RISK FACTORS FOR OBESITY DEVELOPMENT IN CAUCASIAN AND ZULU WOMEN: PERSONAL AND PARENTAL WEIGHT HISTORY, WEIGHT MANAGEMENT PRACTICES, EATING BEHAVIOUR AND TASTE SENSITIVITY (A CASE-CONTROL STUDY).

by

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Thesis presented for the partial fulfillment of the requirements for the degree of MSc Dietetics

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Signature Date

DECLARATION

I, Fiona Herrmann, student number HRRFIO002, declare that the work contained in this thesis is my own original work and where the work of others has been used (whether quoted verbatim, paraphrased or referred to), it has been attributed and acknowledged. This work has not previously been submitted in part or in its entirety to any university for a degree.

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SUMMARY

Obesity is a significant health problem in South Africa and the need for intervention in this regard has been emphasized. Existing information indicates that modifiable risk factors such as diet and physical activity may be contributing to this problem. However, little other information on many of the other potential risk factors for obesity development is available. The primary aim of this study therefore was to investigate the associations between weight status, personal and parental weight history, weight management practices (including body weight and shape satisfaction), eating behaviour and 6-n-propylthiouracil (PROP) taste sensitivity in Zulu and Caucasian women using a case control design. The secondary aim was to compare Zulu and Caucasian cases as well as Zulu and Caucasian controls for key variables.

Caucasian cases (n=89) and controls (n=102) were recruited in Cape Town and Stellenbosch while Zulu cases (n=94) and controls (n=86) were recruited in Durban and Pietermaritzburg. Cases were eligible for participation if they had a BMI>27kg/m^2, applied for entry into our conservative weight loss programme, were 23-40 years old and had at least a Grade 12 certificate. Controls had to fall within the normal weight BMI range (18.5-24.9kg/m^2), have at least a Grade 12 certificate and formal exercise participation not exceeding three hours per week. Measures/assessments included anthropometry (height, weight, BMI), a questionnaire designed for the purpose of this study (socio-demographic variables, personal weight history, parental weight history, weight loss practices, body weight and shape satisfaction), the Three Factor Eating Questionnaire (eating behavior) and a PROP taste sensitivity test using impregnated filter paper, with taste sensitivity being recorded on the Labeled Magnitude Scale.

Multivariate regression analysis using a generalized linear model (GLM) was used to compare mean(± SD) for continuous data, controlling for demographic variables that differed significantly between cases and controls (Caucasians: age, language, education; Zulus: age, marital status, education). Categorical variables were compared using Pearson's Chi squared/Fischer's exact tests. Odds ratios were calculated for categorical variables (including dichotomized continuous variables) that differed significantly between the groups, controlling for demographic variables as mentioned. Group comparisons for Zulu vs. Caucasian cases and Zulu vs. Caucasian controls were conducted using the GLM for continuous variables to control for age, education and marital status for both groups and Pearson's Chi squared/Fischer's exact tests for categorical variables.

Subjects were more likely to be obese as adults if they perceived themselves to be overweight as children (Caucasian OR 8.24; Zulu OR: 20.1), as adolescents (Caucasian OR 13.3; Zulu OR: 17.39), as young adults (Caucasian OR 62.4; Zulu OR: 95.17) and as having weighed more than their peers in adolescence (Caucasian OR: 22.32; Zulu OR: 10.42). Having a "perceived overweight" mother in childhood (Caucasian OR: 3.2; Zulu OR: 2.56) was also associated with overweight/obesity. Weight loss attempts were prevalent in both Caucasian cases (97.8%) and Zulu cases (67.7%) and were associated with significant risk for overweight/obesity development

(Caucasian OR: 30.2; Zulu OR: 12.02). Caucasian controls were significantly more likely to report previous dieting attempts than their Zulu counterparts ($p<0.001$), although Zulu controls also reported to having dieted previously, with a wide variety of weight loss strategies having been used by both groups. Caucasian and Zulu cases were significantly more likely to use unhealthy weight loss methods than their normal weight counterparts (Caucasian $p \leq 0.012$; Zulu $p \leq 0.05$). Weight regain following weight loss increased the risk for overweight/obesity for Caucasian women (OR: 5.8). Dissatisfaction with body weight (Caucasian OR: 74.88; Zulu OR: 27.45) and fear of weight gain (Caucasian OR: 9.9; Zulu OR: 19.8) were also associated with an increased risk for overweight/obesity. Caucasian cases were, however, more likely to be dissatisfied with all body parts except arms ($p \leq 0.002$) and Caucasian controls with their middles and thighs ($p<0.001$) than their respective Zulu counterparts. For both Zulu and Caucasian women, disinhibition (Caucasian OR: 19.85; Zulu OR: 5.5) and perceived hunger (Caucasian OR: 3.16; Zulu OR: 2.14) were significant risk factors for overweight/obesity, with no significant differences found between Caucasian and Zulu cases or Caucasian and Zulu controls. PROP taste sensitivity tests revealed no significant risk for overweight/obesity for Caucasian women although a significant risk was found for Zulu women (OR: 2.76) if the data was not adjusted for eating behaviours.

From this study it can be concluded that risks for overweight/obesity are similar for Zulu and Caucasian women who join a weight loss programme. Although healthy weight loss strategies are used, previous dieting attempts increase the risk for overweight/obesity and the use of unhealthy and extreme strategies is a concern and needs attention. Dissatisfaction with body weight and body parts and fear of weight gain are risks for overweight/obesity, with disinhibition and perceived hunger also increasing this risk. Cultural norms for acceptance of a larger body size in overweight/obese and normal weight Zulu women as well as pressure to conform to the slim western body weight/shape norm is present in normal weight Zulu women and should be considered when developing health education/ weight loss programmes. There is insufficient information available to consider taste sensitivity as a risk factor for overweight/obesity in Zulu and Caucasian women.

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INTRODUCTION AND MOTIVATION FOR THE STUDY

1.1 **INTRODUCTION AND MOTIVATION FOR THE STUDY**

According to the World Health Organisation (WHO 2011) there were an estimated 1.5 billion overweight adults (BMI >25 kg/m²) globally in 2008 and approximately 500 million who were clinically obese (BMI >30kg/m²). Added to this, nearly 43 million children under the age of 5 years were overweight in 2010. There has been an exponential increase in prevalence of overweight and obesity worldwide with these rates increasing by more than 75% between 1980 and 1994 (Flegal et al. 1998). Projections for the future estimate that 2.3 billion adults would be overweight and more than 700 million obese by the year 2015 (WHO 2011).

Once considered a problem only in the developed world, overweight and obesity are increasing in middle- and low-income countries, particularly in urban settings (WHO 2011). While obesity prevalence in "percentage" terms is generally lower in poorer countries, the developing world faces a larger absolute burden of overweight and obesity owing to these countries having larger populations (Reddy et al. 2003; Gu et al. 2005). In these countries the obesity epidemic is being driven largely by the nutrition transition (Bourne et al. 2002; Prentice 2006; Steyn et al. 2006; Reddy et al. 2010), whereby increased urbanisation, globalisation and economic growth have resulted in changes in eating habits and activity patterns that have been blamed for the increasing prevalence of obesity.

South African rates of overweight and obesity follow similar trends. The South African Demographic and Health Survey (SADHS 2003) showed that 21% of adult men and 27.5% of adult women in South Africa were overweight, while 8.8% of men and 27.4% of women were obese. Amongst the women, urbanised Africans had the highest prevalence of overweight and obesity (60.9%), followed by Indian women (59.2%), women of mixed ancestry (52.2%), non-urbanised Africans (49.6%) and then Caucasian women (38%). For South African men, the ethnic distribution of obesity shows a different picture. Caucasian men had the highest incidence of overweight and obesity (48.1%), followed by Indian men (44.6%), men of mixed ancestry (36.2%) and lastly African men from both urban and rural settings (27.2%). For both men and women of all ethnic groups, BMI was found to increase with increasing age.

Similarly, overweight and obesity in children is becoming increasingly prevalent with South African children showing similar trends to those in developed countries from ten

years ago (Armstrong et al. 2006). The most recent National Food Consumption Survey reported that 17.1% of South African children between the ages of one and nine living in urban areas are overweight or obese (Steyn et al. 2005). In an examination of this phenomenon in older children, the South African National Youth Risk Behaviour Survey conducted in 2008 found that 19.7% of adolescents were overweight and 5.3% were obese (Reddy et al. 2010). These figures indicate an increase in the prevalence of both overweight and obesity amongst South African adolescents since 2002 (overweight in 2002: 17.2%; obesity in 2002: 4.2%) (Reddy et al. 2003). No significant differences in overweight or obesity prevalence were found between Caucasian and African female adolescents in this survey and females had significantly higher prevalences of overweight and obesity than males for both measures (*overweight*: females 27.8%, males 11.2%; *obesity*: females 7.2%, males 3.3%). Furthermore, Kwazulu-Natal had the highest rates of overweight in adolescents (25.5%) when compared to all other provinces in South Africa.

Obesity is a pre-disposing factor for a number of chronic conditions including osteoarthritis, psychological problems and sleep apnoea (Kumanyika et al. 2002). Furthermore, an increase in abdominal adipose tissue has metabolic effects and can predispose the individual to an increased risk of insulin resistance, diabetes, hypertension, dyslipidaemia and artherosclerosis and certain types of cancer (Kumanyika et al. 2002; Havel 2004). It is also evident that individuals who were undernourished in early life are more likely to become obese in adulthood and tend to develop conditions such as hypertension, heart disease and diabetes in a more severe form and at an earlier age than those who were never undernourished (Sawaya et al. 2003; Prentice 2006). Brazil, India, China and South Africa, for example, still have high rates of infant malnutrition but are also experiencing high levels of adult obesity and associated chronic diseases (Kumanyika et al. 2002; Sawaya et al. 2003; Steyn et al. 2005).

The economic consequences of obesity are immense. Obesity accounts for 2-6% of total health care costs in several developed countries and some estimates put the figure as high as 7% (WHO/FAO 2003). These estimates exclude indirect costs such as days of work missed, visits to doctors, impaired quality of life and premature mortality. The true costs of obesity are thus undoubtedly much greater. In the developing world, where four-fifths of the world's population live, deaths from non-communicable diseases have been projected to rise from 47% of the burden in 1990 to approximately 70% in 2020

(Kumanyika et al. 2002). The emergence of non-communicable diseases as a health issue in countries still struggling with infant malnutrition and infectious diseases has been termed “The Double Burden of Disease” and threatens to overwhelm the already struggling health services of many developing countries (WHO 2005).

It is clear that obesity is a significant health problem in South Africa and, considering the associated disease burden and related potential economic costs, intervention is essential (Steyn et al. 2005). Risk factors for obesity development need to be considered when designing intervention strategies for the different ethnic groups resident in this country. When considering risk factors, it is important to bear in mind that obesity is a complex multifactorial condition resulting from dynamic interactions between genes and environment, including socio-environmental factors such as those related to food, physical, cultural and/or economic environments. The interaction between hereditary and environmental factors results in behavioural and biological phenotype outcomes that may be conducive to the development of obesity (Newell et al. 2007; Huang et al. 2009). Factors such as genotype, age and gender cannot be changed. Thus modifiable risk factors for obesity such as dietary intake and physical activity should become the focus of obesity prevention/intervention (WHO 2004). Information on non-modifiable risk factors, including inherited factors, may assist in identifying individuals who have greater risk of developing obesity to ensure that intervention strategies are targeted at these individuals. Within the South African context, it is very important to also consider the multicultural nature of our society, with the possibility of cultural/ethnic differences being apparent between the groups.

International research has shown that ethnic/cultural differences in attempting weight loss are apparent, with Africans being less concerned with being overweight and less likely to try to lose weight than Caucasians (Serdula et al. 1999; Millstein et al. 2008). Furthermore, Caucasian women are more likely than men and women from other ethnic groups to attempt weight loss (Serdula et al. 1999; Senekal et al. 2003; Weiss et al. 2006; Pillitteri et al. 2008). South African research has also indicated a lesser concern regarding weight reduction amongst African populations (Senekal et al. 2001). A further factor that needs to be considered is that weight loss is often associated with illness such as HIV and AIDS in some South African communities (Renzaho 2004; Kruger et al. 2005). However, South Africans of all ethnicities are exposed to similar pressures from the media to be slim as well as to a wide variety of easily attainable weight loss products

(Puoane et al. 2002) and it is possible that the prevalence of weight reduction attempts is increasing amongst Africans living in South Africa.

Examining all contributing risk factors for the development of obesity is not possible in the context of one study. With the potential to advise the development of suitable targeted intervention strategies, modifiable risk factors should be the central focus in such research. We know from research that urbanised South Africans have high energy, fat and sugar intakes, low fruit and vegetable consumption as well as low levels of physical activity (Steyn et al. 2006). Therefore, the focus of this study is on other less investigated potential risk factors for the development of overweight/obesity in South African Caucasian and Zulu women. These include hereditary trends concerning body weight and shape as reflected by parental weight history (Davis et al. 2008), personal weight history including both weight tracking from childhood and adolescence into adulthood and weight gain in adulthood (Singh et al. 2008), weight management practices that may contribute to the development of overweight/obesity (Ikeda et al. 2004) and includes body weight and shape perception and satisfaction that are strongly influenced by ethnic/cultural norms (Puoane et al. 2005; Godfrey et al. 2008) and eating behaviours (cognitive restraint, disinhibition and perceived hunger) that may impact on energy intake (Savage et al. 2009). Furthermore, since food preferences and choices are important in determining eating behaviour and thus longitudinal weight status, the association between taste perception and weight status is also of interest (Tepper 2008).

1.2 **AIM**

The primary aim of this study is thus to investigate risk factors for obesity development in Caucasian women and in Zulu women with specific reference to weight history (personal and parental), weight management practices including body weight and shape perception and satisfaction, eating behavior and taste sensitivity in a case-control study.

The secondary aim of this study is to explore the differences between Caucasian and Zulu women with regards to weight history (personal and parental), weight management practices including body weight and shape perception and satisfaction, eating behavior and taste sensitivity by comparing Caucasian with Zulu cases and Caucasian with Zulu controls.

1.3 **OBJECTIVES**

The following objectives were formulated to realize these aims:

1) For both Zulu and Caucasian overweight and obese cases and normal weight controls:
   - Assess weight status
   - Determine personal and parental weight history
   - Determine body weight and shape satisfaction and weight management practices
   - Determine eating behaviour with regard to cognitive dietary restraint, disinhibition and perceived hunger and their subscales
   - Determine PROP phenotype
   - Classify participants as non-tasters, medium tasters and super-tasters.

2) Compare cases and controls in the Caucasian group and cases and controls in the Zulu group for the following variables:
   - Current parental weight status and parental weight history
   - Current personal weight status and personal weight history
   - Body weight and shape satisfaction
   - Weight management practices
   - Eating behaviours (dietary restraint, disinhibition and perceived hunger)
   - PROP phenotype, controlling for dietary restraint and disinhibition.

3) Compare Caucasian cases with Zulu cases and compare Caucasian controls with Zulu controls for the following variables:
   - Current parental weight status and parental weight history
   - Current personal weight status and personal weight history
   - Body weight and shape satisfaction
   - Weight management practices
   - Eating behaviours (dietary restraint, disinhibition and perceived hunger)
   - PROP phenotype, controlling for dietary restraint and disinhibition.

