. (2001) Dietary variety, energy regulation and obesity. *Psychological Bulletin,* 127 (33), 325-341.

Rissanen, A.M., Heliovaara, M., Knekt, P., Reunanen, A. and Aromaa, A. (1991) Determinants of weight gain and overweight in adults Finns. *European Journal of Clinical Nutrition,* 45, 419-430.

Rissanen, A., Hakala, P., Lissner, J., Mattlar, C-E., Koskenvuo, M. and Ronnemaa, T. (2002) Acquired preference especially for dietary fat and obesity: a study of weight-discordant monozygotic twin pairs. *International Journal of Obesity,* 26, 973-977.

Robinson, R.G., McHugh, P.R., and Folstein, M.F. (1975) Measurement of appetite disturbances in psychiatric disorders. *Journal of Psychiatric Research,* 12, 59-68.

Roe, L., Strong, C., Whiteside, C., Neil, A. and Mant, D. (1994) Dietary intervention in primary care: validity of the DINE method for diet assessment. *Family Practice,* 11, 375-378.

Rolls, B.J. (1988) Food beliefs and food choices in adolescents. *Medical Journal of Australia,* 148, S9-S13.

Romieu, I., Willett, W., Stampfer, M.J. *et al* (1988) Energy intake and other determinants of relative weight. *American Journal of Clinical Nutrition,* 47, 406-412.

Romon, M., Lebel, P., Velly, C., Marecaux, N., Fruchart, J.C. and Dallongeville, J. (1999) Leptin response to carbohydrate or fat meal and association with subsequent satiety and energy intake. *American Journal of Physiology-Endocrinology and Metabolism,* 277 (5), 855-861.

Romsos, D.R., Gosnell, B.A., Morley, J.E. and Levine, A.S. (1987) Effects of kappa opiate agonists, cholecystokinin and bombesin on intake of diets varying in carbohydrate-to-fat ratio in rats. *Journal of Nutrition,* 117, 976-985.

Rozin, P. (1990) Acquisition of stable food preferences. *Nutrition Reviews,* 48, 106-113.

Rozin, P. (1998) *Towards a Psychology of Food Choice.* Danone Chair Monograph, Institut Danone.

Rozin, P. and Millman, L. (1987) Family environment, not heredity, accounts for family resemblances in food preferences and attitudes. A twin study. *Appetite,* 8, 125-134.

Saba, A., Turrini, A., Di Natale, R. and D'Amicis, A. (1999) Attitudes towards food containing fats in subjects of different body size. *International Journal of Obesity,* 23, 1160-1169.

Saelens, B. E. and Epstein, L.H. (1996) Reinforcing value of food in obese and non-obese women. *Appetite,* 27, 41-50.

Saris, W.H.M. (1996) Physical inactivity and metabolic factors as predictors of weight gain. *Nutrition Reviews,* 54 (suppl), S110-S115.

Sawayer, A.L., Tucker, K., Tsay, R., Willett, W., Saltzman, E., Dallal, G.E. and Robert, S.B. (1996) Evaluation of four methods for determining energy intake in young and old women: comparison with doubly labelled water measurements of total energy expenditure. *American Journal of Clinical Nutrition,* 63, 491-499.

Schaefer, E.J., Augustin, J.L., Schaefer, M.M., Rasmussen, H., Ordovas, J.M., Dallal, G.E. and Dwyer, J.T. (2000) Lack of efficacy of a food-frequency questionnaire in assessing dietary macronutrient intakes in subjects consuming diets of known composition. *American Journal of Clinical Nutrition,* 71, 746-751.

Schoeller, D.A. (1990) How accurate is self-reported dietary energy intake? *Nutrition Reviews,* 48, 373-379.

Schoeller, D.A. (1995) Limitations in the assessment if dietary energy intake by self report. *Metabolism,* 44, 18-22.

Schofield, J. (1985) Predicting basal metabolic rate, new standards and reviews of previous work. *Human Nutrition and Clinical Nutrition,* 44, 1-19.

Schrauwen, P., van Marken Lichtenbelt, W.D., Saris, W.H.M. and Westerterp, K.R. (1997) Changes in fat oxidation in response to a high fat diet. *American Journal of Clinical Nutrition,* 66, 276-282.

Schrauwen, P. and Westerterp, K. R. (2000) The role of high fat diets and physical activity in the regulation of body weight. *British Journal of Nutrition,* 84, 417-427.

Sclafani, A. (1990) Nutritionally based learned flavour preferences in rats. In E.D. Capaldi and T.L Powley (eds) *Taste, Experience and Feeding,* Washington. DC: American Psychological Association. pp. 139-156.

Sclafani, A. (1997) Learned controls of ingestive behaviour. *Appetite,* 29, 153-158.

Segal, L., Carter, R. and Zimmet, P. (1994) The cost of obesity. The Australian perspective. *PharmacoEconomics,* 5 (suppl 1), 45-52.

Seidell, J.C. (1998) Dietary fat and obesity: an epidemiologic perspective. *American Journal of Clinical Nutrition,* 67 (suppl), 546S-550S.

Shepherd, R. (1990) Overview of factors influencing food choice. In M. Ashwell (Ed.) Why we eat what we eat, Proceedings of the 12th British Nutrition Foundation Annual Conference. *The British Nutrition Foundation Nutrition Bulletin,* 15 (suppl. 1), 12-30.

Shepherd, R. and Stockley, L. (1985) Fat consumption and attitudes towards food with a high fat content. *Human Nutrition: Applied Nutrition,* 34A, 431-442.

Shepherd, R. and Stockley, L. (1987) Nutrition knowledge, attitudes and fat consumption. *Journal of the American Dietetic Association, 37, 615-319.*

Shepherd, R. and Towler, G. (1992) Nutrition knowledge, attitudes and fat intake: application of the theory of reasoned action. *Journal of Human Nutrition and Dietetics,* 5, 387-397.

Smith, J.A. (1995) The search for meanings. Semi-structured interviewing and qualitative analysis. In Smith et al. *Rethinking Methods in Psychology.* London:Sage.

Smith, J.A. *et al* (1995). *Rethinking Methods in Psychology.* London:Sage.

Sonne-Holm, S. and Sorensen, T.I. (1977) Post war course of the prevalence of extreme overweight among Danish young men. *Journal of Chronic Diseases,* 30, 351-358.

Spurs, G.B., Prentice, A.M., Murgatroyd, P.R., Goldberg, G.R., Reina, J.C. and Christman, N.T. (1988) Energy expenditure from minute by minute heart rate recording: comparison with indirect calorimetry. *American Journal of Clinical Nutrition,* 48, 552-559.

Stafleu, A., de Graaf, C., van Staveren, W.A. and de Jong, M.A. (1994) Attitudes towards high fat foods and their low fat alternatives: reliability and relationship with fat intake. *Appetite,* 22, 183-196.

Steptoe, A., Pollard, T.M. and Wardle, J. (1995) Development of a measure of the motives underlying the selection of food: the food choice questionnaire. *Appetite,* 25, 267-284.