4) Formulate recommendations that can be used to advise the development of suitable weight management strategies for prevention and management of overweight/obesity in South African Zulu/African and Caucasian women based on the outcomes of the objectives mentioned above.

1.4 **DESCRIPTION OF KEY CONCEPTS**

Key concepts for the purposes of this study are described as follows:

Personal weight history.

Personal weight history refers to self reported weight (underweight, normal weight, overweight, obese) in childhood (2 - 10 years), adolescence (11-19 years) and as a young adult (20-25 years). Self-reported weight serves as a proxy for actual weight in this study.

Personal weight management related practices.

Weight management related practices refer to whether weight reduction has been attempted in the past, the age at first attempt, methods used and the most successful weight loss method.

Parental weight history.

Parental weight history refers to a subject's perception of the weight of both parents (underweight, normal weight, overweight, obese) during the subject's adolescence.

Current parental weight.

Current parental weight refers to a subject's perception of the current weight of the subject's living parents (underweight, normal weight, overweight, obese).

Eating behaviour.

Eating behaviour refers to the following three concepts (see section 6 of Chapter 3 for further detail):

- Cognitive dietary restraint: the definition of dietary restraint by Herman (1975) is applied, namely, 'the tendency of some persons to restrict their food intake in order to control their body weight'.
- Disinhibition: the definition of dietary disinhibition by Stunkard & Messick (1985) and Field et al. (2004) is applied, namely, 'the loss of control over eating resulting from specific cues such as the ingestion of certain foods, alcohol intake or psychological depression'.
- Perceived hunger: defined as food intake in response to feelings and perception of hunger / lack of satiety (Provencher et al. 2007).

PROP phenotype.

PROP phenotype refers to the ability of cases or controls to taste 6-*n*-propylthiouracil (PROP) during a PROP taste test and the degree to which they experience this taste as indicated on the Labelled Magnitude Scale (LMS) (see section 7 of Chapter 3 for further detail).

Ethnicity.

Ethnicity implies group identity that may include common ancestry, language and religion (Myer & Ehrlich 2007). It can be used to describe differences between groups of people owing to "culture" rather than biology. The ethnically distinct groups included in this study are from Caucasian and Zulu ancestry.

- Caucasians: women with European ancestry on both the mother's and father's side of the family.
- Zulus: women with Zulu ancestry on both the mother's and father's side of the family.

Culture.

Culture refers to a shared set of attitudes, values and behaviours that characterize a group of people. Culture can moderate attitudes towards weight, including weight perception, weight satisfaction and weight reduction attempts (Wardle et al. 2006).

1.5 **THESIS OUTLINE**

A review of the literature is presented in Chapter 2 (Figure 2.1). Firstly, a general overview of the aetiology of obesity is presented. This is followed by an in-depth discussion of the role that personal and parental weight history, weight reduction history, eating behaviour and taste sensitivity play in the determination of body weight, with specific reference to the development of overweight and obesity.

Chapter 3 comprises a detailed section on methods and procedures. The methods and research instruments described are common to both the Caucasian and Zulu groups of women and apply to the results and discussion that follow after this chapter.

The results are presented in Chapter 4. For each concept examined, results are presented for the Caucasian and Zulu case control studies separately. Results of the comparisons between Caucasian and Zulu cases and between Caucasian and Zulu controls are included in the results tables for the Zulu case control study.

Chapter 5 includes an integrated discussion of the results followed by conclusions and noteworthy trends for each of the concepts examined in this study.

Finally, a critique of the study design is presented in Chapter 6. A tabulated summary of the core conclusions and trends evident from this research and recommendations that should be considered when designing weight management strategies for prevention and management of overweight/obesity in South African Zulu/African and Caucasian women is then presented.

CHAPTER 2

LITERATURE REVIEW

The information covered in this review is illustrated in Figure 2.1. Firstly, a general overview of the aetiology of obesity is presented. This is followed by an in-depth discussion of the role that personal and parental weight history, eating behavior, weight reduction history and taste sensitivity play in the determination of body weight, with specific reference to the development of overweight/obesity.

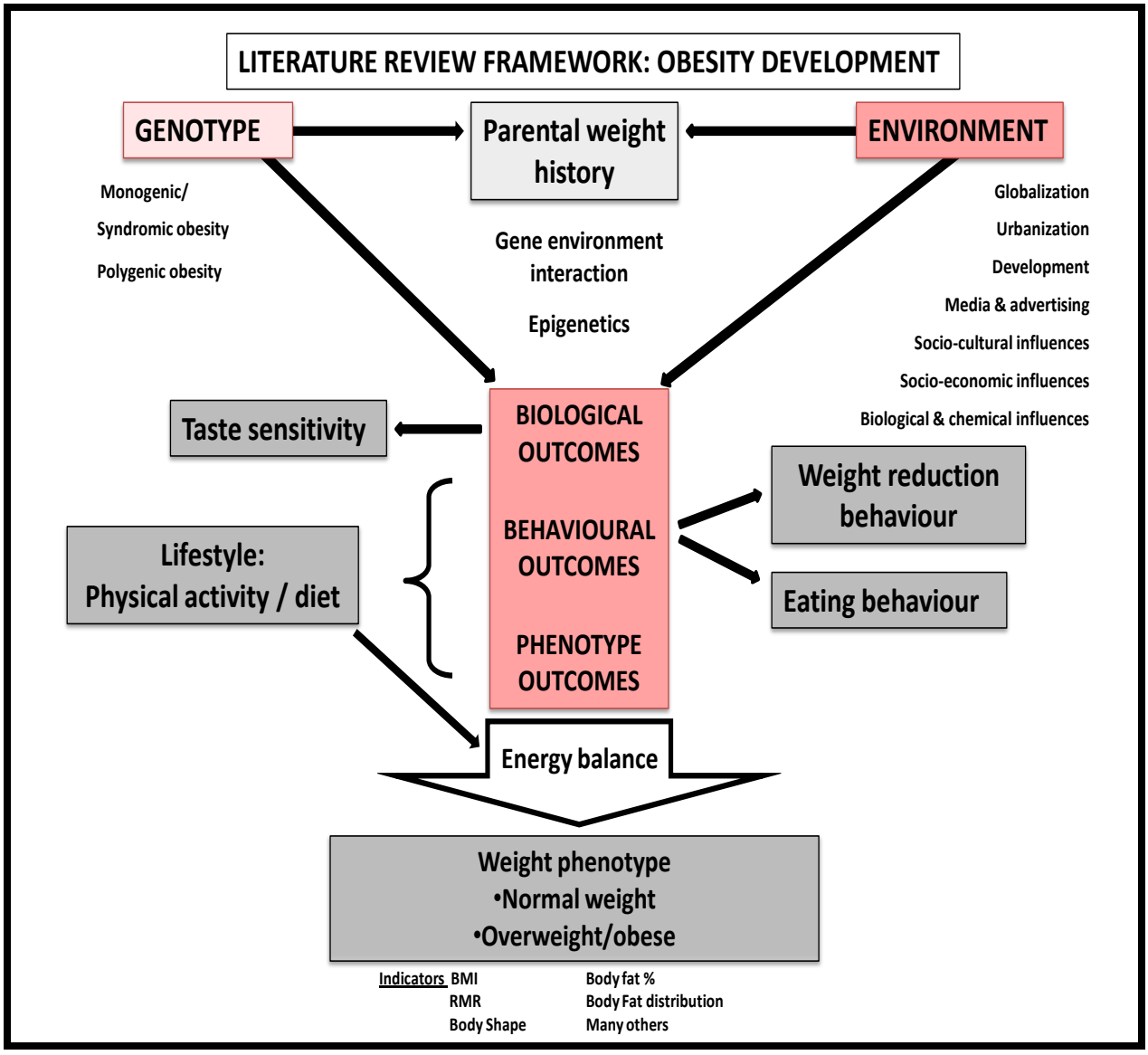


Figure 2.1: Literature review framework and overview of the multifactorial development of obesity.

1. **Overview of the Aetiology of Obesity**

Energy balance implies that energy intake equals energy expenditure. Disruptions to this balance can lead to an increase or reduction in energy stores and consequently an increase or reduction in body weight. Obesity results from an excess of dietary energy intake and/or low physical activity whereby energy intake from food (a modifiable factor) exceeds energy expenditure (physical activity being the most variable/modifiable factor). Over time, this energy imbalance can result in increasing stores of energy as body fat (Stipanuk 2006). Disruptions in energy balance occur in South African communities, with high energy, fat and sugar intakes being reported (Steyn et al. 2005). This, together with low levels of physical activity has contributed to the increasing prevalence of overweight/obesity in South Africa across all ethnicities (Steyn et al. 2005; Reddy et al. 2010).

Energy intake is controlled by a complex system of biological and behavioural components with many genetic and environmental influences (Peters 2006; Kumanyika et al. 2008; Bouchard 2008). With advances in genetic research, there is increasing evidence to suggest that genes are involved in all aspects of weight regulation or energy balance, including food intake and energy expenditure (Newell et al. 2007). Genes appear to be important in determining a person's risk for weight gain but the rapid rise in global obesity rates has occurred in too short a time for evolutionary genetic changes within populations to be considered as an explanation for the current obesity epidemic (Kumanyika et al. 2008). With the improvement in methods for biological research, it is becoming clear that obesity is a multifactorial disorder which reflects complex interdependent interactions of multiple genes, environmental and lifestyle/behavioural factors (Newell et al. 2007; Bouchard 2008; Huang et al. 2009) (see Figure 2.1). This may explain the very poor success rates achieved with current prevention and treatment modalities. The greatest difficulty in the exploration of the interaction between genes and the environment lies in separating the multitude of environmental exposures and genotype that contribute to this disruption in energy balance (Fernandez et al. 2007).

1.1. **Genotype and Obesity**

1.1.1. The Heritability of Obesity

Knowledge of obesity has developed to such an extent that it is no longer seen purely as a result of inappropriate eating and/or inactivity. Recent research indicates that there are individual differences in the predisposition to gain weight and that genetic variation plays

an important role in determining the risk of becoming obese, especially for severe obesity (Bouchard 2007). Genetic correlations have been found for a number of obesity related factors. These include hunger and appetite, eating behaviour, taste, satiety, spontaneous physical activity such as fidgeting, metabolic rate and thermogenesis as well as motivation to exercise (O'Rahilly et al. 2003, Newell et al. 2007).

The extent to which genes and the environment contribute to the variability in body weight is, however, unclear. Recent twin studies have indicated that heritability of BMI may be as high as 77% in children aged 8-11 years, with shared and non-shared environmental influences contributing a further 13% (Wardle et al. 2008). Other estimates of inheritance of body shape and weight range from 16% to 85% for BMI, 37% to 81% for waist circumference, 6 % to 30% for WHR and from 35% to 63% for percentage body fat (Stunkard et al. 1990; Loos et al. 2003; Tholin et al. 2005; Yang et al. 2007). On the basis of the review by Loos et al. (2003), four levels of inheritance of obesity were proposed, two of which are influenced by environmental factors. These levels of obesity include:

- *Level 1*: genetic obesity - genetic mutation in a single gene leads to obesity in spite of environment (1%-5% of cases; Monogenic / Syndromic obesity);
- *Level 2*: strong predisposition - overweight in a non-obesogenic environment and obese in an obesogenic environment;
- *Level 3:* slight predisposition - normal weight in a non-obesogenic environment and overweight in an obesogenic environment;
- *Level* 4: genetically resistant – normal weight in an obesogenic environment.

1.1.2. Monogenic and Syndromic Obesity

Monogenic and syndromic obesity are very rare forms of obesity that exhibit high genetic penetrance (Bouchard 2008) with only 176 cases being reported in the 12th update of the obesity gene map (Rankinen et al. 2006). These forms of obesity have been identified in a small number of inter-bred families distributed throughout the world. Affected individuals have a distinctive phenotype and varying degrees of hypothalamic and pituitary dysfunction (Rosmond 2004).

Monogenic obesity results from a mutation or deficiency of a single gene (Ranadive & Vaisse 2008) whereas syndromic obesity results from discrete genetic defects of chromosomal abnormalities and can be either autosomal or an x-linked disorder (Mutch

& Clement 2006). Syndromic obesity describes obesity that occurs as part of a distinct set of associated clinical phenotypes such as mental retardation, dysmorphic features of the face or limbs, congenital organ defects and endocrine dysfunction (Mutch & Clement 2006; Ranadive & Vaisse 2008; Ichihara & Yamada 2008). To date, approximately 25 syndromic obesity disorders have been identified (Ichihara & Yamada 2008).

Although extremely rare, identification of these gene mutations has helped to identify some of the genes associated with energy balance and eating behaviour and this has allowed ongoing investigation into the genetic basis of polygenic obesity (Rankinen et al. 2006; Bouchard 2008). While a detailed discussion of these conditions is beyond the scope of this review, Table 2.1 provides a brief summary of the more common forms of monogenic and syndromic obesity.

Table 2.1: SUMMARY OF MONOGENIC AND SYNDROMIC OBESITY DISORDERS

GENE	GENE FUNCTION	PHENOTYPIC EXPRESSION	PREVALENCE	REFERENCES
Gene Defects Affecting the Hypothalamic leptin-melanocortin 4 system				
Leptin	Energy homeostasis. Maintenance of normal function of several neuroendocrine axes including reproductive and thyroid function.	Early onset hyperphagic obesity. Hypogonadotrophic hypogonadism. Can be successfully treated with exogenous leptin.	12 individuals identified.	Blüher & Mantzoros 2004 Ranadive & Vaisse 2008 Ichihara & Yamada 2008
Leptin Receptor	Receptor for leptin	Severe early onset obesity similar to leptin deficient individuals. Hypogonadotrophic hypogonadism.	Extremely rare.	Ranadive & Vaisse 2008
Melanocortin 4 receptor (MC4R)	The most important molecule for body weight regulation in the leptin / melanocortin system.	Variable penetrance and clinical expression. Obesity phenotype can vary from extreme hyperphagic obesity to leanness. No adverse physical, hormonal or developmental symptoms.	Over 100 gene mutations.2.5% of all extremely obese	Mergen et al. 2001 Kobayashi et al. 2002 Ranadive & Vaisse 2008 Ichihara & Yamada 2008
Pro-opiomelanocortin (POMC)	Precursor to the melanocortin peptides.	Normal weight newborns with adrenal insufficiency and red hair pigmentation. Hyperphagic obesity owing to a lack of MCR4 activation.	Extremely rare.	Ranadive & Vaisse 2008 Ichihara & Yamada 2008
Prohormone convertase 1/3 (PC 1/3)	Synthesis of peptides involved in energy homeostasis (proinsulin, proglucagon and POMC).	Hyperphagic obesity. Mild hypocortisolism. May show signs of malabsorption and hyperglycaemia.	Extremely rare.	Ranadive & Vaisse 2008 Ichihara & Yamada 2008
Heterozygous carriers of leptin, leptin receptor & POMC mutations	See above. Found in relatives of homozygous carriers.	Intermediate weight phenotype with increased fat mass (suggests these genes may be involved in common obesity).	Mutations found in cohorts of extremely obese.	Farooqi et al. 2006 Farooqi et al. 2007 Ranadive & Vaisse 2008
Defects in Genes Involved in Hypothalamic development				
Drosophila single-minded, gene mutation (SIM1)	Hypothalamic development. Post-developmental energy balance by functioning down-stream of MC4R to control food intake (requires more research).	Hyperphagic obesity, increased linear growth.	Mutations found in cohorts of extremely obese individuals.	Holder et al. 2000 Kublaoui et al. 2006 Ahituv et al. 2007 Ranadive & Vaisse 2008
Brain-derived neurotrophic factor (BDNF), tropomyosin-related kinase B (TRKB) neurotropic tyrosine kinase receptor type 2 gene (NTRK2)	Regulate the development, differentiation and survival of neurons. Play a role in memory, behaviour and cognitive development.	Hyperphagic obesity, developmental delays, impaired cognition, memory and nociception and hyperactivity.	Unknown.	Xu et al. 2003 Ranadive & Vaisse 2008 Ichihara & Yamada 2008
SYNDROME	**GENE ABERRATION/S**	**PHENOTYPIC EXPRESSION**	**PREVALENCE**	**REFERENCES**
Syndromic Obesity				
Prader-Willi Syndrome (PWS)	Defects in the inheritance of imprinted genes in the chromosomal region 15q11.2-q12. Ghrelin regulates hunger and the stimulation of growth hormone. Defects may cause hyperphagia.	Hyperphagic obesity. Developmental delay, mental retardation, hypothalamic hypogonadism, short stature, facial dysmorphism, small hands and feet.	1 in 25 000 births.	Mutch & Clement 2006 Horsthemke & Buiting 2006 Ranadive & Vaisse 2008 Ichihara & Yamada 2008
Bardet-Biedl Syndrome (BBS)	Associated with at least 11 chromosomal locations with several mutations identified. Genetic basis of 50% of BBS families unknown.	Early onset hyperphagic obesity (can be reversed with exercise & calorie restriction) Retinal degeneration, morphological finger abnormalities, dyslexia, learning disabilities, progressive renal disease and other clinical manifestations.	More common. Unknown.	Mutch & Clement 2006 Ranadive & Vaisse 2008 Ichihara & Yamada 2008
Alstrom Syndrome (ALMS)	Linked to mutations on chromosome 2p13 that disrupts the ALMS1 gene.	Early onset obesity, retinal degeneration, type 2 diabetes mellitus, hearing loss, cardiomyopathy, liver and kidney dysfunction and delayed puberty.	Unknown.	Ranadive & Vaisse 2008 Ichihara & Yamada 2008

1.1.3. Polygenic Obesity

A limited number of genes have been confirmed to play a clear role in the development of obesity (Bouchard 2008). The mutations mentioned in the previous section are extremely rare and thus, for the majority of individuals, the genetic predisposition to obesity must be polygenic (Hinney & Hebebrand 2008; Bouchard 2008). Gene variants (alleles) that contribute towards obesity may be found in both obese and normal weight individuals, although more frequently so in the obese. In the polygenic model, each single allele change makes only a small contribution to the development of obesity in an individual. Gene expression is determined by an individual's profile of alleles and their interaction between each other as well as with the environment (Hinney & Hebebrand 2008). The complexity of these interactions in determining body weight phenotype may explain why some individuals do not become obese in an obesogenic environment while others are obese in environments that do not favour weight gain (Loos et al. 2003). However, the role of gene-environment interactions in the development of obesity is not yet fully understood (Fraga et al. 2005; Mutch & Clement 2006).

A review of the 2005 obesity gene map, which includes data up to October 2005, revealed that there are 127 genes which exhibit at least one positive association with an obese phenotype and that for 22 of these genes, there are at least 5 studies confirming this association (Rankinen et al. 2006; Bouchard 2007). Sorting these genes according to biological or behavioural traits reveals five major classes of genotype (Bouchard 2007):

1. A thrifty genotype: low metabolic rate and insufficient thermogenesis.
2. An hyperphagic genotype: poor regulation of appetite and satiety and a tendency to over-eat.
3. A sedentary genotype: a tendency to be physically inactive.
4. A low lipid oxidation genotype: tendency to store and not oxidize lipids.
5. An adipogenesis genotype: an ability to increase the number and storage capacity of adipocytes.

A discussion of all of the genes that may contribute to polygenic obesity is beyond the scope of this review. However, the TAS2R38 gene, a G-protein-coupled bitter receptor located on chromosome 7q (Drayna et al. 2003) that may play a role in obesity development via taste sensitivity is discussed in more detail in Section 6 of this review.

1.1.4. Epigenetic Influences

Finally, the recently developed concept of epigenetics needs to be considered in the aetiology of obesity. Epigenetics can be defined as the study of stable heritable alterations in gene expression that occur without a change in the sequence of DNA (Jaenisch & Bird 2003). These changes occur via methylation and histone modification of DNA during cell development and proliferation (Fraga et al. 2005). Epigenetic changes can occur with aging and on exposure to environmental influences such as viruses and diet (Jaenisch & Bird 2003).

In a study of monozygous twin pairs, approximately one third showed epigenetic differences in DNA methylation and histone modification between members of each twin pair that impacted on gene expression. These epigenetic changes were more prevalent in individuals who were older, had different lifestyles and had spent more time apart, illustrating the role of environmental influences in the development of different phenotypes from an identical genotype (Fraga et al. 2005). Another study by Gallou-Kabani and Junien (2005) showed that inadequate maternal nutrition and metabolic disturbances during foetal development led to incorrect "epigenetic programming", which resulted in the development of metabolic syndrome in a certain group of individuals. These individuals may also have displayed "transgenerational effects" by inheriting epigenetic changes first experienced by their parents and/or grandparents. Similarly, epigenetic changes in gene expression may be used to describe why some people remain lean while others gain weight in an obesogenic environment (Gallou-Kabani & Junien 2005; Bouchard 2008).

The field of epigenetics is relatively new and more research needs to be done to unravel its complexities with respect to the development of disease and the role thereof in the aetiology of obesity (Jaenisch & Bird 2003).

1.2. **Environmental Influences in the Development of Obesity**

The exponential increase in obesity over the last three decades cannot be ascribed to genetic factors alone as the human genome is not likely to have changed to such an extent over this relatively short period (Stipanuk 2006; Yang et al. 2007; Bouchard 2007; Kumanyika et al. 2008). However, changes in our technological and social environments have created what has been termed the "global obesogenic environment" that favours obesogenic behaviour in humans (Bouchard 2007). Thus, high energy intakes coupled with low energy expenditure and the interaction between these behavioural changes and genetic factors seems to be fueling the acute rise in the global prevalence of overweight and obesity (Bouchard 2008).

The interaction between genetics and environment in the development of obesity can be illustrated by comparisons made between the Pima Indian communities of Arizona who show very high levels of obesity and their Mexican counterparts (Stipanuk 2006). Whilst both groups are genetically similar and carry a number of gene variants associated with obesity (Traurig et al. 2009), their environments differ. The Mexican Pima Indians live in a remote mountainous area where they follow a traditional lifestyle and are very physically active, grow their own food and consume diets low in animal fats and high in complex carbohydrates (Ravussin et al. 1994). In contrast, Arizonan Pima Indians, who originate from the same Mexican community, are significantly more obese and follow a more westernized lifestyle, with high energy intakes and low levels of physical activity (Ravussin et al. 1994). Thus, environmental influences can protect against or promote the development of obesity in communities where there is a genetic tendency for obesity development (Ravussin et al. 1994; Stipanuk 2006).

1.2.1. Globalisation, Urbanisation, Development and the Built Environment

Globalisation can be defined as a process of interaction and integration between people, companies and governments of different nations (*www.globalization101.org)*. It is driven by international trade and investment in free-market economies and is assisted by dramatic improvements in communications and transportation. Globalisation implies the movement of people between countries, the exchange of goods across borders, the international sharing of knowledge and the redistribution of labour *(http://globalpolicy.org).* From an obesity standpoint, the increasing availability of inexpensive, energy dense foods throughout the world has influenced global food habits. The resulting dietary changes together with a reduction in energy expenditure owing to improved transport, mechanization and the increasing popularity of sedentary leisure activities such as television, video games and computers have contributed to a disruption in the energy balance equation and a rise in obesity prevalence (Armstrong et al. 1998; Speakman 2004; Godfrey 2008).

In conjunction with globalisation, urban population numbers are rapidly increasing as people move from rural areas to the cities in order to search for employment and a better way of life (United Nations 2007). Newly urbanised individuals experience what is known as the “nutrition transition”, which includes a change in food habits from unrefined, nutrient rich traditional diets to energy dense, nutrient depleted refined foods (Steyn et al. 2005). Furthermore, the lack of supermarkets as well as easier access to high energy fast foods in recently urbanised areas has an impact on obesity risk (Morland et al. 2001; Lopez 2007). In South Africa, the nutrition transition is reflected in an increase in dietary fat intake, reduction in unrefined dietary carbohydrate, an increase in rates of obesity and in non-communicable diseases (Bourne et al. 2002). The 2003 South African Demographic and Health Survey reported that the prevalence of overweight and obesity is high for both urbanised and non-urbanised African

women. However, the effect of urbanisation is clearly illustrated with a higher prevalence reported for urbanised (60.9%) vs. non-urbanised (49.6%) women.

Urbanisation is also associated with a drop in physical activity levels as food is more accessible and there is a much greater reliance on public transport (Puoane et al. 2005). High crime rates in informal, recently urbanised South African communities have also been blamed for lower physical activity levels as safety concerns limit out-door activities (Kruger et al. 2005).

The physical or built environment can also have an impact on energy expenditure. Obesity risk has been found to be associated with urban sprawl, a pattern of development of low density land use, decentralisation and the reliance on motorised vehicles for transportation (Lopez 2004). In contrast, neighbourhoods with interconnected streets, adequate street lighting, sidewalks, walkable destinations and facilities such as parks and public sporting facilities may positively influence physical activity patterns and reduce obesity risk (Berrigan & Troiano 2002).

The effect of physical environment on obesity development is illustrated by the results of the Thusa Bana Study conducted in the North West Province of South Africa (Schutte et al. 2003). The results show that BMI and % body fat were lowest amongst rural African children (BMI: 17.4kg/m²; % BF: 19.9%) and those of mixed ethnicity (BMI: 16.8kg/m²; %BF: 17.6%) when compared to urbanized Caucasian (BMI: 19.0kg/m²; %BF: 20.8%) and Indian children (BMI: 17.5kg/m²; %BF: 20.2%). While there may have been genetic and / or socio-cultural factors influencing these results, it is evident that the environmental differences in food supply and transportation (with the rural children walking long distances to school) had a significant effect on BMI (Schutte et al. 2003).
It is clearly evident that environmental factors affect the energy balance equation, contributing to the development of obesity by increasing the availability, accessibility and intake of energy in the form of energy dense foods and by reducing energy output in the form of physical activity.

1.2.2. Socio-cultural Influences

Culture, defined as a shared set of attitudes, values and behaviours, is often used to describe differences between ethnic groups (Myer & Ehrlich 2007). It plays an important role in determining food intake and attitudes towards obesity (Birch et al. 2003; Stunkard et al. 2004; Wardle et al. 2006). While the Western beauty ideal is for leanness with societal pressure placed on women to be slim (Godfrey 2008), in many sub-Saharan African communities, overweight and obesity, especially among women, indicates success, wealth, good health and happiness (Renzaho 2004; Puoane et al. 2005). Puoane et al. (2002) reported that few

overweight and obese South African women of African descent considered themselves to be overweight and that moderately overweight women are seen to be attractive, dignified and wealthy and are respected by the community. Consequently, lower levels of body size dissatisfaction are found in African women when compared to their Caucasian counterparts (Mchiza et al. 2005). In a study conducted amongst rural women in Kwazulu Natal, only 4% of overweight women and 25% of obese women were not satisfied with their weight and only 2% and 30% respectively considered themselves to be too fat (Faber & Kruger 2005). Thinness and weight loss among many South African Africans has also been equated with illness, especially HIV/AIDS (Kruger et al. 2005; Puoane et al. 2010), further promoting the preference for a larger body size. However, there is evidence to suggest that cultural attitudes are changing amongst African women with regards to body weight, with some adolescents showing preference for a slimmer body shape (Puoane et al. 2010). This internalisation of western norms by persons from other cultures is known as acculturation (O'Dea 1995; Senekal et al. 2001; Renzhao 2004).

As far as food intake is concerned, black South Africans traditionally eat large amounts of unrefined high carbohydrate foods and relatively small amounts of protein and fat. These cultural eating habits are being replaced by more westernized eating patterns that include higher amounts of protein and fat and more refined carbohydrate foods. This shift in eating habits (the nutrition transition) may play a role in the increasing obesity prevalence seen in traditional South African communities (Bourne et al. 2002).

A more detailed discussion of the socio-cultural and personal factors associated with obesity is included in Sections 2 and 3 of this review.

1.2.3. Media and Advertising

Advertising and the media have played an important role in encouraging behavioural changes that have lead to increased energy consumption (Speakman 2004; Lobstein & Dibb 2006; Hoek & Gendall 2006). Foods are marketed via television advertising, on popular websites and via food-company designed internet games (Speakman 2004; Weber & Story 2006; Alvy & Calvert 2008). Consumption of high energy foods are also encouraged via product placements in films and on popular television programmes as well as via advertising before the previews at theatres (Guenther et al. 2006; Godfrey 2008). It is anticipated that in the future, cellular telephone advertising will also become common and may further contribute to increasing obesity prevalence (Godfrey 2008).

Evidence relating to food advertising suggests that it may influence the demand for advertised foods as well as re-enforce and maintain existing behaviour patterns (Hastings et al. 2003,

Lobstein & Dibb 2006). In depicting the frequent consumption of high energy foods and of larger portion sizes as normal behaviour, food advertising is contributing to the rise in obesity prevalence (Hoek & Gendall 2006).

The constant barrage of commercial messages in the media and via advertising reinforces a desire for obesogenic, nutrient-poor foods. According to Godfrey (2008), this, together with inadequate levels of physical activity is contributing to the obesity epidemic. In contrast, as mentioned in section 1.2.2 above, advertising and the media have also been blamed for encouraging individuals, but especially women, to conform to a slim body shape (Serdula et al. 1999; Godfrey 2008) and this has fueled body weight dissatisfaction and a corresponding increase in weight loss attempts (Godfrey 2008). A more detailed discussion of aspects surrounding weight loss is included in Section 5 of this review.

1.2.4. Socio-economic Environment

Economic factors have been shown to play a role in the risk for obesity development, although other factors such as ethnicity/culture moderate this effect. This is evident in South Africa with, for example, obesity being most prevalent in middle to upper income white males as well as poor urbanized African females (SADHS 2003). At the other end of the BMI scale, it is interesting to note that African men, who are of a lower socio-economic status and middle to upper income white women show an opposite trend with both groups having relatively low levels of obesity (SADHS 2003).

Individuals with high income levels are, however, more likely to live in safe areas with available recreational facilities for physical activity and a greater choice of healthy foods (Lopez 2007). Conversely, for poor families, obtaining sufficient dietary energy at low cost can be an over-riding concern. Healthier low fat foods and fresh fruit and vegetables are often more expensive than energy dense fast foods and not as freely available in poorer areas (Morland et al. 2001; Senekal et al. 2003; Drewnowski 2003). Consequently, high levels of consumption of inexpensive foods high in fat and sugar may result in weight gain (Drewnowski 2003).