Story, M. and Resnick, M.D. (1986) Adolescents' views on food and nutrition. *Journal of Nutrition Education,* 18, 188-192.

Stubbs, R.J. (1995) Macronutrient effects on appetite. *International Journal of Obesity,* 19, S11-S19.

Stubbs, R.J. (1998) Appetite, feeding behaviour and energy balance in human subjects, *Proceedings of the Nutrition Society,* 57, 1.

Stubbs, R.J. (1999) Peripheral signals affecting food intake. *Journal of Nutrition,* 15, 7-8.

Stubbs, R.J, Ferres, S. and Horgan, G. (2000) Energy density of foods: effects on energy intake. *Critical Reviews in Food Science and Nutrition,* 40 (6), 481-515.

Stubbs, R.J., Goldberg, G.R., Murgatroyd, P.R. and Prentice, A.M. (1993) Carbohydrate balance and day-to-day food intake in man. *American Journal of Clinical Nutrition,* 57, 897-890.

Stubbs, R.J., Harbron, C.G. and Prentice, A.M. (1996) Covert manipulation of the dietary fat to carbohydrate ratio of isoenergentically dense diets: effect of food intake in feeding men *ad libitum, International Journal of Obesity,* 20, 651-660.

Stubbs, R.J., Harbron, C.G., Murgatroyd, P.R. and Prentice, A.M. (1995) Covert manipulation of dietary fat and energy density: effect on substrate flux and food intake in men eating ad libitum. *American Journal of Clinical Nutrition* 62, 316-329.

Stubbs, R.J., Sepp, A., Hughes, D.A., Johnstone, A.M., Horgan, G.W., King, N. and Blundell, J.E. (2002) The effect of graded levels of exercise on energy intake and balance in free-living men, consuming their normal diet. *European Journal of Clinical Nutrition, 56*, 129-140.

Stunkard, A.J. and Messick, S. (1985) The three factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *Journal of Psychosomatic Research,* 29, 71-83.

Tataranni, P.A. and Ravussin, E. (1997) Effect of fat intake on energy balance. *Nutritional Implications of Macronutrient Substitutes Annuals of the New York Academy of Sciences,* 819, 37-43.

Tate, J. and Cade, J. (1990) Public knowledge of dietary fat and coronary heart disease. *Journal of Health Education,* 49 (1), 35-35.

Thomas, C.D., Peters, J.C., Reed, G.W. Abumrad, N.W., Sun, M. and Hill, J.O. (1992) Nutrient balance and energy expenditure during ad-libitum feeding of high fat and high carbohydrate diet in humans. *American Journal of Clinical Nutrition,* 55, 934-942.

Thompson, D.A. and Campbell, R.G. (1977) Hunger in humans induced by 2-deoxy-D-glucose: glucoprivic control of taste preference and food intake. *Science,* 198, 1065-1068.

Thomson, D., Edelsberg, J., Colditz, G., Bird, A. and Oster, G. (1998) The lifetime health and economic costs of obesity. *International Journal of Obesity,* 22 (suppl. 3), S19.

Totterdell, P. and Folkard, S. (1992) In situ repeated measures of affect and cognitive performance facilitated by use of a hand held computer. *Behavioural Research Methods (Instr Comp),* 24 (4), 545-553.

Tremblay, A., Plourde, G., Despres, J.P. and Bouchard, C. (1989) Impact of dietary fat content and fat oxidation on energy intake in humans. *American Journal of Clinical Nutrition*, 49, 799-805.

Triandis, H.C. (1977) *Interpersonal Behaviour.* Brook/Cole: Monterey, CA.

Tucker, L.A. and Kano, M.J. (1992) Dietary fat and body fat: a multivariate study of 205 adult females. *American Journal of Clinical Nutrition*, 56, 616-622.

Underwood, B.J. (1975) Individual differences as a crucible in theory construction. *American Psychologist*, 30, 128-134.

Van Stratum, P., Lussenburg, R.N., van Wezel, L.A., Vergroeson, A.J. and Cremer, H.D. (1978) The effect of dietary carbohydrate: fat ration on energy intake by adult women. *American Journal of Clinical Nutrition*, 31, 206-212.

Van Strien, T., Fritjers, J.E.R., Bergers, G.P.A. and Defares, P.B. (1986) Dutch eating behaviour questionnaire for assessment of restrained, emotional and external eating behaviour. *International Journal of Eating Disorders*, 5, 295-315.

Votruba, S.B., Horvitz, M.A. and Schoeller, D.A. (2000) The role of exercise in the treatment of obesity. *Nutrition*, 16, 179-188.

Wang, G.J., Volkow, N.D., Logan, J., Pappas, N.R., Wong, C.T., Zhu, W., Netusil, N. and Fowler, J.S. (2001) Brain dopamine and obesity. *The Lancet*, 357, 354-357.

Wardle, J. (1986) The assessment of restrained eating. *Behaviour Research and Therapy*, 24, 213-215.

Wardle, J. (1987) Eating style: a validation study of the Dutch Eating Behaviour Questionnaire in normal subjects and women with eating disorders. *Journal of Psychosomatic Research*, 31, 161-169.

Wareham, N.J., Hennings, S.J., Prentice, A.M. and Day, N.E. (1997) Feasibility of heart rate monitoring to estimate total level and pattern of energy expenditure in a population based epidemiological study. *British Journal of Nutrition,* 78, 889-900.

Weir, J.B. (1949) New method for calculating metabolic rate with special reference to protein metabolism. *Journal of Physiology,* 109, 1-9.

Wells, A.S., Read, N.W., Idzikowski, C. and Jones, J. (1995) Increases in objective measures of sleepiness after meals. *Sleep Research,* 24, 34.

Well, A.S., Read, N.W., Uvnas-Moberg, K. and Alster, P. (1997) Influences of fat and carbohydrate on post prandial sleepiness, mood and hormones. *Physiology and Behaviour,* 61, 679-686.

West, D.B. and Yorke, B. (1998) Dietary fat, genetic predisposition, and obesity: lessons from animal models. *American Journal of Clinical Nutrition,* 67 (suppl), 505S-512S.

Westerterp, K.R., Saris, W.H.M., Van Es M. and TEN Hoor, F. (1986) The use of doubly labelled water technique in humans during heavy sustained exercise. *Journal of Applied Physiology,* 61, 2162-2167.

Westerterp, K.R., Wilson, S.A.J. and Rolland, V. (1999) Diet induced thermogenesis measured over 24-hours in a respiratory chamber: Effect of diet composition. *International Journal of Obesity,* 23, 287-292.

Westerterp-Plantenga, M.S., Pasman, W.J., Yedema, M.J.W. and Wijckmans-Duijsens, N.E.G. (1996) Energy intake adaptation of food intake to extreme energy densities of food by obese and non-obese women. *European Journal of Clinical Nutrition,* 50, 401-407.

Westerterp-Plantenga, M.S., Rolland, V., Wilson, S.A. and Westerterp, K.R. (1998) Satiety related to 24 hr diet-induced thermogenesis during high protein/ carbohydrate vs. high fat diets measured in a respiratory chamber. *European Journal of Clinical Nutrition,* 53, 495-502.

Weststrate, J.A. (1993) Resting metabolic rate and diet-induced thermogenesis: a methodological reappraisal. *American Journal of Clinical Nutrition,* 58, 592-601.

Willett, W.C. (1998) Is dietary fat a major determinant of body fat? *American Journal of Clinical Nutrition,* 67 (suppl), 556S-562S.

Wolf, A.M. and Colditz, G.A. (1998) Current estimates of the economic cost of obesity in the United States. *Obesity Research,* 6, 97.

World Health Organization (2003) Obesity and overweight. *Global Strategy on Diet, Physical Activity and Health.* WHO report.

Wurtman, J.J. (1993) Depression and weight gain: the serotonin connection. *Journal of Affective Disorders,* 29 (2-3), 183-192.

Wurtman, R.J. and Wurtman, J.J. (1995) Brain serotonin, carbohydrate craving, obesity and depression. *Obesity Research,* 3 (4), 477S-480S.

Yeomans, M.R. (1996) Palatability and the micro-structure of feeding in humans: the appetiser effect. *Appetite,* 27, 119-133.

Yeomans, M.R. and Symes, T. (1999) Individual differences in the use of pleasantness and palatability ratings. *Appetite,* 32, 383-394.

Zurlo, F., Nemeth, P.M., Choksi, R.M., Sesodia, S. and Ravussin, E. (1994) Whole body energy metabolism and skeletal muscle biochemical characteristics. *Metabolism: Clinical and Experimental,* 43, 481-486.

Appendices

Appendix i: The Consent Form

CONSENT FORM

NAME : ....

Please answer the following questions by circling the appropriate response:

Do you suffer from asthma?	YES	NO
Do you suffer from any medical condition?	YES	NO
Are you currently taking any medication?	YES	NO
Are you of sound physical & mental health?	YES	NO

I give my informed consent to participate in this study. I consent to the publication of study results so long as the information is anonymous. I understand that although a record will be kept of my having taken part in this study, all data collected from my participation will be identified by number only.

I have been informed that the general purpose of the study is to investigate contributing factors to overall energy balance in healthy males. I have also been informed that the full nature of the study will be revealed to me once I have completed the study.

I have been informed that the School of Psychology Ethics Committee has approved the study and all the ingredients of the foods used during the study pose no risks and are currently commercially available.

I have had the opportunity to ask for explanation of the study and procedures. In addition, I have been given a copy of the participant information sheet, which I have read and understood.

I have been informed that I am free to withdraw from the study at any time.

Signed .... Date ....

Researcher .... Date ....

Appendix ii : The Food Frequency Questionnaire (FFQ) (Margetts *et al*, 1989)

FOOD FREQUENCY QUESTIONNAIRE

Please read the following instructions carefully before completing the questionnaire

1. Please answer ALL the questions
2. Select the answer that best applies to your situation and TICK the appropriate column.

Only tick ONE box on each line (i.e. one tick per food).

If you make a mistake put a cross through the tick incorrectly made and tick the correct answer.

For example:

How often do you eat the following foods ?		2 or more times a day	once a day	3-5 times a week	1-2 times a week	1-3 times month	Rarely /never
Milk (including in tea/coffee)	:Whole	☐	☐	☐	☐	☐	☐
	:Semi-Skimmed	☐	☐	☐	☐	☐	☐
	:Skimmed	☐	☐	☐	☐	☐	☐

HOW OFTEN DO YOU EAT EACH OF THE FOLLOWING FOODS ? (tick the appropriate box)
Please record what you normally eat and drink.

How often do you eat the following foods ?		2 or more times a day	once a day	3-5 times a week	1-2 times a week	1-3 times month	Rarely /never
DAIRY PRODUCTS							
Milk (including in tea/coffee)	: Whole	☐	☐	☐	☐	☐	☐
	: Semi-Skimmed	☐	☐	☐	☐	☐	☐
	: Skimmed	☐	☐	☐	☐	☐	☐
Butter		☐	☐	☐	☐	☐	☐
Margarine (eg. Stork, Clover)		☐	☐	☐	☐	☐	☐
Polyunsaturated Margarine (eg.Flora, sunflower)		☐	☐	☐	☐	☐	☐
Low Fat Spreads (eg.Outline, Gold)		☐	☐	☐	☐	☐	☐
Ice Cream		☐	☐	☐	☐	☐	☐
Yoghurt, Fromage Frais		☐	☐	☐	☐	☐	☐
Cheese (eg.cheddar, stilton, cream cheese)		☐	☐	☐	☐	☐	☐
Low Fat Cheese (eg.cottage, reduced fat cheese)		☐	☐	☐	☐	☐	☐
Eggs - Fried		☐	☐	☐	☐	☐	☐
- not Fried (boiled, poached, in baking)		☐	☐	☐	☐	☐	☐
Cheese and/ or Egg Dishes (eg. pizza, quiche, macaroni cheese)		☐	☐	☐	☐	☐	☐

How often do you eat the following foods ?	2 or more times a day	once a day	3-5 times a week	1-2 times a week	1-3 month/never	Rarely
MEATS AND FISH						
Beef - roast/steak	☐	☐	☐	☐	☐	☐
Lamb - roast/chops	☐	☐	☐	☐	☐	☐
Pork - roast/chops	☐	☐	☐	☐	☐	☐
Chicken, Turkey or other poultry	☐	☐	☐	☐	☐	☐
Bacon or Gammon	☐	☐	☐	☐	☐	☐
Meat Dishes (eg. stew, curry, chilli, lasagne)	☐	☐	☐	☐	☐	☐
Canned Meats (eg. corned beef, ham)	☐	☐	☐	☐	☐	☐
Meat pies, Sausage rolls or Pasties	☐	☐	☐	☐	☐	☐
Sausages or Beefburgers	☐	☐	☐	☐	☐	☐

Liver, Kidney, Pate (other offal products)	☐	☐	☐	☐	☐	☐
Fish and Seafood - not fried	☐	☐	☐	☐	☐	☐
- fried	☐	☐	☐	☐	☐	☐
- canned (eg.tuna,salmon)	☐	☐	☐	☐	☐	☐
BREAD AND CEREALS						
White Bread	☐	☐	☐	☐	☐	☐
Brown / Granary Bread	☐	☐	☐	☐	☐	☐
Wholemeal Bread (including chapattis)	☐	☐	☐	☐	☐	☐
Sweet Biscuits (plain and chocolate)	☐	☐	☐	☐	☐	☐
Crackers / Crispbread	☐	☐	☐	☐	☐	☐
Cakes, Buns, Pastries	☐	☐	☐	☐	☐	☐
Puddings (eg. fruit pies, cheesecake)	☐	☐	☐	☐	☐	☐
Breakfast Cereal:						
- High Fibre (eg. bran flakes, Weetabix)	☐	☐	☐	☐	☐	☐
- Ordinary (eg.cornflakes, rice krispies)	☐	☐	☐	☐	☐	☐
- Muesli	☐	☐	☐	☐	☐	☐
Rice or Pasta	☐	☐	☐	☐	☐	☐
FRUIT AND VEGETABLES						
Apples, Pears	☐	☐	☐	☐	☐	☐
Oranges, Grapefruit or other citrus fruit	☐	☐	☐	☐	☐	☐
Bananas	☐	☐	☐	☐	☐	☐
Green Vegetables (eg.cabbage,peas,broccoli)	☐	☐	☐	☐	☐	☐
Carrots, Tomatoes (fresh or canned)	☐	☐	☐	☐	☐	☐
Other vegetables (including salad vegetables)	☐	☐	☐	☐	☐	☐
Baked Beans	☐	☐	☐	☐	☐	☐
Other Beans / Lentils (eg. dahl)	☐	☐	☐	☐	☐	☐
Vegetable dishes (eg. stew, curry - NO meat)	☐	☐	☐	☐	☐	☐
Potatoes - chips, roasted, fried	☐	☐	☐	☐	☐	☐
-not fried (boiled, baked)	☐	☐	☐	☐	☐	☐