In South Africa a large proportion of the population lives under conditions of poverty. Associations have been found between low education levels, gender, ethnicity, area of residence and high BMI in South Africans (Puoane et al. 2002; Senekal et al. 2003). Furthermore, the Thusa Bana Study (Schutte et al. 2003) showed that, amongst four ethnic groups of 10-15 year old children in the North West Province of South Africa, BMI and body fat were lowest amongst African children (BMI:17.4kg/m²; %BF:19.9%) and those of mixed ethnicity (BMI:16.8kg/m²; %BF:17.6%) when compared to Caucasian (BMI:19.0kg/m²; %BF:20.8%) and Indian children (BMI:17.5kg/m²;%BF:20.2%). In this study, the Caucasian

and Indian children were from urban areas and of a higher socio-economic status than the African and mixed origin children, who came from the poor rural areas of the North West Province. Hence, both the economic and environmental differences (food supply and transport to school) may have been responsible for this result.

The exact effect that socio-economic status has on obesity risk is unclear with opposite effects being shown for some ethnic groups (SADHS 2003). It is likely that other environmental and/or cultural as well as genetic factors also influence the determination of body weight status and this further illustrates how complex the aetiology of obesity is.

1.2.5. Biological and Chemical Influences

It has been suggested that environmental exposures that increase obesity risk in the developing foetus include chemical and biological factors (Ong et al. 2007). Maternal nutrient deprivation or smoking during pregnancy can result in intrauterine growth retardation of the foetus and influence hypothalamic-pituitary axis programming to increase the future risk of obesity and diabetes (Meany & Seckl 2004; Ong et al. 2007; Oken et al 2007). Infants born to women with insulin dependent and gestational diabetes mellitus also have an increased obesity risk (Ong et al. 2007).

Exposure to certain synthetic endocrine disrupting chemicals such as bisphenol A (BPA) and phthalates during pregnancy may have the capacity to disrupt energy balance (Ong et al. 2007; Newbold et al. 2007, Trasande et al. 2009). BPA is used to manufacture polycarbonate resin for coating food and beverage containers. In vitro and animal studies have found that BPA induces differentiation of fibroblasts into adipocytes, affects glucose transport into cells and disrupts glucagon secretion (Trasande et al. 2009) and may be linked to the current obesity epidemic. Phthalates are also used in the synthesis of polyvinyl chloride for a variety of personal care products such as shampoos and, while little research is currently available, phthalates have been found to have an anti-androgenic effect. Analysis of the 1999-2000 US National Health and Nutrition Examination Survey has shown increased urinary phthalate levels among men who have an increased waist circumference and show insulin resistance (Stahlhut et al. 2007).

In other recent research, certain viral infections have been recognized as possible causes of obesity. Most of the research to date has been conducted on animal models using animal viruses, although 3 human adenoviruses, Ad-36, Ad-37 and Ad-5 have been found to induce obesity in animals (Atkinson 2007). These viruses stimulate enzymes that cause the accumulation of triglycerides and development of adipocytes as well as reducing leptin expression and secretion from these cells (van Ginneken et al. 2009). In human studies, antibodies to Ad-36 were found in 30% of obese individuals compared to 11% in the non-

obese (Atkinson 2007; van Ginneken et al. 2009). Furthermore in twins, where only one individual in each twin-pair tested positive for viral antibodies, the infected twins were found to be heavier and had more adipose tissue than their co-twins (Atkinson 2007).

This growing body of evidence suggests that environmental factors of a chemical or biological nature may also be contributing to the increase in obesity prevalence.

1.3. **Phenotype outcomes associated with obesity**

Obesity may be associated with a number of biological traits. These traits include increased appetite, reduced satiety, low metabolic rate, and diminished taste sensitivity (Trayhurn 2007; Tepper 2008). As taste sensitivity is a focus of this research, its association with obesity is discussed in Section 6 of this review.

Behavioural outcomes associated with obesity include inappropriate eating behavior (low cognitive restraint, high disinhibition and perceived hunger) (Terracciano et al. 2009) (see Section 4), an increase in weight reduction attempts (see Section 5) and reduced physical activity (a detailed discussion of this factor is beyond the scope of this review).

Weight status as is discussed from the perspective of familial influence /genetics in Section 2. Weight history, which reflects energy balance over time, is discussed in Section 3.

2. **Association between Parental Weight History and Obesity Development**

A large body of evidence exists that points to the fact that parents' BMI influences the BMI of their offspring (Table 2.2). It is evident that the impact of family history on body weight may be a result of environmental factors including dietary habits and family lifestyle as well as inherited genetic factors (Whitaker et al. 1997).

Table 2.2: Summary of research on the association between family weight history and obesity development wt=weight ht= height yrs = years

Author / year	Sample	Study Design / objectives	Age at Measurement 1) Offspring 2) Parent	Cut-offs for: overweight / obesity 1). Child 2). Adult	Results	Study Conclusions
Lake JK et al. 1997	6540 males 6207 females (from 1958 British Birth Cohort Study) Caucasian plus "British immigrants" Not defined or analysed separately.	**Longitudinal.** Weight tracking from childhood to adulthood vs. parental body weight	1) 7, 11, 16, 23 & 33 yrs 2) When child was 11 yrs old	1) Overweight: BMI >85th percentile 2) Overweight 24,9-27.78kg/m² Obese>27.7kg/m²	At each age mean BMI of children increased as parental BMI increased. Children with overweight or obese parents had a higher risk of adult obesity (at 33 yrs). Odds ratio for obesity for children with 2 obese parents vs. 2 normal wt parents was 8.4 (sons) and 6.8 (daughters). Children with 2 obese parents showed strongest child to adult tracking of BMI	Children of obese and overweight parents have increased risk of obesity at all ages. Subjects with two obese parents are heavier in childhood and show stronger weight tracking from childhood to adulthood.
Whitaker et al. 1997	854 subjects & their parents (747 mothers, 699 fathers) (USA) Ethnicity not specified	**Retrospective cohort study** Risk of obesity in young adulthood vs. obesity in childhood and obesity in one or both parents.	1) 1-2, 3-5, 6-9, 10-14, 15-17 & 21-29yrs of age (average BMI for each age category) Height measurement after age 18yrs in males & 16yrs in females. 2) Not specified	1) Obesity: BMI >85th percentile 2) obesity: BMI ≥27.8kg/m² for males ≥27.3kg/m² for females)	Probability of being obese as a young adult increased with age of the obese child and was highest at all ages for the group of very obese children. After age 6yrs, probability of being obese as an adult exceeded 50% for obese children vs. approximately 10% for non-obese children. No significant gender differences re obesity risk in adulthood. OR for offspring obesity was higher for maternal obesity vs. paternal obesity but not statistically significant. Before the age of 3 yrs, parents' obesity was the primary predictor of adult obesity risk. Between ages 3 & 9 yrs, both child and parental obesity status were important determinants of obesity risk. After age 9 yrs, child's obesity status became more important. Especially before age 6yrs, obesity in both parents substantially increased the odds of adult obesity in the children (OR age 1-2 yrs:13.6 (95% CI:3.7–50.4)(vs. 1 obese parent OR:3.2 (1.8–5.7)), OR age 3-5: 15.3 (95% CI:5.7–41.3) (vs. 1 obese parent OR:3.0 (1.7–5.3))	Obesity at age 1-2 does not predict adult obesity. Obesity after age 6yrs increases adult obesity risk by more than 50% Maternal obesity had no greater predictive effect than paternal obesity on obesity of the child in adulthood. After age 9yrs, child's obesity had greatest predictive effect on obesity in adulthood For children younger than 6yrs, having two obese parents increased the risk of obesity in adulthood 4.5 – 5 times.

Author / year	Sample	Study Design / objectives	Age at Measurement 1) Offspring 2) Parent	Cut-offs for: overweight / obesity 1). Child 2). Adult	Results	Study Conclusions
Pietiläinen et al. 2001	4376 subjects (2188 twin pairs) (from FinnTwin16 study) (Finland) Caucasian	**Longitudinal.** To assess influence of birth length, weight, gestation duration, parents BMI and twin-ship) All measures were self-reported	1) Height & weight at birth. BMI at age 16 yrs. 2) At offspring age of 16 yrs	1) Overweight: ≥25kg/m² at age 16-18 2) Overweight≥ 25kg/m²	High birth weight was associated with tall height and high BMI at age 16yrs for both males & females. Body size tracked from birth to age 16. Individuals who were of average length and heavy weight at birth had the highest risk for overweight in adolescence. Parents' height had no effect on twins BMI at age 16yrs. Parents' overweight significantly influenced the effects of birth weight on adolescent weight and BMI. The higher the birth weight category & the number of overweight parents, the heavier the twins were at age 16yrs, irrespective of parental gender.	Obesity risk at 16 yrs was greatest for individuals with normal birth length and high birth weight, followed by those with high birth weight and high birth length for gestational age. Obesity risk is associated with an overweight mother and / or father At adolescence, maternal and paternal effects on BMI were similar. Not possible to determine whether this is a result of genetic or environmental effects
Laitinen et al. 2001	2876 males 3404 females (from N Finland birth cohort for 1966) (Finland) Caucasian	**Longitudinal** Adult BMI vs. family social class in childhood, maternal weight, weight tracking in childhood & age at menarche. Weight at 14 yrs was self reported. 30% of weight at 31 yrs was self reported. No data was collected on fathers.	1) Birth, 1, 14 & 31yrs 2) Maternal pre-pregnancy BMI	1) Obesity: BMI≥95th centile Overweight: 85th-95th centile 2) Overweight: BMI 25-30 kg/m² Obesity: BMI ≥30 kg/m²	Children of overweight and obese mothers had a higher mean BMI at all age points than children of normal weight or underweight mothers. At age 31 overweight and obesity were more common in children of mothers who were overweight or obese before pregnancy, with no significant difference was found between maternal BMI and daughter's BMI WHR and waist and hip circumference increased at age 31yrs with increasing maternal BMI BMI at 14 yrs was the most important predictor of BMI at 31 yrs. Low and high birth weight were associated with increased risk of overweight & obesity, the association being stronger in men.	Children of overweight or obese mothers were more likely to be overweight or obese themselves. BMI at puberty (age 14 yrs) was the greatest predictor of adult BMI. Low and high birth weight increased risk of increased BMI in adulthood, especially for men.

Author / year	Sample	Study Design / objectives	Age at Measurement 1) Offspring 2) Parent	Cut-offs for: overweight / obesity 1). Child 2). Adult	Results	Study Conclusions
Burke et al. 2001	174 fathers 214 mothers 104 sons 115 daughters (Western Australia) Ethnicity not specified	**Longitudinal** BMI & weight tracking of children vs. parental BMI (including lifestyle factors: alcohol, smoking, physical fitness, education & dietary fat intake)	1) Weight at birth, BMI at 9,12,15 & 18 yrs. 2) BMI at child's age of 18yrs.	1) Obesity: BMI>95th centile using Australian data Overweight: 85th-95th centile 2) Overweight: BMI 25-30 kg/m² Obesity: BMI >30 kg/m²	Birth weight showed an association with BMI at age 9yrs in girls only. Birth weight was associated with waist-hip ratio in girls at age 15yrs & 18yrs. Birth weight was not associated with overweight or obesity at all measured ages Significant tracking of BMI found for both genders. BMI of mothers and fathers correlated significantly. Among 18 yr olds, BMI was significantly associated with father's BMI in sons and mother's BMI in both sons and daughters There were significant independent associations between daughter's weight & obesity in fathers (OR 3.83, 95% CI 1.01, 14.54) and mothers (OR 7.88, 95% CI 1.97, 31.43)	BMI in 18 yr olds was significantly predicted by parental BMI, independent of lifestyle factors. Obesity in fathers was associated with a four-fold increase in risk of obesity at age 18 in both sons and daughters. If the mother was also obese, this independently increased the risk 8 times for girls. Birth weight showed no association with overweight or obesity at 18yrs.
Savva et al. 2002	2467 children, 6-17 yrs old (1212 male, 1255 females) (Cyprus) Greek / Caucasian	**Cross sectional study** Estimation of prevalence of childhood & adolescent obesity in Cyprus & identification of possible associated risk factors (birth weight & parental weight was self reported)	1) Birth weight & gestational age, BMI at age at time of survey (6-17 yrs). 2) Unspecified: at age at time of survey.	1) Obesity: BMI>95th centile Overweight: 85th-95th centile 2) Overweight: BMI 25-30 kg/m² Obesity: BMI >30 kg/m²	Prevalence of overweight and obesity amongst fathers was greater than mothers (27.2% vs. 22.2% respectively). Odds ratios for obesity when both parents were obese ranged from 11.34 (95%CI: 1.83-75.50) in females 6-11yrs to 18.09 (95%CI: 2.06-158.81) for males 12-17yrs. A gradual increase in OR's was found for obesity risk in relation to combinations of parental obesity. Father's obesity is a more important predictor of obesity in male offspring & mother's obesity for female offspring.	Parental obesity is the most significant predictor of obesity for both males and females (vs. physical activity & dietary intake). Father's obesity is more predictive of sons obesity. Mother's obesity is more predictive of daughter's obesity.

Author / year	Sample	Study Design / objectives	Age at Measurement 1) Offspring 2) Parent	Cut-offs for: overweight / obesity 1). Child 2). Adult	Results	Study Conclusions
Giampietro et al. 2002	869 children 448 male, 421 female 846 fathers 849 mothers (Italy) Ethnicity not specified	**Retrospective cohort** Comparison of BMI with familial factors and disease risk (birth weight and parent height / weight were self-reported)	1) Weight at birth & ≈ 10yrs. Skin-fold thickness of triceps, biceps, sub-scapular & supra-iliac areas. 2) not specified	1)Cutoffs not defined 2) Cutoffs not defined	No difference in BMI found between boys and girls although girls had significantly lower birth weight. Child BMI was positively and independently associated with parental BMI (r0.4, p<0.001). This association was stronger than the association between BMI & television watching (r0.1, p<0.01) or birth wt (r0.1, p<0.05).	BMI of 10 year old children is independently and positively associated with both maternal BMI and paternal BMI.
Hunt et al. 2002	655 women & 660 men from 521 families (from the Canadian Fitness Survey) (Canada) Ethnicity not specified	**Prospective cohort study** Investigation of the familial resemblance of 7-year changes in body mass & adiposity among Canadian families using a heritability estimate. (step-wise multiple regression analysis)	Baseline and 7-year measures of: Weight, BMI, sum of five skin-folds (SF5) & waist circumference (WC).	Cut-off values not used. BMI changes compared	All weight phenotypes showed significant familial correlations (all p<0.003) Parent-offspring and sibling correlations for BMI and skin-fold thickness were significant (p<0.0001) Parent-offspring WC measure were not significant (p=0.07) although there was evidence of sibling resemblance (p<0.002) Maximum heritability for baseline body mass (using heritability index) were moderately high: Mass: 56% BMI: 39% SF5: 41% WC: 39%	Maximum heritability for measurements (using heritability index) were moderately high: Mass: 56% BMI: 39% SF5: 41% WC: 39%
Trudeau et al. 2003	70 males 64 females (from Trois-Rivieres semi-longitudinal study) (Canada) Caucasian	**Longitudinal** Comparisons of child-parent and child-adult relationships of BMI (adopted children excluded) Parental BMI from self-reported data.	Children: Ht, Wt, BMI at age 10, 11 &12 yrs and ≈35 yrs. Parents: BMI at ≈ 36 ½ (mothers) & 39 ½ (fathers)	Cut-off values not used. BMI values compared	At age 12 yrs, child-parent BMI correlations were low, especially for sons. There was a stronger association between BMIs of mothers and daughters (r=0.41) than mothers and sons (r=0.27) Child – adult BMI correlations were strong (36% of variance in women and 30% of variance in men)	BMI at age 12 yrs was a stronger predictor of adult BMI than parental BMI in both men and women (p<0.001). Study does not support the concept of parental BMI being a strong predictor of offspring BMI.