How often do you eat the following foods ?	2 or more times a day	once a day	3-5 times a week	1-2 times a week	1-3 times a month	Rarely /never
BEVERAGES						
Beer or Lager	☐	☐	☐	☐	☐	☐
Wine, Sherry or Spirits	☐	☐	☐	☐	☐	☐
Tea or Coffee	☐	☐	☐	☐	☐	☐
Squash or Fizzy Drinks	☐	☐	☐	☐	☐	☐
Low Calorie Drinks	☐	☐	☐	☐	☐	☐
Pure Fruit Juices	☐	☐	☐	☐	☐	☐
MISCELLANEOUS						
Chocolate	☐	☐	☐	☐	☐	☐
Sweets	☐	☐	☐	☐	☐	☐
Sweet spreads (eg. jam, marmalade)	☐	☐	☐	☐	☐	☐
Sugar (eg. in tea/coffee, on cereal)	☐	☐	☐	☐	☐	☐
Crisps and savoury snacks	☐	☐	☐	☐	☐	☐
Nuts (including peanut butter)	☐	☐	☐	☐	☐	☐
Sauces and Pickles (eg. Ketchup, Branston)	☐	☐	☐	☐	☐	☐
Salad oils, Dressings, Mayonnaise	☐	☐	☐	☐	☐	☐

Are there any other foods that have not been recorded that you regularly eat ?
Please write what they are and how often you eat them:

--------------------	☐	☐	☐	☐	☐	☐
--------------------	☐	☐	☐	☐	☐	☐

Appendix iii : The Dietary Instrument for Nutrition Education (DINE) (Roe, 1994)

DINE QUESTIONNAIRE

About how many times a week do you eat a serving of the following foods?

	less than 1 a week	1-2 a week	3-5 a week	6 or more a week
Beefburgers or sausages	1	2	4	6
Beef, pork or lamb	1	2	6	9
Bacon, meat pies, processed meat	1	2	5	8
Chicken or turkey	0	1	3	5
Fish (NOT fried)	0	0	1	2

□□

About how many times a week do you eat a serving of the following foods?

	less than 1 a week	1-2 a week	3-5 a week	6 or more a week
Cheese (any except cottage)	1	2	6	9
ANY fried food, fried fish, chips cooked breakfast, samosas	1	2	6	9
Cakes, pies, puddings, pastries	1	2	5	8
Biscuits, chocolate, or crisps	1	2	4	6

□□

About how much milk do you yourself use in a day, for drinking or in cereal, tea or coffee? What is your usual type of milk?				
	less than quarter pint	about a quarter pint	about a half pint	1 pint or more
Full cream (sliver top) or Channel Islands (gold top)	1	3	6	12
Semi-skimmed (red top)	0	1	3	6
Skimmed (blue top)	0	0	0	0

□□

About how many pats or rounded teaspoons of margarine or butter do you usually use in a day, for example on bread, sandwiches, toast, potatoes or vegetables?			
Butter	pats	(score 4 for each pat in a day	total)
Margarine	pats	(score 4 for each pat in a day	total)
Low fat spread	pats	(score 2 for each pat in a day	total)

□□

TOTAL SCORE		

Appendix iv : The Short Fat Questionnaire (SFQ) (Dobson *et al*, 1993)

Short Fat Questionnaire (Version B). **Name**________________________________

Please tick one box for each question...Tick the number that applies to your diet.

1. *How often do you eat fried food with a batter or breadcrumb coating?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

2. *How often do you eat gravy, cream sauces or cheese sauces?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

3. *How often do you add butter, margarine, oil or sour cream to vegetables, cooked rice or spaghetti?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

4. *How often do you eat vegetables that are fried or roasted with oil?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

5. *How is your meat usually cooked?*

Fried (4) _
Stewed or goulash (3) _
Grilled or roasted with added oil or fat (2) _
Grilled or roasted without added oil or fat (1) _
Eat meat occasionally or never (0) _

6. *How many times a week do you eat sausages, salamis, meat pies, hamburgers or bacon?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

7. *How do you spread butter/margarine on your bread?*

Thickly (3) _
Medium (2) _
Thinly (1) _
Don't use butter or margarine (0) _

8. *How many times a week do you eat chips or french-fries?*

Six or more times a week (4) _
Three to five times a week (3) _

Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

9. *How often do you eat pastries, cakes, sweet biscuits or croissants?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

10. *How many times a week do you eat chocolate, chocolate biscuits or sweet snack bars?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

11. *How many times a week do you eat potato crisps, corn chips or nuts?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

12. *How often do you eat cream?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

13. *How often do you eat ice cream?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

14. *How many times a week do you eat cheddar, edam or other hard cheeses, cream cheese or cheese like camembert?*

Six or more times a week (4) _
Three to five times a week (3) _
Once or twice a week (2) _
Less than once a week (1) _
Never (0) _

15. *What type of milk do you drink or use in cooking or tea and coffee?*

Condensed (4) _
Full-cream (3) _
Full-cream and reduced fat (2) _
Reduced fat (1) _
Skimmed or none (0) _

16. *How much of the skin on your chicken do you eat?*

Most or all of the skin (2) _
Some of the skin (1) _

None of the skin/I am vegetarian (0) _

17. *How much of the fat on your meat do you eat?*

Most or all of the fat (2) _
Some of the fat (1) _
None of the fat/I am vegetarian (0) _

THANK YOU FOR YOUR CO-OPERATION

Score: [ ]

Appendix v : The Food Diary (example sheet)

DATE | | | DAY OF WEEK

TIME	FOOD Meal	FOOD Snack	BRAND NAME	QUANTITY, SIZE WEIGHT	DESCRIPTION AND PREPARATION
BEFORE BREAKFAST					
BREAKFAST					
MID MORNING – between breakfast time and lunch time					

Appendix vi - a: The Leeds Sleep Questionnaire (LSQ) (Parrot and Hindmarch, 1980) (Habitual Sleep patterns)

SLEEP EVALUATION QUESTIONNAIRE

Each of the following questions are about a **TYPICAL night's sleep**. Answer the questions by placing a vertical mark through the line in the place that best indicates your answer.

1. In a typical night how EASY is it to get to sleep?

very easy ____ very difficult

2. How QUICKLY do you get to sleep?

very quickly ____ very slowly

3. What is the QUALITY of your sleep in a typical night?

very restful ____ not at all restful

no periods of wakefulness ____ many periods of wakefulness

4. What is your pattern of AWAKENING like in a typical morning?

very easy ____ very difficult

takes a short time ____ takes a long time

5. How do you usually FEEL ON AWAKENING?

alert ____ tired

6. How do you usually feel 1 HOUR AFTER awakening?

alert ____ tired

Appendix vi - b: The Leeds Sleep Questionnaire (LSQ) (Parrot and Hindmarch, 1980) (State Sleep patterns)

SLEEP EVALUATION QUESTIONNAIRE

Each of the following questions are about **LAST night's sleep**. Answer the questions by placing a vertical mark through the line in the place that best indicates your answer.

1. How EASY was it to get to sleep last night?

very easy ________________________________ very difficult

2. How QUICKLY did you get to sleep last night?

very quickly ________________________________ very slowly

3. What is the QUALITY of your sleep last night?

very restful ________________________________ not at all restful

no periods of wakefulness ________________________________ many periods of wakefulness

4. What was your pattern of AWAKENING like this morning?

very easy ________________________________ very difficult

took a short time ________________________________ took a long time

5. How did you FEEL ON AWAKENING this morning?

alert ________________________________ tired

6. How did you feel 1 HOUR AFTER awakening this morning?

alert ________________________________ tired

Appendix vii : The Three Factor Eating Questionnaire (TFEQ) (Stunkard and Messick, 1985)

EATING INVENTORY

This booklet contains a number of statements. Each statement should be answered either TRUE or FALSE. Read each statement and decide how you feel about it in PART 1.
If you agree with the statement , or if you feel that it is true about you then circle T next to the statement.
If you disagree with a statement, or if you feel that it is false as applied to you, circle the F next to the statement.

1) When I smell a sizzling steak or see a juicy piece of meat I find it very difficult to keep from eating, even if I have just finished a meal	T	F
2) I usually eat too much at social occasions, like parties and picnics.	T	F
3) I am usually so hungry that I eat more than 3 times a day.	T	F
4) When I have eaten my quota of calories I am usually very good about not eating any more.	T	F
5) Dieting is so hard for me because I just get too hungry.	T	F
6) I deliberately take small helpings as a means of controlling my weight.	T	F
7) Sometimes things just taste so good that I keep on eating, even when I am no longer hungry.	T	F
8) Since I am often hungry, I sometimes wish that while I am eating an expert would tell me that I have had enough or that I can have something more to eat.	T	F
9) When I feel anxious I find myself eating.	T	F
10) Life is too short to worry about dieting.	T	F
11) Since my weight goes up and down, I have gone on reducing diets more than once.	T	F
12) I often feel so hungry I just have to eat something.	T	F
13) When I am with someone who is overeating I usually overeat too.	T	F
14) I have a pretty good idea of the number of calories in common foods	T	F
15) Sometimes when I start eating, I just can't seem to stop.	T	F
16) It is not difficult for me to leave something on my plate.	T	F
17) At certain times of the day I get hungry because I have gotten used to eating then.	T	F
18) While on a diet, if I eat food that is not allowed, I consciously eat less for a period of time to make up for it.	T	F

19) Being with someone who is overeating often makes me hungry enough to eat also.	T	F
20) When I feel blue I often overeat.	T	F
21) I enjoy eating too much to spoil it by counting calories or watching my weight.	T	F
22) When I see a real delicacy I often get so hungry that I have to eat it right away.	T	F
23) I often stop eating when I am not really full as a conscious means of limiting the amount I eat.	T	F
24) I get so hungry my stomach feels like a bottomless pit.	T	F
25) My weight has hardly changed at all in the last ten years.	T	F
26) I am always hungry so it is hard for me to stop eating before I finish the food on my plate.	T	F
27) When I feel lonely, I console myself by eating.	T	F
28) I consciously hold back at meals in order not to gain weight.	T	F
29) I sometimes get very hungry late in the evening or at night.	T	F
30) I eat anything I want, anytime.	T	F
31) Without even thinking about it I take a long time to eat.	T	F
32) I count calories as a conscious means of controlling my weight.	T	F
33) I do not eat some foods because they make me fat.	T	F
34) I am always hungry enough to eat at anytime.	T	F
35) I pay a great deal of attention to changes in my figure.	T	F
36) While on a diet, if I eat food that is not allowed, I often then splurge and eat other high calorie foods.	T	F

Please answer the following questions by circling the number above the response that is appropriate to you.

37) How often are you dieting in a conscious effort to control your weight?

1	2	3	4
rarely	sometimes	usually	always

38) Would a weight fluctuation of 5lbs affect the way you live your life?

1	2	3	4
not at all	slightly	moderately	very much

39) How often do you feel hungry?

1	2	3	4
only at meal times	sometimes between meals	often between meals	almost always

40) Do your feelings of guilt about overeating help you to control your food intake?

1	2	3	4
never	rarely	often	always

41) How difficult would it be for you to stop eating halfway through dinner and not eat for the next four hours?

1	2	3	4
easy	slightly difficult	moderately difficult	very difficult

42) How conscious are you of what you are eating?

1	2	3	4
not at all	slightly	moderately	extremely

43) How frequently do you avoid 'stocking up' on tempting foods.

1	2	3	4
almost never	seldom	usually	almost always

44) How likely are you to shop for 'low calorie' foods?

1	2	3	4
unlikely	slightly likely	moderately likely	very likely

45) Do you eat sensibly in front of others and splurge alone?

1	2	3	4
never	rarely	often	always

46) How likely are you to consciously eat slowly in order to cut down on how much you eat?

1	2	3	4
unlikely	slightly likely	moderately likely	very likely

47) How frequently do you skip dessert because you are no longer hungry?

1	2	3	4
never	seldom	at least once a week	almost every day

48) How likely are you to consciously eat less than you want?

1	2	3	4
unlikely	slightly likely	moderately likely	very likely

49) Do you go on eating binges even though you are not hungry?

1	2	3	4
never	rarely	sometimes	at least once a week

50) On a scale of 0-5 where 0 means no restraint in eating (eat whatever you want, whenever you want it), and 5 means total restraint (constantly limiting food intake and never 'giving in'). What number would you give yourself?

0
Eat whatever you want, whenever you want it.
1
Usually eat whatever you want, whenever you want it.
2
Often eat whatever you want, whenever you want it.
3
Often limit food intake, but often 'give in'.
4
Usually limit food, rarely 'give in'
5
Constantly limiting food intake, never 'giving in'.

51) To what extent does this statement describe your eating behaviour?

'I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising myself to start dieting again tomorrow.'

1	2	3	4
not like me	little like me	pretty good description	describes me perfectly

Appendix viii: The Dutch Eating Behaviour Questionnaire (DEBQ) (van Strien *et al*, 1986)

EATING PATTERNS QUESTIONNAIRE

INSTRUCTIONS – Please answer the following questions as carefully and honestly as possible. Read each question and simply tick the circle which best applies to you.