Author / year	Sample	Study Design / objectives	Age at Measurement 1) Offspring 2) Parent	Cut-offs for: overweight / obesity 1). Child 2). Adult	Results	Study Conclusions
Hui et al. 2003	343 children aged 6-7 yrs. (Hong Kong) Asian	**Case-control study** 3 groups of students: overweight group (cases) middle weight & low weight groups (controls) vs parents' BMI, energy intake, exercise and television viewing	1) Birth weight, 6-7 yrs. 2) Not specified	1) Overweight (cases) 2)Not specified	No significant difference between males and females in each weight group. Child's weight was significantly correlated with parents' BMI. Regression analysis showed that parental obesity but not parental overweight was significantly associated with child overweight (paternal: OR=2.66 CI=1.51-4.70; maternal: OR=5.07 CI=2.62-9.79). The greatest association was found in the mother – daughter relationship(OR=5.17; CI=1.94-13.79) There was a significant association between child's birth weight and weight at 6-7yrs in all three groups.	Obesity in fathers increases the risk of overweight in offspring 2.66 times. Obesity in mothers increases the risk of overweight in offspring 5.07 times; almost double the risk for fathers. The mother-daughter association showed the greatest risk of overweight for the child.
Danielzik et al. 2004	2631 5-7 yr old children & their parents (Germany) Caucasian	**Cross-sectional study** To identify the major risk factors of overweight & obesity in pre-pubertal children Ht & wt of parents & siblings were self-reported (1,62units of BMI were added to correct for this)	Childs ht, wt & BMI Skin-folds: Triceps, biceps, sub-scapular & supra-iliac (fat mass) Bioelectric impedance analysis (fat mass) Family: BMI of parents and siblings	1)Overweight: 90-97th percentile Obese: >97th percentile: German BMI percentiles 2) Overweight: BMI 25-30 kg/m² Obesity: BMI >30 kg/m²	Birth wt was associated with obesity at age 5-7 yrs but not with overweight Overweight & obesity in the children was associated with overweight & obesity in mothers, fathers and siblings Children with two risk factors (birth wt & parental wt) had a higher BMI, higher skin-fold thickness & higher fat mass when compared to children with one risk factor.	High birth wt & parental overweight & obesity independently predict childhood obesity. Together, these two factors increase the BMI, fat mass & skin-fold thickness of the children when compared to children who only have one of these risk factors.
Silveira et al. 2005	83 overweight & 89 non-overweight subjects (Brazil) Ethnicity not specified	**Case-control study** (obese vs. non-obese adolescents) Determine risk factors for overweight among Brazilian adolescents of low income families.	Adolescents birth weight, previous obesity, ht, wt , BMI Parents ht, wt, BMI	1)Overweight: BMI >85th percentile 2)Overweight: BMI 25-30 kg/m² Obesity: BMI >30 kg/m²	Offspring with obese parents were twice as likely to be owt as those whose parents were not obese. Previous overweight in childhood showed a direct relationship with overweight during adolescence. Birth wt showed no significant association with adolescent overweight or obesity	Parental obesity doubles the risk of the development of overweight in adolescence.

Author / year	Sample	Study Design / objectives	Age at Measurement 1) Offspring 2) Parent	Cut-offs for: overweight / obesity 1). Child 2). Adult	Results	Study Conclusions
Gale et al. 2007	216 children (9 yrs old) (UK) Caucasian	**Prospective cohort**. Association between maternal size in pregnancy vs. early growth and body composition in children. Pre-pregnancy wt was self-reported	Mother's pre-pregnancy BMI, MUAC and wt at 37 weeks of pregnancy, wt gain during pregnancy Children's wt at birth, 9 months and 9 yrs. BMI & fat mass at 9 yrs.	1) Not assessed. Fat mass analysed. 2) Calculated pre-pregnancy BMI from weight at 37 weeks gestation obesity: BMI ≥30kg/m² overweight 25-30kg/m²	A larger mid-upper arm circumference (MUAC) in late pregnancy and a high pre-pregnancy BMI were independent predictors of greater fat mass index in both boys and girls. In boys, greater fat mass at age 9 was associated with increased wt gain in the first 9 months. Lean mass in children was greater in those who weighed more at birth.	Mothers who have a large MUAC in pregnancy and a high pre-pregnancy BMI tend to have children with increased adiposity.
Oliveira et al. 2007	699 children (5-9yrs) (Brazil) ±50% white & black ±50% mixed race. Not analysed for ethnicity	**Cross-sectional study** To identify family risk factors for the development of obesity in children from Brazil	Child's ht, wt BMI Parents' overweight / obesity (BMI≥85 & BMI≥95 percentile)	1) Obesity: BMI≥95th centile Overweight: 85th-95th centile 2) Not defined	Overweight and obesity were significantly associated with fathers' ($\rho < 0.03$), mothers' ($\rho < 0.03$) and parents' ($\rho < 0.03$) obesity (OR 3.5 (95%CI: 1.9-6.3, $p<0.001$). Obesity tended to be less prevalent in children whose parents were separated ($\rho = 0.07$)	Parental obesity is a significant independent predictor for the development of overweight & obesity in children.
Lawlor et al. 2007	3340 parent / offspring trios (Australia) Ethnicity not specified	**Prospective cohort** Pre-pregnancy BMI and fathers BMI vs. offspring BMI at age 14 yrs Mother's pre-pregnancy wt self reported Fathers BMI calculated from mother's report of fathers ht & wt.	Offspring ht & wt: 3-5 days after birth, at 6 months, 5yrs & 14yrs. Parents (pre-pregnancy) ht & wt.	1) Cutoffs not defined 2) Cutoffs not defined	Data for sons and daughters was combined as no differences in associations were found with either gender & their parents. Maternal pre-pregnancy wt was positively associated with birth wt & ht. No strong association was found for fathers. Associations between offspring BMI and parental BMI were statistically stronger for mother's BMI than father's BMI, even when adjusting for fast food consumption and exercise at age 14 yrs.	Maternal effect on child's BMI was significantly stronger than the paternal effect.

Author / year	Sample	Study Design / objectives	Age at Measurement 1) Offspring 2) Parent	Cut-offs for: overweight / obesity 1). Child 2). Adult	Results	Study Conclusions
Davey Smith et al. 2007	4654 parent / offspring trios (UK) Ethnicity not specified	**Longitudinal** Comparison of relative strengths of paternal and maternal BMI on BMI of offspring. (controlling for non-paternity) Pre-pregnancy BMIs calculated from self reported data.	Parental ht & wt Ht & wt of offspring at approximately 7.5yrs of age. Parental BMI data were age adjusted and for offspring were both age and sex adjusted	Cut-off values not used. BMI values compared	Correlations between maternal and paternal BMI and offspring BMI were significant and similar for both parents. When applying corrections for non-paternity, correlations between paternal BMI and offspring BMI approach those shown with maternal BMI. No evidence of a difference in effect for obese individuals.	Strength of association of paternal and maternal BMI with offspring BMI were similar at age 7.5 yrs.
Davis MM et al. 2008	2591 children Parental data for 2437 children. Grandparents data for 1573 children (USA) Ethnicity not specified	**Cross-sectional study** Prevalence of overweight (BMI ≥95th percentile for age & sex) among children aged 5-19 yrs stratified by obesity status of parents & grandparents. Data from parents & grandparents were self-reported	Parental & grandparent ht, wt & BMI (maternal and grandmother's data used unless not available. Male data only used when female data not available) Children's ht, wt & BMI,	1) Overweight BMI≥95th centile 2) obesity: BMI ≥30kg/m² overweight 25-30kg/m²	For children with normal wt grandparents, parental overweight & obesity had a statistically significant positive association with child's BMI. For children with normal wt parents, grandparental overweight & obesity had a statistically significant positive association with child's BMI. Children with obese parents had almost twice the prevalence rate of overweight regardless of grandparents' wt status.,	Overweight among children is strongly associated with obesity in parents and grandparents.
Mihas et al. 2009	2008 12-17 yr olds (1021 males and 987 females) (Greece) Greek / Caucasian	**Cross-sectional study** Determination of associations between adolescent BMI & personal, lifestyle and parental characteristics (including BMI)	BMI (physical & sedentary activities, smoking)	1) obesity: BMI ≥30kg/m² overweight 25-30kg/m² Age adjusted 2)obesity: BMI ≥30kg/m² overweight 25-30kg/m²	BMI & prevalence of overweight & obesity increased with increasing age. A 5 unit increase in fathers' BMI predicted a one unit increase in BMI of both male and female offspring. A 5 unit increase in mothers' BMI predicted a one unit increase in BMI of girls but not boys. A 10 unit increase in mothers' BMI predicted a one unit increase in sons' BMI.	Parental BMI has a significant positive effect on offspring BMI (both male & female). Fathers' obesity has a similar predictive effect on sons' and daughters' obesity. Mothers' obesity is more predictive of daughters' obesity than sons' obesity.

Author / year	Sample	Study Design / objectives	Age at Measurement 1) Offspring 2) Parent	Cut-offs for: overweight / obesity 1). Child 2). Adult	Results	Study Conclusions
Li et al. 2009	16 794 parents 2908 offspring (UK) Caucasians plus "British immigrants" Not defined Not analysed separately.	**Cohort study** Effect of recent parental BMI and parental BMI in childhood on offspring BMI (aged 4-18yrs)	1) Between ages 4 & 18 yrs. 2) 7, 11, 16, 23 & 33 yrs	1) obesity: BMI ≥30kg/m² overweight 25-30kg/m² Age adjusted 2)obesity: BMI ≥30kg/m² overweight 25-30kg/m²	In general, the BMIs of offspring were greater than those of the parents at similar ages (overweight & obesity ≈ 10% of the cohort at ages 7 and 11 yrs in 1965–1969 vs. ≈16% for children in 1991). Parents' BMI in childhood and adulthood are independently and similarly associated with offspring BMI Maternal and paternal effects were similar.	Intergenerational BMI associations are influenced by BMI of parents during their childhood. Parents recent BMI and parents BMI in childhood were independently, equally and significantly associated with BMI of their offspring.
Carvalho Francesc-antonio Menezes et al. 2009 .	University students <20 yrs old (most 16-18yrs) 106 overweight/ obese cases 233 normal weight controls (Brazil) Ethnicity not specified	**Case-control study** To determine risk factors for overweight & obesity (dietary intake, smoking, alcohol, dieting practices in previous month, perception of wt 10 years previously, parental wt, activity levels) (Parents ht & wt and students birth wt self reported)	1) Students' birth wt, ht, wt, BMI, perceived wt status 10 yrs ago. 2)Parents ht, wt & BMI	1)Overweight: BMI >85th percentile 2) obesity: BMI ≥30kg/m² overweight 25-30kg/m²	Risk factors for overweight & obesity included male gender (OR 2.27), mother's BMI >25kg/m^2 (OR 3.56), and awareness of excessive wt 10 years earlier (OR 2.96) Having been on a wt loss diet showed the strongest associated with overweight & obesity (adjusted OR 6,33)	Risk for overweight & obesity is greatly increased if the mother is overweight or obese. Personal history of overweight as well as male gender are also risk factors. These factors had a significantly greater influence on body wt than lifestyle factors, except for previous dieting

The studies summarized in Table 2.2 employed a variety of different methodologies, vary greatly in sample size and assessed different aspects and measurements of body weight. For example, while the majority of the studies defined BMI according to WHO guidelines (WHO 1998), the cut-off points for overweight and obesity are not consistent, with some studies using a BMI >27,5kg/m² as the defining value for obesity instead of the more generally accepted value of a BMI ≥ 30kg/m². Furthermore, BMI is lower in children and adolescents than in adults and the WHO definitions are not suitable for these individuals. Singh et al. (2008) recommends the use of the definition of the International Obesity Task Force (Cole et al. 2000), which includes age and sex specific international reference data and is linked to the adult BMI cut off for obesity of 30kg/m². However, several studies in Table 2.2 used internally generated BMI percentile cut-off points (eg. the 85th percentile for children calculated from the actual data). As the global prevalence of childhood obesity increases, so these calculated cut-off points would increase, resulting in different cut-off points for each time period and for different populations. This phenomenon makes it difficult to compare the studies and draw accurate conclusions. Furthermore, few of the studies seem to have controlled for activity levels and dietary intake and none of them take into account the extent of pubertal development of the study subjects. Many, but not all of the studies also use self-reported parental height and weight and this may have affected the results, although self-reported weights have been shown to be sufficiently accurate in some research (Hill & Roberts 1998) but not in others (Nyholm et al. 2007).

Bearing in mind these limitations, it is evident that the results of the studies presented in Table 2.2 point to the fact that parental body weight and shape impacts profoundly on offspring size and shape. Trans-generational associations are also evident with BMI in children being significantly and independently associated with the BMI of their grandparents (Davis et al. 2008). Only one study (Trudeau et al. 2003) did not show an association between BMI and family weight history, but indicated that child BMI is a far stronger predictor of adult BMI (at age 35 years) than parental BMI. However, the very small sample size of this study indicates that these results need to be interpreted with caution. When excluding this small study, Table 2.2 shows that having an obese parent (or parents) carries a two- to eighteen-fold increase in risk for obesity. The largest study of nearly 13 000 subjects by Lake et al. (1997) found that children with overweight or obese parents had a higher risk of obesity at the age of 33 years and that children with two obese parents were 6.8 – 8.4 times more likely to be obese in adulthood. Although obesity is defined as a BMI >27.7kg/m² in this study, by virtue of the sample size and compared to all of the studies in Table 2.2, this data may provide the most reliable prediction of obesity risk based on family history.

While there is little South African data available on the influence of family history on obesity, Senekal et al. (2003) showed that having at least one obese parent was a risk factor for obesity.

Although only three of the studies in Table 2.2 examined the effect of one vs. two obese parents on BMI, in each of these studies the number of obese parents was shown to have a cumulative effect on offspring BMI (Lake et al. 1997; Whitaker et al.1997; Pietilainen et al. 2001). Furthermore, Whitaker et al. (1997) determined that having two obese parents vs. one further increased the likelihood of being obese in adulthood 4.5 – 5 fold. Thus, obesity risk is higher for individuals with two obese parents when compared to those with only one.

When comparing the effect of parental gender on BMI, the evidence is conflicting. Some of the studies showed that the maternal effect on offspring BMI was significantly greater than the paternal effect (Hui et al. 2003; Lawlor et al. 2007). It was suggested that this provides support for the "foetal over-nutrition" hypothesis, which implies that over-eating by the pregnant mother results in a greater delivery of nutrients to the developing foetus. This high nutrient load may result in permanent epigenetic changes in appetite control, neuroendocrine functioning or energy metabolism and may lead to obesity (Lawlor et al. 2007). Another explanation could be that there may be a greater maternal effect on the development of the child's eating and activity patterns that might also influence body weight (Stunkard et al. 2004).

Other studies have not shown any significant parental gender link (Whitaker et al. 1997; Davey Smith et al. 2007; Oliviera et al. 2007). The authors concluded that many of the earlier conflicting results may have been as a result of the small sample sizes used in much of the research and from error resulting from the possible inclusion of non-biological fathers (Davey Smith et al. 2007). Pietilainen et al. (2001) showed that while maternal effects on offspring BMI were greater in infancy and early childhood, by the age of 16 years, this effect was not significantly different from the BMI effect of the father. This may explain the greater difference in effect of each parent's BMI seen in the study by Hui et al. (2003) as the children were still very young and in the study by Lawlor et al. (2007) where the children were assessed at the age of 14 years while beginning or still experiencing pubertal development. It is possible that during puberty, the body shape changes that occur are influenced by both parents equally whereas, in childhood, the mother may exert a greater environmental influence. It is not possible, however, from these studies, to determine whether the increased maternal influence is owing to pre-natal conditions or the greater behavioural influence the mother may have on the child in his or her early years.

Interestingly, four studies indicate that there may be differing BMI associations between the genders of both parents and offspring with stronger correlations shown between the BMI of mothers and daughters than between mothers and sons (Burke et al. 2001; Trudeau et al. 2003; Savva et al. 2003; Mihas et al. 2009). Furthermore, paternal BMI was more predictive of son's BMI in studies conducted in Cyprus (Savva et al. 2003) and Greece (Mihas et al. 2009). Other research does not support this result as there is general agreement that the influence of each parent on offspring BMI is similar (Oliveira et al. 2007; Gale et al. 2007; Li et al. 2009). The Greek/Greek Cypriot studies may indicate a genetic or gender-cultural influence on this BMI association between males which is not seen in Caucasian populations from the rest of Europe and North America. This may be further reflected in the fact that there are greater prevalences of obesity for men than women in Greece and Cyprus, which is also in contrast with gender specific rates of obesity in other communities (Savva et al. 2002, Mihas et al. 2009).

Apart from the possible genetic/gender-cultural influence found in the Greek studies mentioned above, other differences are not apparent for ethnicity from the studies in Table 2.2. While there is some diversity between the studies regarding the ethnic background of the study subjects, none of the studies analysed the effect of ethnicity in parental/offspring associations. There is also little South African data examining these associations. However, Senekal et al. (2003) showed that having at least one obese parent was a risk factor for obesity. As this study did not differentiate for the effect of family history on obesity by ethnicity, it is not possible to comment on any similarities or differences between the ethnic groups living in South Africa.

While there appears to be general agreement that parental body weight and shape is associated with offspring measurements, the extent to which the associations can be explained by genes, environmental factors and learned behaviours were not determined by these studies. Hunt et al. (2002) attempted to calculate the extent of heritability of body mass, BMI, waist circumference and five skin fold measures and concluded that values seem to be influenced to a large degree by familial factors with heritability values varying between 39% and 56%. However, heritability in this case included both genetic aspects and learned behaviours. An early Danish study examined the relationship between the BMI of adoptees, firstly with that of their half-siblings with whom they shared the same environment and secondly, the BMI relationship between adoptees and their full siblings, with whom they share the same parents (and genetic influences) but not the same environments (Sorensen et al. 1989). These results showed very strong correlations between the BMIs of the adoptees and their biological siblings at all BMI levels, but especially for overweight and obese individuals. Similar but weaker associations were found between the adoptees and

their half-siblings. This data implies that there are both a genetic and an environmental influence on body weight although genetic inheritance appears to have a greater effect (Sorensen et al. 1989).

In summary, parental BMI has a profound effect on offspring body weight and shape and this effect seems to be equal in magnitude for both parents in most instances with some cultural variability. This effect is cumulative such that the risk of being obese in adulthood is greater for individuals with two obese parents than for those with one. While it appears that much of this effect is inherited, it is not possible to determine the extent of genetic inheritance from the available literature and environmental influences may well interact with genotype to determine an individual's weight phenotype. It is possible that the pre-natal environment may lead to epigenetic changes that influence obesity development although most of the literature discounts an increased maternal influence after puberty and suggests that the early influence of mothers on feeding, eating behaviour and activity levels may explain the increased influence of maternal BMI in the younger child. Other shared environmental influences that may also result in similarities in BMI between children and their parents include socio-economic, socio-cultural and built environment effects.

3. **Association between personal weight history and obesity development**

Personal weight history refers to weight status throughout the lifecycle. This includes actual weight history (covered in this section), attempts made on the part of the individual to change body weight, the reasons for weight loss attempts, methods used as well as the risks associated with such behavior (Section 5).

According to Freedman et al. (2005[a]) body weight status over a lifetime tends to remain within the same weight category. Furthermore, associations between childhood weight and body fat measurements and overweight, obesity and chronic disease in adulthood are evident (Guo et al. 2002; Freedman et al. 2005[a]). Thus overweight and obesity in children and adolescents is of particular concern. This phenomenon of persistence of body weight over time is referred to as weight tracking, which is defined as follows: (i) the inter-relationship between weight measurements made both early and later in life or the stability of these measurements over time and (ii) the predictability of future weight measurements on the basis of measurements made in early life (Twisk 2003; Singh et al. 2008).

A summary of relevant research in this regard is presented in Table 2.3.

Table 2.3: Summary of research on weight tracking from childhood to adulthood

M=male F=female wt=weight ht= height yrs = years

Author / year	Sample	Study Design	Age at Measurement 1) Child/adolescent 2) Adult	Definition of overweight / obesity 1) Child/adolescent 2) Adult	Results	Study Conclusions
Weight Tracking according to BMI						
Power et al. 1997	11 212 individuals (5512 M; 5700 F) Born 1958 (UK) Caucasian plus "British immigrants" Not defined No ethnic analysis	Prospective longitudinal study (British Birth Cohort Study)	1) 7, 11 and 16 yrs 2) 23 yrs (self reported), 33 years	1) Obesity: BMI ≥98th percentile 2) Overweight: BMI≥25kg/m² obesity: BMI ≥30kg/m²	**Children obese at 7 yrs (M / F)** 20% / 21% normal wt at 33yrs 37% / 18% overweight at 33 yrs 43% / 60% obese at 33yrs **Children obese at 11 yrs (M / F)** 12% / 9% normal wt at 33 yrs 34% / 34% overweight at 33 yrs 54% / 57% obese at 33 yrs **Adolescents obese at 16 yrs(M / F)** 4% / 4% normal wt at 33 yrs 32% / 24% overweight at 33 yrs 64% / 72% obese at 33 yrs	Weight tracking of obesity into adulthood is more prevalent for obesity at age 16 yrs than at 7 & 11 yrs. Extremely overweight children tended to stay overweight Less than a third of adults who were obese at age 33 had been obese as children. Thus overweight and normal weight children moved up the BMI scale with age.
Laitinen et al. 2001	6280 individuals (2876 M, 3404 F) Born 1966 (Finland) Caucasian	Prospective longitudinal study	1) Birth, 1yr, 14 yrs (self reported) 2) 31 yrs (30% self-reported) Follow-up period: 31 yrs	1) Overweight: BMI ≥85th percentile Obesity: BMI ≥95th percentile 2) Overweight: BMI≥25kg/m² obesity: BMI ≥30kg/m²	**Normal weight youth (M / F)** 58% / 78% normal wt in adulthood 38% / 18% overweight in adulthood 4% / 4% obese in adulthood **Overweight youth (M / F)** 19% / 64 % normal wt in adulthood 56% / 42% overweight in adulthood 25% / 22% obese in adulthood **Obese youth (M / F)** 12% / 18% normal wt in adulthood 41% / 27% overweight in adulthood 47% / 55% obese in adulthood	BMI at age 1yr and 14yrs predicted BMI at age 31 yrs. BMI at age 14 (adolescence) was the best predictor of adult BMI. Early maturation imparted the highest risk of obesity.
Guo et al. 2002	347 individuals (166 M, 181 F) (USA) Caucasian	Prospective longitudinal study	1) 3, 8, 13,18 yrs 2) 35 yrs	1) (Age 18yrs) Overweight: BMI ≥ 50th percentile Obesity: BMI≥72nd percentiles 2) Overweight: BMI ≥25kg/m² Obesity: BMI ≥30kg/m²	**OR (95% CI) for being overweight in adulthood (35yrs)** Overweight vs. normal weight at 18yrs: M: 12.1 (5.5; 27.3) F: 7.9 (3.6; 17.4) **OR (95% CI) for being obese in adulthood (35yrs)** Overweight vs. normal weight at 18 yrs: M: 19.3 (5.2; 71.4) F: 15.7 (4.7; 52.2)	For both male & female overweight or obese adults, BMI values were significantly higher in childhood than for normal weight adults ($p<0.05$) BMI at age 18 yrs significantly positively predicted BMI at age 35 yrs. (NB: relatively small sample size)

Author / year	Sample	Study Design	Age at Measurement 1) Child/adolescent 2) Adult	Definition of overweight / obesity 1) Child/adolescent 2) Adult	Results	Study Conclusions
Engeland et al. 2004	128 121 individuals (61 522 M, 66 599 F) Born 1943-1969 (Norway) Caucasian	Retrospective Longitudinal study	1) 14-19 yrs 2) 24 – 54 yrs Follow-up period: mean 23 yrs	1) Overweight: ≥85th percentile 2) Overweight: BMI ≥25kg/m² Obesity: BMI ≥30kg/m²	**OR (95% CI) for being obese in adulthood:** Adolescents with BMI between 75th & 84th percentile vs. adolescents with BMI between 25th-74th percentile: M: 5.1 (4.7;5.5) F: 4.0 (3.7;4.3) Adolescents with BMI ≥ 85th percentile vs. adolescents with BMI between 25th-74th M: 15 (14;17) F: 12 (11;13)	Adolescent obesity tends to persist into adulthood. Persistence of obesity into adulthood increases as BMI increases in adolescence.
Freedman et al. 2005[a]	2392 individuals (1074 M, 1314 F) (USA) 64% Caucasian 36% African American	Prospective longitudinal study (Bogalusa Heart Study)	1) 5-14 yrs 2) ≥18 yrs Follow-up period: Mean 15 yrs	1) Overweight: BMI 85th-94th percentile. Obesity ≥95th percentile 2) Overweight: BMI ≥25kg/m² Obesity: BMI ≥30kg/m²	**For overweight children:** Girls: 65% white & 84% black became obese adults Boys: 71% white & 82% black became obese adults **OR for being overweight in adulthood** (youth BMI<85th percentile vs. youth BMI 85th-94th percentile) 7.0 (4.5-10.9) (Singh et al. 2008) **OR for being obese in adulthood** (youth BMI<85th percentile vs. youth BMI : ≥95th percentile) 19.9 (13.6-29.9) (Singh et al. 2008)	Initial BMIs were similar for black & white children. BMI increases were larger for black girls & overweight black boys than for whites. In contrast, thin (BMI<50th percentile) white boys were more likely to become overweight than thin black boys in adulthood.
Juonala et al. 2005	2260 individuals (selected in 1980) (Finland) Caucasian	Prospective longitudinal study	1) 3,6,9,12,15, 18 yrs 2) 24 – 39 yrs Follow-up period: 21 yrs	1) Overweight: ≥80th Percentile Obesity: BMI ≥ 90th percentile 2) Overweight: BMI ≥25kg/m² Obesity: BMI ≥30kg/m²	**For children aged 3-9 yrs, percentage who became obese adults:** Lean: 3.6% Overweight : 21% Obese: 34% **For youth aged 12-18 yrs, percentage who became obese adults** Lean: 5.2% Overweight: 27% Obese: 64%	BMI in adolescence showed consistent tracking with BMI in adulthood. Tracking was similar for both sexes and was greater for adolescents than for younger children. Being overweight or obese in adolescence carried a fourfold risk of obesity in adulthood.

Author / year	Sample	Study Design	Age at Measurement 1) Child/adolescent 2) Adult	Definition of overweight / obesity 1) Child/adolescent 2) Adult	Results	Study Conclusions
Deshmukh-Taskar et al. 2006	841 individuals (307 M, 534 F) (USA) 65% Caucasian 35% African American	Prospective longitudinal study (Bogalusa Heart Study)	1) 9-11 yrs 2) 19-35 yrs	1) Overweight: BMI ≥85th percentile 2) Overweight (including obesity): BMI≥25kg/m²	There was significant correlation between youth BMI & adult BMI (r=0.66, p<0.0005) for both genders and ethnicities. **For youths in the highest BMI quartile (4th quartile**), 61.9% remained in this quartile as adults. **For youths in the 3rd BMI quartile**, 62.5% remained in this quartile as adults **For youths in the 2nd BMI quartile,** 63.8% remained in this quartile as adults **For youths in the lowest BMI quartile (1st quartile),** 53.8% remained in this quartile as adults	BMI in childhood accounts for a significant proportion of the variance of BMI in adulthood. 20-40% of individuals moved up into the next BMI quartile in adulthood. 21% moved up two quartiles. Tracking was highest for white women & lowest for white men Relative risk for overweight in adulthood (overweight children vs normal weight children) =1.9
Weight Tracking according to BMI and Body Fat Measurements						
Laitinen et al. 2004	5771 individuals Born 1966 (Finland) Caucasian	Prospective longitudinal study	1) Birth, 1, 14 yrs 2) 31 yrs Follow-up period: 31 yrs	1) Overweight (self-reported): BM I≥85th percentile 2) Overweight: BMI ≥25kg/m² Obesity: BMI >29.9kg/m² Abdominal obesity: waist/hip ratio≥ 90th percentile (30% self reported)	**OR (95% CI) for having abdominal obesity in adulthood** (overweight 14 yr olds who are obese in adulthood vs overweight 14 yr olds who are normal weight in adulthood): M:11.1 (3.7;33.4) F: 46.8 (11.0;199.6)	A high BMI at age 31 yrs was the strongest predictor of abdominal obesity at age 31yrs. Adolescents who showed weight tracking were at higher risk of developing abdominal obesity in adulthood.
Sayer et al. 2004	737 men Born 1931-1939 (UK) Ethnicity not specified	Retrospective cohort study	1) Birth, 1yr 2) mean (±SD) age: 64.3(±2.6)yrs	1) Unspecified. Weights divided into quintiles 2) Unspecified. BMI calculated Body fat percentage (sum of four skin folds) Waist circumference	Birth weight was strongly positively associated with adult height, weight and fat free mass and only moderately associated with adult BMI & waist circumference. Weight at 1 yr was associated with adult BMI, fat free mass and fat mass	The relationship between birth size and adult BMI is related to fat free mass and not fat mass. Fat mass in adulthood was only associated with fat mass at 1 year and not at birth.