	Never	Seldom	Sometimes	Often	Very Often
1. If you have put on weight, do you eat less than you usually do?.............................	O	O	O	O	O
2. Do you have a desire to eat when you are irritated?..	O	O	O	O	O
3. If food tastes good to you, do you eat more than you usually do?..........................	O	O	O	O	O
4. Do you try and eat less at mealtimes than you would like to eat?...........................	O	O	O	O	O
5. Do you have a desire to eat when you have nothing to do?..................................	O	O	O	O	O
6. Do you have a desire to eat when you are fed up?..	O	O	O	O	O
7. If food smells and looks good, do you eat more than you usually do?.....................	O	O	O	O	O
8. How often do you refuse food or drink offered because you are worried about how you weigh?..	O	O	O	O	O
9. Do you have a desire to eat when you are feeling lonely?..................................	O	O	O	O	O
10. If you see or smell something delicious, do you have a desire to eat it?.................	O	O	O	O	O
11. Do you watch exactly what you eat?...	O	O	O	O	O
12. Do you have a desire to eat when somebody disappoints you?.............................	O	O	O	O	O
13. If you have something delicious to eat, do you eat it straight away?.......................	O	O	O	O	O
14. Do you deliberately eat foods that are slimming?...	O	O	O	O	O
15. Do you have a desire to eat when you are cross?...	O	O	O	O	O
16. Do you have a desire to eat when you are expecting something to happen?..............	O	O	O	O	O
17. If you walk past the baker do you have a desire to buy something delicious?...........	O	O	O	O	O
18. When you have eaten too much do you eat less than usual on the following days?......	O	O	O	O	O
19. Do you get a desire to eat when you are anxious, worried or tense?......................	O	O	O	O	O
20. If you walk past a snack bar or café, do you have a desire to buy something delicious?	O	O	O	O	O

	Never	Seldom	Sometimes	Often	Very Often
21. Do you deliberately eat less in order not to become heavier?...............................	O	O	O	O	O
22. Do you have a desire to eat when things are going against you or when things have gone wrong?.	O	O	O	O	O
23. If you see others eating, do you also have a desire to eat?....................................	O	O	O	O	O
24. How often do you try not to eat between meals because you are watching your weight?	O	O	O	O	O
25. Do you have a desire to eat when you are frightened?.......................................	O	O	O	O	O
26. Can you resist eating delicious foods?..	O	O	O	O	O
27. How often in the evening do you try not to eat because you are watching your weight?	O	O	O	O	O
28. Do you have a desire to eat when you are disappointed?..................................	O	O	O	O	O
29. Do you eat more than usual when you see others eating?..................................	O	O	O	O	O
30. Do you think about how much you weigh before deciding how much to eat?...........	O	O	O	O	O
31. Do you have a desire to eat when you are upset?...	O	O	O	O	O
32. When you see someone preparing a meal, does it make you want to eat something?...	O	O	O	O	O
33. Do you have a desire to eat when you are bored or restless?.............................	O	O	O	O	O

Appendix ix : The Food Choice Questionnaire (FCQ) (Steptoe *et al*, 1995)

Food Choice Questionnaire—Items

It is important to me that the food I eat on a typical day:

Factor 1—Health
- 22. Contains a lot of vitamins and minerals
- 29. Keeps me healthy
- 10. Is nutritious
- 27. Is high in protein
- 30. Is good for my skin/teeth/hair/nails etc
- 9. Is high in fibre and roughage

Factor 2—Mood
- 16. Helps me cope with stress
- 34. Helps me to cope with life
- 26. Helps me relax
- 24. Keeps me awake/alert
- 13. Cheers me up
- 31. Makes me feel good

Factor 3—Convenience
- 1. Is easy to prepare
- 15. Can be cooked very simply
- 28. Takes no time to prepare
- 35. Can be bought in shops close to where I live or work
- 11. Is easily available in shops and supermarkets

Factor 4—Sensory Appeal
- 14. Smells nice
- 25. Looks nice
- 18. Has a pleasant texture
- 4. Tastes good

Factor 5—Natural Content
- 2. Contains no additives
- 5. Contains natural ingredients
- 23. Contains no artificial ingredients

Factor 6—Price
- 6. Is not expensive
- 36. Is cheap
- 12. Is good value for money

Factor 7—Weight Control
- 3. Is low in calories
- 17. Helps me control my weight
- 7. Is low in fat

Factor 8—Familiarity
- 33. Is what I usually eat
- 8. Is familiar
- 21. Is like the food I ate when I was a child

Factor 9—Ethical Concern
- 20. Comes from countries I approve of politically
- 32. Has the country of origin clearly marked
- 19. Is packaged in an environmentally friendly way

Item numbers refer to the order in which statements were presented in the final 36 item Food Choice Questionnaire.

Subjects were asked to endorse the statement "It is important to me that the food I eat on a typical day . . ." for each of the 68 items by choosing between four responses: *not at all important, a little important, moderately important* and *very important*, scored 1 to 4.

Appendix x : The Forced Choice Method of Measuring Food Preferences

Forced Choice Photographic Questionnaire (Response Sheet)

Subject number:__________ Initials:__________

Date:__________ Time:__________

Please circle A or B for each food pair (1-30) to indicate which food you would eat if you had to eat one portion at this particular moment.

1	A	B
2	A	B
3	A	B
4	A	B
5	A	B
6	A	B
7	A	B
8	A	B
9	A	B
10	A	B
11	A	B
12	A	B
13	A	B
14	A	B
15	A	B
16	A	B
17	A	B
18	A	B
19	A	B
20	A	B
21	A	B
22	A	B
23	A	B
24	A	B
25	A	B
26	A	B
27	A	B
28	A	B
29	A	B
30	A	B

FCQ1 – Forced Choice Photographic Questionnaire

Key to the presentation of photographs within the questionnaire

Pork pie (HF/SAV): 1A, 14B, 25A
Chicken breast (LF/SAV): 1B, 7A, 24A
Doughnut (HF/SW): 2A, 9B, 11B
Jelly (LF/SW): 2B, 8B, 20B
Ham (LF/SAV): 3A, 15A, 19B
Rich Tea biscuits (LF/SW): 3B, 25B, 28A
Muffin (HF/SW): 4A, 7B, 21B
Fruit Salad (LF/SW): 4B, 24B, 30B
Shortbread biscuits (HF/SW): 5A, 19A, 26B
Marshmallow (LF/SW): 5B, 13B, 17B
Cream cake (HF/SW): 6A, 23B, 29A
Potatoes (LF/SAV): 6B, 10B, 27A
Chips (HF/SAV): 8A, 16B, 26A
Sausages (HF/SAV): 9A, 12B, 22A
Cheddar cheese (HF/SAV): 10A, 17A, 21A
Bread roll (LF/SAV): 11A, 16A, 20A
Jelly babies (LF/SW): 12A, 27B, 29B
Spaghetti/tomato sauce (LF/SAV): 13A, 18A, 22B
Cream slice (HF/SW): 14A, 18B, 28B
Tuc biscuits (HF/SAV): 15B, 23A, 30A

Appendix xi: The EAT-26 (Garner *et al*, 1982)

EAT-26 Questionnaire

Name:

Please place a tick under the column that applies best to each of the numbered statements. All of the results will be strictly confidential. Most of the questions directly relate to food or eating, although other types of questions have been included. Please answer each question carefully.