Author / year	Sample	Study Design	Age at Measurement 1) Child/adolescent 2) Adult	Definition of overweight / obesity 1) Child/adolescent 2) Adult	Results	Study Conclusions
Freedman et al. 2005[b]	2610 individuals (USA) 32% African American, 68% Caucasian No ethnic analysis	Prospective longitudinal study (Bogalusa Heart Study)	1) 2-5, 9-11,15-17 yrs 2) 18-37yrs Follow-up period: mean 18 yrs	1) Overweight: ≥95th percentile 2) Obesity: BMI ≥30kg/m² Overfat: mean triceps skin fold: m: ≥21mm f: ≥30.3mm	**Percentage of overweight youth who became obese in adulthood**: 2-5 yrs (M & F): 83% 9-11yrs: (M) 76%; (F) 78% 15-17yrs: (M) 86%; (F) 90% **Percentage of overweight youth who became overfat in adulthood** 2-5 yrs (M & F): 65%% 9-11yrs: (M) 67%%; (F) 67%% 15-17yrs: (M) 81%; (F) 65%	Childhood and adolescent BMI is associated with adiposity in adulthood. Overweight children and adolescents have a greatly increased risk of becoming overfat in adulthood. Both associations are strongest for adolescents.
Yliharsila et al. 2008	1917 individuals (885 M, 1032 F) Born 1934-1944 (Finland) Caucasian	Retrospective longitudinal study	1) Birth, 1-2yrs, 2-7yrs, 7-11yrs 2) 56-70 yrs	1) Overweight: ≥95th percentile 2) Overweight: BMI ≥25kg/m² Obesity: BMI ≥30kg/m² Body fat percentage Lean mass (Bioelectric impedance)	In both sexes, higher BMI in childhood predicted a higher BMI in adulthood. Birth weight and rapid weight gain in infancy predicted adult lean body mass and BMI but not fat mass. Higher adult body fat percentage was predicted by a higher BMI only after the age of 2 yrs.	Childhood body fat and BMI before the age of 2 yrs showed no correlation with adult BMI and body fat percentage. Associations were only found for children older than two years. Overweight children between 7 & 11 yrs were the most likely group to remain overweight in adulthood. Majority of adults who were overweight or obese had not been overweight or obese in childhood. Thus normal weight children gained weight with age and moved up the BMI scale.

Once again, differences in study design make it difficult to make accurate comparisons. BMI cut-off measurements to determine overweight and obesity in adulthood vary and the discussion from Section 2 regarding the phenomenon of upwardly shifting percentile cut-offs in children is also relevant here. The duration of time of follow-up also differs considerably with some studies reporting time between childhood and adult measurements to be 13 -17 years and others reporting up to 70 years. Sample sizes also differ greatly between the studies and much of the adult data was self-reported. Two of the studies used skinfold measurements to assess adiposity and body composition as a marker of obesity (Sayer et al. 2004; Freedman et al. 2005[b]). In this regard, assessing body fat may be a more accurate way of determining adiposity than BMI, which includes the measurement of fat free mass and may reflect a high muscle rather than fat mass (Wright et al. 2001). However, potential inaccuracies in skinfold measurement techniques should be considered as this might also affect the strength of the associations drawn from these papers (Watts et al. 2006). Nevertheless, while these issues make comparison between the studies difficult, fairly strong trends are evident.

An examination of the data in Table 2.3 reveals that childhood BMI at birth showed no correlation with adult BMI, with associations only found for children older than 1 year (Laitinen et al. 2001; Laitinen et al. 2004; Sayer et al. 2004; Yliharsila et al. 2008). A positive relationship was found between childhood (>1 year) and adult BMI and/or adiposity in all of the studies, with the strongest association between childhood and adult weight being for adolescents (Power et al. 1997; Laitinen et al. 2001; Guo et al. 2002; Laitinen et al. 2004; Juonala et al. 2005; Freedman et al. 2005[b]). Weight tracking was also shown to be greater with increasing BMI so that the obese child is highly likely to remain so in adulthood (Power et al. 1997; Laitinen et al. 2004; Engeland et al. 2004). Owing to the methodological differences in the studies, it is difficult to determine what proportion of the overweight and obese populations show weight tracking. However, in a review on weight tracking by Singh et al. (2008), the percentage of overweight adolescents remaining overweight in adulthood varied between 22% and 58%. For obese adolescents mentioned in the same review, the percentage of individuals likely to be overweight or obese in adulthood varied between 24% and 90%. From Table 2.3, it is evident that an overweight or obese adolescent carries a 4 to 20-fold increase in risk for obesity in adulthood.

It was evident in many of the studies that while most overweight children were obese or over-fat in adulthood, the majority of obese adults had not been overweight or obese in childhood (Laitinen et al. 2001; Guo et al. 2002; Freedman et al. 2005[a]; Freedman et al. 2005[b]; Juonala et al. 2005;

Deshmukh-Taskar et al. 2006). One study found that 20% to 40% of individuals moved up into the next BMI quartile in adulthood and 21% moved up two quartiles (Deshmukh-Taskar et al. 2006).

With regard to differences along gender lines, the results of the studies are conflicting. Two studies showed that in mixed race samples weight tracking was greatest for Caucasian women and lowest for Caucasian men (Freedman et al. 2005[a]; Deshmukh-Taskar et al. 2006). However, a larger study by Juonala et al. (2005) indicated that weight tracking was similar for both male and female Caucasians. Other studies in Table 2.3 show differences for some BMI categories and not others. Variations in study design make it difficult to draw definite conclusions and it is thus not possible to determine from Table 2.3 whether there are actual gender differences in weight tracking.

Ethnic/cultural differences in weight tracking were also difficult to clarify as there is little research available and none conducted on South African populations. However, in the study by Freedman et al. (2005[a]) mentioned above, differences in weight tracking between Caucasians and individuals of African descent were examined. It was found that although initial BMIs were similar in early childhood and weight tracking was evident in both ethnic groups, BMI increases from childhood to adulthood were larger for black girls and for overweight black boys than for white children. In contrast, thin white boys (BMI<50th percentile) were more likely to become overweight than thin black boys. Thus weight tracking was most evident for white women, who may be more weight stable than black men and women, and least evident for white men. It is possible that Caucasian women are more influenced by media pressures to be slim and more likely to attempt to prevent weight gain than African women. Black women have been found to be less concerned about being overweight and thus, weight gain with age may be more acceptable for this ethnic group (Puoane et al, 2002). This data illustrates that there may be ethnic differences in weight change over time which, for the USA at least, might result from a higher prevalence of obesity amongst black children. In addition, normal weight black children may experience greater increases in body weight in adulthood than do white children (Freedman et al. 2005[a]). The research by Freedman et al. (2005[a]) did not clarify why the ethnic differences were evident, but it was suggested by Morland et al. (2001) that it may be as a result of recent environmental changes that have increased accessibility to inexpensive, high energy foods in the poorer areas of the USA. However, generalizing these findings regarding ethnic/cultural differences to South African populations should be done with caution as these results were obtained from African American individuals who have their genetic roots in West Africa and West Central Africa

(Thomas 1998; Salas et al. 2004). The underlying genetic, cultural and environmental influences for these people may be different from those for South African Africans.

From the above discussion it is clear that weight tracking from childhood (>1 year of age) to adulthood is evident and that childhood BMI can be used to predict adult BMI with some accuracy. Weight tracking is greatest at and after adolescence and increases with age and increasing BMI. Puberty appears to be an important marker of weight status in adulthood, as early pubertal maturation tends to be associated with a higher BMI (Laitinen et al. 2001). Table 2.3 also shows that weight gain with increasing age is very common, with individuals from all weight classes moving up one or two BMI categories in adulthood. This phenomenon reflects the general global trend of increasing prevalence of overweight and obesity. With regard to differences along gender lines, the results of the studies are conflicting and it is difficult to draw definite conclusions. Ethnic differences in weight tracking were also difficult to clarify as there is little research available. However, from Table 2.3, it appears that weight gain over time is greatest for black women but that tracking is most evident for white women and least for white men.

In support of this evidence, an extensive review of 25 studies by Singh et al. (2008) that classified the studies according to their methodological quality (especially with regard to accurate description of measurement protocol and self-reported versus measured weight and height) showed that both the low and high quality studies reflected similar results, namely that there is an increased risk for overweight and obese youth to become overweight or obese adults. Interventions during childhood and adolescence should thus focus on weight gain prevention, especially for high-risk groups. However, if one compares the prevalence of overweight and obesity in childhood to that in adults, it is clear that not all overweight or obese individuals were overweight as children, indicating the prevalence of weight gain over time. Therefore, population based preventative measures are also necessary (Singh et al. 2008; Freedman et al. 2005[a]; Yliharsila et al. 2008).

Finally, it is important to note that children are currently growing up in an environment that is totally different to that for those individuals included in the studies reviewed. The studies are based on cohorts of individuals who were children at least 20 years ago when the prevalence of obesity was lower and the environment was less “obesogenic” (Singh et al. 2008). The phenomenon of moving up a BMI class with age may currently be greater than was determined in the studies as global rates of obesity increase. The studies were also all conducted in high-income countries and generalizing the results to the global community is not possible. South Africa is a country with large differences in socio-economic status and so, while the results from

Table 2.3 may have some relevance for wealthier urbanized communities, research is needed to determine weight tracking among the many ethnically and economically diverse groups resident in this country.

4. Association between weight reduction history and obesity development

The aim of this section is to present information on the prevalence of weight reduction (see Table 4.1 for detail), methods used for weight reduction and the prevalence thereof (see Table 2.4.1 for detail), reasons for weight reduction and the risks associated with weight cycling (see Table 2.4.2 for detail).

4.1. **Prevalence of Weight Reduction**

Attempting weight reduction is a common practice throughout the world and, as the prevalence of obesity has increased with time, so too has the number of people attempting to lose weight. This is illustrated clearly in Table 2.4.1 when the US Behavioral Risk Factor Surveillance System (BRFSS) study of 1996 (Serdula et al. 1999) is compared to that of 2000 (Bish et al. 2005), with 2.4% more women and 4.2% more men attempting weight loss in the later study. Other studies have also shown an increasing prevalence in weight loss attempts (Weiss et al. 2006; Millstein et al. 2008) and it is clear that "dieting" is a common practice, with weight loss attempts and frequency of attempts increasing with increasing BMI (Ikeda et al. 2004; Raynor et al. 2008).

Ethnic/cultural differences in attempting weight loss are apparent, with African Americans less concerned with being overweight and less likely to try to lose weight than Caucasians (Serdula et al. 1999; Millstein et al. 2008). Furthermore, Caucasian women are more likely than men and women from other race groups to attempt weight loss (Serdula et al. 1999; Weiss et al. 2006; Pillitteri et al. 2008).

One could speculate that since obesity prevalence is lower in South Africa compared to the USA, the incidence of attempting weight reduction, especially amongst black South Africans is also lower. However, obesity rates have been shown to be following international trends, with South African populations showing figures similar to those reported in westernized countries about 10 years ago (Armstrong et al. 2006). Senekal et al. (2003) suggested that while Caucasian women are the most likely to attempt weight reduction, the frequency of dieting amongst all South Africans is associated with overweight and obesity and with those who assessed themselves as having a body weight above normal levels. With this in mind and considering that urbanized South Africans are exposed to similar pressures from the media to be slim as well as to a wide variety of

easily attainable weight loss products (Puoane et al. 2002), it is possible that the prevalence of weight reduction attempts is currently similar to that reported from the 1996 and 2000 BRFSS studies from the USA, at least for South African Caucasian populations.

The studies reviewed in Table 2.4.1 all point to a higher dieting prevalence for women than men independent of BMI and socio-economic status (Serdula et al. 1999; Kruger et al. 2004). Women were also more likely to attempt weight loss at lower BMI values than men and overweight and obese women were more likely than men to have weight loss goals within the normal BMI range (Serdula et al. 1999). Interestingly, 25-30% of normal weight adult women were found to have attempted weight reduction (Serdula et al. 1999; Kruger et al. 2004; Bish et al. 2005; Weiss et al. 2006; Millstein et al. 2008). With regards to women, these weight loss behaviours may be explained firstly by obesity being more common in women than men (Puoane et al, 2002; Prentice 2006; WHO 2006) and secondly, by the increased societal pressure on women to conform to a slim ideal (Serdula et al. 1999; Godfrey, 2008; Wharton et al. 2008). Further detail regarding weight reduction attempts amongst normal weight women is discussed in section 4.3.

When considering adolescents and young adults, it is evident that weight loss attempts are also independent of BMI, with approximately 42-44% of individuals who attempt weight reduction being within the normal BMI range (Lowry et al. 2002; Wharton et al. 2008). South African data shows similar results amongst female Caucasian students when body weight perception was examined (Cilliers et al. 2006). Although only 10% of the students assessed in this study were overweight or obese, 36% thought that they were overweight and 55% reported to have dieted in the past two years. Furthermore, overweight status, whether real or perceived, was a strong motivator for weight reduction attempts in this group of young adults. For African female university students, 42% reported to have dieted in the past two years (Senekal et al. 2001). Thus attempting weight reduction is common for young South Africans.

In summary, bearing in mind the differences in study sample size and age, study outcomes as well as the different methodologies used, it appears that a large number of individuals attempt to lose weight at some point in their lives and many attempt weight loss more than once. Weight reduction attempts are more common amongst women, but especially Caucasian women, irrespective of their weight- or socio-economic status across all age groups. These phenomena are also prevalent in South African communities but may be less common amongst Africans when compared to their Caucasian counterparts.

Table 2.4.1: Summary of research on the association between weight management practices and obesity development

wt=weight ht= height yrs = years N=normal weight OW= overweight OB=obese

Author / year	Sample	Study Design/ objectives	Relevant Indicators	Main Results	Study Conclusions
WEIGHT MANAGEMENT PRACTICES OF ADOLESCENTS AND YOUNG ADULTS					
Senekal et al. 2001	180 female university students from rural & urban settings (South Africa) African	Cross-sectional descriptive study	BMI Body shape dissatisfaction Eating behaviour Weight management practices Self-concept	¼ of normal weight females felt that they were overweight 58.5% of normal weight females wanted to lose 1-3kg or more. 50% of overweight females felt that they were normal weight. Dissatisfaction with body shape is correlated with disordered eating habits, dietary restraint, attempting wt loss, use of unhealthy or extreme weight reduction methods and high BMI. 42% of students had attempted wt reduction in last 2 years Methods used include: balanced diet (37%), exercise+diet (22%) Missing meals / eating less between meals (46%), slimming clubs (6.5%), diet formulae (13.5%), unhealthy diets (15.5%), fasting (21%), diuretics (2%), appetite suppressants (10.5%), laxatives (15%), traditional herbal mixtures (1.7%), vomiting (12%), injections (3%), "exercise" machines (3.5%)	Weight loss attempts were prevalent in this group of African females (42%) ¼ normal weight females felt they were OW. Half of OW females felt they were normal weight. More than half the normal weight females wanted to lose some weight. Body shape dissatisfaction was associated with weight loss attempts and with less healthy strategies for weight loss A wide variety of weight loss strategies were used with unhealthy methods common.
Lowry et al. 2002	15 349 high school students (7613 Female) (USA) 61% Caucasian 14% African American 25% Hispanic / other	Cross-sectional survey (telephone survey) (The Behavioral Risk Factor Surveillance System 1999)	Wt management goals & practices Physical activity, fruit & vegetable intake & smoking	25% of students were overweight or at risk of becoming OW. 18% of white female students OW but 35.7% perceived themselves OW. 34.6% black students were OW & 32.3 perceived themselves to be OW. For females, OW black students less likely to attempt wt loss than white students (OR: 0.44). This is similar for males (OR: 0.46) Black males less accurate about weight (measured OW: 32.3 vs. perceived OW: 17.1%) than white males (measured OW: 26.6% vs. perceived: 23%) Females less likely to be overweight but more likely trying to lose weight. Wt loss attempts associated with exercise and smoking among females Wt loss attempts were associated with exercise and eating ≥ 5 servings of fruit & vegetable among males Wt loss / maintenance practices included: 62% of females & 41% of males included exercise & a low fat / low energy diet 32% of females & 17% of males used unhealthy wt control methods (fasting, diet pills, vomiting, laxatives)	Wt loss attempts are common among senior school students and especially amongst females, irrespective of their wt status. Black OW students less likely than white OW students to attempt wt reduction (OR: 0.44 females; OR: 0.46 males) More students used healthy wt loss maintenance practices (exercise & reduced fat / calories) than non-healthy practices although non-healthy practice use was high (32% in females & 17% in males)
Malinauskas et al. 2006	185 female college graduates (all completed introductory nutrition courses) 18-24 yrs 113 N 35 OW 21 OB (USA) Ethnicity not specified	Quasi-experimental design	Wt control practices (normal wt vs. OW vs. obese)	83% of individuals dieted to control their wt (80% N, 91% OW, 86% OB). Most common wt control behaviour was exercise (80%) although only 19% exercised sufficiently to control wt (21% N, 21% OW, 5% OB). Next most common wt loss strategies included the use of fat-reduced products (59%), eating less than you want (51%), using sugar-free products (43%) & "counting calories" (40%).Only consciously eating less than you want (44% N, 57% OW, 81% OB) showed significant differences between the wt groups. Unhealthy methods included skipping breakfast (27% N, 40% OW, 48% OB), lunch (10%) and dinner (4% N, 9% OW, 0%OB). Meal replacement drinks (35%) and bars (18%) were also used, as well as weight loss supplements (26%), commercial diets (e.g. low protein: 20%) and support groups (11%).Laxatives (3%) and vomiting (5%) were also prevalent. Smoking for wt control (9%) most prevalent maladaptive behaviour.	Dieting is a common wt control practice, irrespective of wt status (80% N, 91% OW, 86% OB). While exercise was used extensively, few of the subjects were exercising to required levels for wt loss. Strategies included reducing fat and total food intake, choosing sugar-free products & "counting calories". The most prevalent unhealthy wt control practice was missing breakfast. Smoking was the most prevalent extreme wt control practice.