		Always	Very Often	Often	Sometimes	Rarely	Never
1.	Am terrified about being overweight.	O	O	O	O	O	O
2.	Avoid eating when I am hungry.	O	O	O	O	O	O
3.	Find myself preoccupied with food.	O	O	O	O	O	O
4.	Have gone on eating binges where I feel that I may not be able to stop.	O	O	O	O	O	O
5.	Cut my food into small pieces.	O	O	O	O	O	O
6.	Aware of the caloric content of the foods I eat.	O	O	O	O	O	O
7.	Particularly avoid foods with a high carbohydrate content (for example bread, potatoes, rice etc.)	O	O	O	O	O	O
8.	Feel that others would prefer if I ate more.	O	O	O	O	O	O
9.	Vomit after I have eaten.	O	O	O	O	O	O
10.	Feel extremely guilty after I have eaten.	O	O	O	O	O	O
11.	Am preoccupied with a desire to be thinner.	O	O	O	O	O	O
12.	Think about burning up calories when I exercise.	O	O	O	O	O	O
13.	Other people think I am too thin.	O	O	O	O	O	O
14.	Am preoccupied with the thought of having fat on my body	O	O	O	O	O	O
15.	Take longer than others to eat my meals.	O	O	O	O	O	O
16.	Avoid foods with sugar in them.	O	O	O	O	O	O
17.	Eat diet foods.	O	O	O	O	O	O
18.	Feel that food controls my life.	O	O	O	O	O	O
19.	Display self-control around food.	O	O	O	O	O	O
20.	Feel uncomfortable after eating sweets.	O	O	O	O	O	O
21.	Engage in dieting behaviour.	O	O	O	O	O	O
22.	Feel that others pressure me to eat.	O	O	O	O	O	O
23.	Give too much time and thought to food.	O	O	O	O	O	O
24.	Like my stomach to be empty.	O	O	O	O	O	O
25.	Enjoy trying new rich foods.	O	O	O	O	O	O
26.	Have the impulse to vomit after meals.	O	O	O	O	O	O

Appendix xii: The Nutritional Knowledge Questionnaire (Tate and Cade, 1990)

NUTRITIONAL KNOWLEDGE QUESTIONNAIRE

Section one

Please choose one of the three options below for each food item by putting a circle around it. If you are not sure, please leave that question blank.

	the same amount of fat as	
1. Red meat contains:	less fat than	**White meat**
	more fat than	**(chicken, poultry)**
	the same amount of protein as	
2. Bananas contain:	less protein than	**salted**
	more protein	**peanuts**
	the same amount of fat as	
3. Sunflower margarine	less fat than	**Butter**
contains:	more fat than	
	the same amount of fat as	
4. Cottage cheese contains:	less fat than	**Cheddar cheese**
	more fat than	
	the same amount of carbohydrate as	
5. Brown bread contains	less carbohydrate than	**White bread**
	more carbohydrate than	
	the same amount of fat as	
6. Sunflower margarine	less fat than	**Low-fat**
contains:	more fat than	**spread**
	the same amount of fibre as	
7. Jacket potatoes contain:	less fibre than	**boiled potatoes**
	more fibre than	**(without skins)**

Section 2

Food may contain both saturated and polyunsaturated fat. Below are some questions about the types of fat in food. Please place a tick under one of the columns below (Saturated fat or Polyunsaturated fat or Not sure) for each food.

	SATURATED FAT	POLYUNSATURATED FAT	NOT SURE
1. Meat (red and white) contains MAINLY			
2. Oily fish contains MAINLY			
3. Cheese contains MAINLY			
4. Butter contains MAINLY			
5. Sunflower marg contains MAINLY			
6. Lard contains MAINLY			
7. Milk contains MAINLY			
8. Corn oil contains MAINLY			

Section 3

Below is a list containing 20 food items. Please place a tick next to those foods which you think are **high in carbohydrate.**

FOOD	HIGH IN CARBOHYDRATE	FOOD	HIGH IN CARBOHYDRATE
Baked potato		Plain omelette	
White bread		Jelly babies	
Cottage cheese		Quiche	
Crispbread/ Ryvita		Muesli	
Bacon		Polyunsaturated marg	
Broccoli		Corned beef	
Cornflakes		Branston pickle	
Sausage		Peanuts	
Tuna fish		Bananas	
Fruit scone		Strawberry jam	

Section Four

Below is a list containing 20 foods. Please place a tick next to those food items that you think are **high in fat.**

FOOD	HIGH IN FAT	FOOD	HIGH IN FAT
Pork pie		Boiled potato	
Swiss roll		Double cream	
Cheese cake		Fruit crumble	
White bread		Eggs (scrambled)	
Low fat spread		Cheddar cheese	
Cottage cheese		Baked beans	
Banana		Peanuts	
Potato crisps		Coco-pops	
Pickled onion		Butter	
Sausage roll		Honey	

Section 5

Below are some statements relating to foods and health.

Please circle number 1 if you think is true, or 2 if you think it is false, or 3 if you are not sure

	TRUE	FALSE	NOT SURE
Many people in this country would benefit health-wise by cutting down the total amount of fat they eat			
The total amount of cholesterol we have in our body is mainly determined by how much cholesterol we eat			
It is important to cut down on cholesterol than saturated fat in the diet if we want to reduce our risk of heart disease			
Eating a fatty diet may increase the risk of coronary heart disease			
It is better to eat saturated rather than polyunsaturated fat if we want to reduce the risk of heart disease			
A good way for people to lose weight is to decrease their intake of fatty foods.			

Appendix xiii: The Food Preference questionnaire (Macdiarmid, 1997)

Food preference questionnaire

Please indicate how much you "like" or "dislike" the following food and drink items, regardless of whether you would *normally eat them, by placing* a tick in the appropriate box. If you neither like or dislike a particular item, please tick "neutral".

	Like Strongly	Like	Neutral	Dislike	Dislike Strongly
Whole milk	☐	☐	☐	☐	☐
Cakes and pastries	☐	☐	☐	☐	☐
Butter	☐	☐	☐	☐	☐
Hard cheese (eg cheddar)	☐	☐	☐	☐	☐
Reduced fat cheese	☐	☐	☐	☐	☐
Potato crisps	☐	☐	☐	☐	☐
Chips/fried potatoes	☐	☐	☐	☐	☐
Potatoes (baked, boiled)	☐	☐	☐	☐	☐
Meat pies and pasties	☐	☐	☐	☐	☐
Cereal (eg cornflakes)	☐	☐	☐	☐	☐
High fibre cereal	☐	☐	☐	☐	☐
Salad vegetables	☐	☐	☐	☐	☐
White fish (not fried)	☐	☐	☐	☐	☐
Skimmed milk	☐	☐	☐	☐	☐
Polyunsaturated margarine	☐	☐	☐	☐	☐
Fruit yoghurt	☐	☐	☐	☐	☐
Pasta	☐	☐	☐	☐	☐
Semi-skimmed milk	☐	☐	☐	☐	☐
Chicken (without skin)	☐	☐	☐	☐	☐
White bread	☐	☐	☐	☐	☐
Sweet biscuits	☐	☐	☐	☐	☐
Green vegetables	☐	☐	☐	☐	☐
Jelly babies	☐	☐	☐	☐	☐
Lamb	☐	☐	☐	☐	☐
Baked beans	☐	☐	☐	☐	☐
Bananas	☐	☐	☐	☐	☐
Beef	☐	☐	☐	☐	☐
Cheese-cake	☐	☐	☐	☐	☐
Jam/marmalade	☐	☐	☐	☐	☐
Peanuts	☐	☐	☐	☐	☐
Bacon	☐	☐	☐	☐	☐
Apples	☐	☐	☐	☐	☐
Rice	☐	☐	☐	☐	☐
Milk chocolate	☐	☐	☐	☐	☐
Fizzy drinks (diet)	☐	☐	☐	☐	☐
Brown/wholemeal bread	☐	☐	☐	☐	☐
Eggs (fried)	☐	☐	☐	☐	☐
Mayonnaise	☐	☐	☐	☐	☐
Sausages	☐	☐	☐	☐	☐
Cream	☐	☐	☐	☐	☐

Appendix xiv: The Attitudes Survey (Armitage and Conner, 1999)

ATTITUDES QUESTIONNAIRE

Section 1

In this questionnaire you are first of all asked to list as many positive or negative thoughts, feelings and beliefs that you can think of with respect to eating a low fat diet. Write one in each box.
Next, rate each thought, *feeling and belief according* to how positive or negative you feel they are for you by circling the appropriate number on the scale. For example extremely positive would be circled as 1, extremely negative as 7.

The thoughts, feelings or belief I associate with eating a low fat diet are:	Rating
1.	Positive 1 2 3 4 5 6 7 Negative
2.	Positive 1 2 3 4 5 6 7 Negative
3.	Positive 1 2 3 4 5 6 7 Negative
4.	Positive 1 2 3 4 5 6 7 Negative
5.	Positive 1 2 3 4 5 6 7 Negative

Section 2

Please circle the number that best describes your opinion.

1. My eating a low-fat diet in the next month is

Bad	1	2	3	4	5	6	7	Good
Harmful	1	2	3	4	5	6	7	Beneficial
Unpleasant	1	2	3	4	5	6	7	Pleasant
Unenjoyable	1	2	3	4	5	6	7	Enjoyable
Foolish	1	2	3	4	5	6	7	Wise
Unnecessary	1	2	3	4	5	6	7	Necessary

2. People who are important to me think I...

Should not eat a low fat diet 1 2 3 4 5 6 7 Should eat a low fat diet

3. People who are important to me would...

Disapprove of my eating a low fat diet 1 2 3 4 5 6 7 Approve of my eating a low fat diet

4. People who are important to me want me to eat a low fat diet

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

5. I feel under social pressure to eat a low fat diet

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

6. Whether or not I eat a low fat diet in the next month is entirely up to me

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

7. How much personal control do you feel you have over eating a low fat diet in the next month?

Very little control 1 2 3 4 5 6 7 Complete control

8. How much do you feel that whether you eat a low fat diet in the next month is beyond your control?

Not at all 1 2 3 4 5 6 7 Very much so

9. I believe I have the ability to eat a low fat diet in the next month?

Definitely do not 1 2 3 4 5 6 7 Definitely do

10. To what extent do you see yourself as being capable of eating a low fat diet in the next month?

Very incapable of eating a low fat diet 1 2 3 4 5 6 7 Very capable of eating a low fat diet

11. How confident are you that you will be able to eat a low fat diet in the next month?

Very unsure 1 2 3 4 5 6 7 Very sure

12. If it were entirely up to me, I am confident that I would be able to eat a low fat diet in the next month.

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

13. I think of myself as a "healthy eater"

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

14. I think of myself as someone who is concerned with healthy eating

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

15. I think of myself as someone who is concerned with the health consequences of what I eat

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

16. I think of myself as someone who enjoys the pleasures of eating

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

17. I intend to eat a low fat diet over the next month

Definitely do not 1 2 3 4 5 6 7 Definitely do

18. I plan to eat a low fat diet over the next month

Definitely do not 1 2 3 4 5 6 7 Definitely do

19. I want to eat a low fat diet over the next month

Definitely do not 1 2 3 4 5 6 7 Definitely do

20. I consider myself to be able to eat what I want without gaining weight

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

Appendix xv: The Semi-Structured Interview Format (ch.10)

FORMAT OF INTERVIEW

STEP 1- MAIN QUESTION: What factors are involved in food choice and body weight control?

STEP 2- MINI QUESTIONS: a) What are most important food values?
b) Can someone really eat what they want?

STEP 3- BREAKDOWN: a) Antecedents to food choice, motivations, intentions vs. behaviour, situational influences, dietary rigidity, liking and preference vs. behaviour.
b) Behaviour- is this conscious? Influences of exercise (if looking at EB). Meal size and patterns, confirmation of each into relevant group, weight history, family history.

MAIN STRUCTURE OF INTERVIEW

Introductory explanation

Meal patterns

Questions regarding motivation, liking

Weight and family history

Specific question if not already covered.

Appendix xvi: Interview Response Sheet

DATE:__________ **Reference no:**

Initials: __________

MEAL PATTERNS

In this section, we would like to ask you about the types of meals you would typically eat at different times during the day.

1. How many meals do you normally eat in a day?

a) Please could you tell me if those meals are:

Breakfast Mid-day meal Evening meal Supper

i) Do you normally eat breakfast? *Yes/No*

If yes: What does your typical breakfast consist of?

Does this alter at weekends and if so what would you normally eat? *Yes/No*

If yes: How?

ii) Do you normally eat a mid-day/lunch meal? *Yes/No*

If yes: What does your typical mid-day/lunch consist of?

Does this alter at weekends and if so what would you normally eat? *Yes/No*

If yes: How?

iii)Do you normally eat a meal in the evening? *Yes/No*

If yes: What does your typical evening meal consist of?

Does this alter at weekends and if so what would you normally eat? *Yes/No*

If yes: How?

iv) Do you normally eat food between meals as snacks? *Yes/No*

If yes: Please give examples of the food items which you would typically eat as a snack:

How many snacks would you say you normally ate per day?

What time of day would you typically eat these snacks?

2. These meal you've described, are they typical of your normal intake? *Yes/No*

3. Have you changed your diet in any way since you filled in the first questionnaire? *Yes/No*

If yes: How?

4. Are you currently a vegetarian? *Yes/No*

If yes: What foods do you not eat as a result of being vegetarian?

5. Do you avoid certain food for religious reasons? *Yes/No*

If yes: What foods do you not eat as a result of your religion?