Author / year	Sample	Study Design/ objectives	Relevant Indicators	Main Results	Study Conclusions
Cilliers et al. 2006	360 female tertiary level student (mean age 18.6±0.4yrs) (South Africa) Caucasian	Cross-sectional study	Ht, wt, BMI (WHO classification) Body wt satisfaction Wt loss practices	10% were overwt or obese but 36.1% thought they were overwt 15.8% were satisfied with their weight 55.3% had tried to lose wt in the last 2 years 26.9% of underweight and 51.3% of normal wt individuals wanted to lose 1-3kg. 34.8% of normal wt individuals wanted to lose ≥4kg Individuals with higher BMI's (whether overwt or not) were more likely to have tried to lose wt Normal wt individuals were more likely to exercise regularly	Wt reduction attempts are common amongst tertiary level students irrespective of wt status. Perceived or actual overweight / obesity is a motivator for wt reduction attempts. Normal wt individuals exercised more than overweight & underweight individuals.
Wharton et al. 2008	38 204 college students (24833 female) (USA) 78% Caucasian 5% African American 17% Hispanic / other Not analysed for ethnicity	Cross-sectional survey (National College Health Assessment Survey: USA)	Wt loss strategies (healthy vs extreme) Wt perceptions	50% were trying to lose wt although only 28% of students were overweight or obese 73% exercised, 43.3 % dieted for wt control but only 38% of wt loss attempters used both diet & exercise 12% had inaccurate body perceptions & these individuals were twice as likely to engage in inappropriate wt control strategies (vomiting, laxative use, diet pills).	Dieting is common in college students, irrespective of wt status. Only 38% of individuals used both diet & exercise. Individuals with inaccurate body perceptions were more likely to engage in unhealthy wt loss strategies.
WEIGHT MANAGEMENT PRACTICES OF ADULTS OLDER THAN 15 YEARS					
Serdula et al. 1999	107 804 (54 333 females) ≥18 yrs (USA) 79.9% Caucasian 10.1% African American 10% Hispanic / other	Cross-sectional survey (telephone survey) (The Behavioral Risk Factor Surveillance System 1996)	Current wt Goal wt Current wt loss attempts/ maintenance & success factors. Wt loss practices: use of diet, exercise or diet + exercise (Unhealthy and extreme wt loss methods not reported)	More women (Total=43.6%: N=28.7%, OW= 60%, OB=70%) than men (Total=28.8%: N=8.6%, OW=36%, OB=60%) were trying to lose wt, independent of socio-economic status. Men were as likely to do nothing about their wt as try to lose wt. Wt loss & maintenance attempts increased with education. African Americans were less likely to attempt wt loss than Caucasians (OR: 0.58 females; OR: 0.84 males). Attempts to maintain wt were similar amongst men (35.1%) & women (34.4%) and were inversely associated with BMI. Black women were 20% less likely to try to maintain wt (vs. all women). Black men were 10% more likely to try to do this (vs. all men). For wt loss, 90% of individuals reported modifying their food intake: almost half reduced energy intake and just over a third ate less fat. While two thirds reported using exercise for wt control, only a fifth reported eating less energy & engaging in sufficient physical activity. For wt maintenance, dietary modification was mentioned more often than exercise Exercise was least likely in the obese, uneducated and elderly.	More women than men attempted wt loss irrespective of wt status. African Americans were less likely to attempt wt loss than Caucasians (OR: 0.58 females; OR: 0.84 males. Approximately ½ of all wt loss attempters reduced energy intake and about ⅓ cut back on fat. Exercise was commonly used as a wt loss method but few exercised sufficiently to achieve wt loss. Diet was used more than exercise, especially in obese individuals, the elderly & those with low education levels. No differences were found for ethnicity.

Author / year	Sample	Study Design/ objectives	Relevant Indicators	Main Results	Study Conclusions
Lappalainen et al. 1999	15 239 adults aged 15 yrs and older (Europe: 15 countries) Ethnicity not specified	Cross-sectional study (±1000 people from each EU member state)	Wt change Attitudes to exercise Wt loss practices: diet, exercise & diet+ exercise.	Females were more likely to report wt change (gain or loss) than males as were overweight or obese individuals. 58% of overwt / obese individuals had gained wt in the last 6 months Differences across age and education level were insignificant. Almost a fifth of underweight people were trying to lose weight. Exercise was used as a weight loss strategy in Austria, Sweden & Ireland (± 14%) vs. very seldom in the Netherlands, Portugal & Belgium (± 2%) Of the 41% who were overweight / obese, 6% were used diet & exercise to control their weight, 10% used diet only & 4 % used other unspecified methods.	A large number of underweight individuals were trying to lose weight (approx 1/5 of underweight individuals). A large number of overweight people continued to gain weight. Exercise was generally not considered as a weight control tool. Few overweight & obese individuals used diet and exercise to manage their wt.
Field et al. 2004	2476 women who had intentionally lost wt between 1989-1993 34-44yrs (USA) Ethnicity not specified	Case control design. Nested study (Nurses' Health Study II) Cases: weight cyclers (WC) Controls: non wt cyclers	Current wt, wt concerns, wt control behaviours, Attitudes re exercise	Most women used a variety of methods. Low fat diet most common approach (60.5%) Skipping meals was used by 13% of non-WC and 22% of severe WC's Weight cyclers (WC) more likely to choose low energy or high protein diets, skipping meals, fasting and commercial diet products than non-WC WC less likely to choose exercise as a wt control method	Low fat diet most common wt loss approach Participation in physical activity was greatest amongst wt stable individuals. WCs more likely to choose unhealthy diet options & less likely to maintain wt loss.
Ikeda et al. 2004	149 obese women (BMI>30 kg/m²) BMI range: 33-77kg/m² (USA) 106 Caucasian 28 African American Not analysed for ethnicity	Cross-sectional Study (self-completed data)	Ht, wt, BMI Early dieting history Wt control practices. Dieting attitudes and experiences	Women with the highest BMI's were more likely to have started their first diet before 14 yrs of age. These individuals were twice as likely to have dieted > 20 times. They were far more likely to disagree that dieting improved health and self-esteem. Most common methods were low-calorie diets (90%), commercial wt loss diets (81%), diet books (64%), diet drinks (52%), overeaters support groups (44%) & VLCD liquid diets or fasting (36%). 44% reported using amphetamines for wt loss. 41% had used OTC drugs to control wt. Negative memories of dieting far exceeded positive ones.	Higher BMI was associated with starting first diet before age 14 years & were more likely to have dieted ≥ 20 times. Common dieting practices include low energy and commercial diets, diet books and support groups, VLCD liquid diets or fasting and the use of amphetamines and OTC drugs . Dieting was associated with negative memories.
Kruger et al. 2004	30,433 adults (wt loss attempts) (16885 females) 9419 adults (wt loss strategies) (6169 females) 68.5% Caucasian 13.4% African American 18.1% Hispanic / other (USA) Not analysed for ethnicity	Cross-sectional study (Data from the 1998 National Health Interview Survey)	Wt loss attempts Wt loss strategies (effectiveness not assessed)	31% of US adults were trying to lose wt. More women (37.6%) than men (24.3%) were trying to lose wt but similar weight loss methods were used. The proportion of individuals trying to lose wt increased with BMI & education level. Weight loss attempts less common for normal weight people (6% men, 24% women) than the overweight (28%, 49%) or obese (50%, 58%) Most common wt loss strategies were reducing energy intake (61%), eating less fat (53%) and exercising more (53%). One third of those trying to lose weight followed recommended guidelines of increasing physical activity & eating less energy. These individuals tended to have higher education levels. Obese individuals more likely to eat less energy & less likely to exercise. Women were more likely to have used a variety of strategies equally but men were more likely to skip meals (11% vs. 9% for women) or do nothing. Herbal and dieting supplements (5%: men, 6%: women) and diet pills (2%, 3%) were less commonly used.	Weight loss was common irrespective of BMI especially for women. ¼ of normal wt women were trying to lose weight (not analysed for ethnicity). More women were trying to lose wt & this increased with education. Wt loss attempts increased with increasing BMI. Most common strategies were eating fewer calories, less fat and increasing exercise. Only about 3% of individuals were using diet pills (OTC or prescription) and 6% using herbal and dietary supplements for weight loss Similar strategies were used for women & men Obese individuals were more likely to eat less energy & less likely to exercise.

Author / year	Sample	Study Design/ objectives	Relevant Indicators	Main Results	Study Conclusions
Bish et al. 2005	164 187 adults ≥18 yrs (wt loss attempts) (94 536 F) 64 799 (wt loss strategies) (42 776 females) (USA) 77.9% Caucasian 7.8% African American 14.3% Hispanic / other	Cross-sectional survey (telephone survey) (The Behavioral Risk Factor Surveillance System 2000)	Current wt Goal wt Current wt loss attempts/ maintenance & success factors. Wt loss practices: diet, exercise & diet + exercise	57% were overweight or obese. More women (46%total: 54% OW, 63% OB) than men (33% total: 37% OW, 55% OB) were trying to lose wt. Medical advice to lose wt was significantly associated with wt loss attempts irrespective of BMI (OR women= 6; OR men=10) but not associated with using the recommended combination of diet & exercise. Body weight/shape dissatisfaction was a strong motivator for wt loss attempts in women. This was greater for younger women. ± 2/3 of men & women reported using physical activity for wt control & this decreased with age & increased with education level. Only one fifth used reduced energy plus sufficient physical activity as a wt loss strategy & African Americans were less likely to follow this strategy	Wt loss attempts had increased from the 1996 BRFSS survey probably as a result of increased levels of obesity. Women were more likely to try to lose weight, irrespective of BMI (not assessed for ethnicity) This is associated with body dissatisfaction. Medical advice associated with wt loss attempts, especially for men. While many individuals used diet + exercise, only 1/5 used sufficient exercise to promote wt loss. African Americans were less likely to use diet + exercise.
Weiss et al. 2006	4354 adults ≥ 20 years (2145 females) (interviewed & examined) (USA) 52.5% Caucasian 19.8% African American 27.7% Hispanic / other	Cross sectional survey (NHANES data: 2001-2002)	Wt control status Wt control practices Physical activity	51% tried to control their wt in the previous year: (lose wt: 34% men: N=10%, OW=37%; OB=55.5% & 48% women :N =30%, OW=55%, OB=64%: maintain wt: 11% men;10% women) More Caucasians attempted wt loss than African Americans & Hispanics, who showed similar prevalence of attempts Top 4 dieting practices were: eat less food (65% for losers vs. 52% for maintainers), exercised (61% vs. 46%) ate less fat (46% vs. 42%) & changed to lower energy foods (37% vs. 36%) Less common practices include skipped meals (17%), used diet foods and liquid meal replacements (10.2%) and used OTC pills, herbal and dietary supplements. Fewer than ¼ of individuals reduced energy intake & exercised > 300 minutes per week	⅓ of normal wt women were trying to lose wt (not assessed for ethnicity) Most common wt loss strategies included eating less, exercising more, eating less fat & changing to reduced energy foods. Only 22.3 % of individuals who used exercise, did so in sufficient amounts for wt loss. Caucasians more likely to try to lose wt than African Americans & Hispanics, who showed similar "dieting" prevalence
Annunziato et al. 2007	112 women (USA) 42 Caucasians 70 African Americans	Cross sectional study	Weight control practices	95.5% of all women reduced energy intake by cutting back on certain foods (e.g. Fats, CHO). 73% of African Americans and 83% of Caucasians used exercise. African Americans were as likely to use meal replacements (58%) vs. Caucasians (57%). Caucasians were more likely to enroll in a commercial wt loss programme (50%) vs. African Americans (30%). African Americans were more likely to use diet pills (48%) and herbal supplements (52%) vs. Caucasians (43% & 19% respectively).	Modifying food and energy intake was the most common practice for both groups. Exercise was also commonly used although slightly more so for Caucasians. Commercial weight loss programmes were more common for Caucasians vs. African Americans. African Americans are more likely to use diet pills and herbal supplements.

Author / year	Sample	Study Design/ objectives	Relevant Indicators	Main Results	Study Conclusions
Millstein et al. 2008	9740 adults (5436 females) (USA) 70.4% Caucasian 12.3% African American 17.3% Hispanic / other	Cross-sectional survey (telephone survey) (Data from The National Physical Activity and Weight Loss Survey (NPAWLS)	Ht Wt Body size satisfaction / dissatisfaction Wt loss practices (diet only, exercise only , diet +exercise)	More women (Total=45%: N=27%, OW=60%, OB=70%) than men (Total=32%: N=9%, OW=36%, OB=60%) were trying to lose wt. Body size dissatisfaction differed by age, race, education, general health status & BMI with women reporting greater dissatisfaction than men in all respects. Older women (≥60 yrs) showed significantly less dissatisfaction than young women (aged 18-29yrs). This was reversed in men. The odds of African American & Hispanic women being dissatisfied were significantly lower than for white women even though they were more likely to be overweight. Body size dissatisfaction was associated with wt loss attempts. Dissatisfied women were less likely to use exercise or exercise plus diet than satisfied women. "Somewhat satisfied" men were more likely to use exercise or diet + exercise for wt control.	Weight loss was common irrespective of BMI especially for women. >¼ of normal wt women were trying to lose weight (not assessed for ethnicity). Body size dissatisfaction is a motivator for attempting to lose wt, especially amongst normal weight women. Women, especially young women were more likely to be dissatisfied than men. African Americans & Hispanics are less likely to be dissatisfied. Dissatisfaction is associated with wt loss attempts using diet only but not with using exercise or diet + exercise as weight loss methods.
THE USE OF NON-PRESCRIPTION DIETARY SUPPLEMENTS FOR WEIGHT LOSS					
Blanck et al. 2001	14 679 adults ≥ 18 years old (8541 females) (USA) 87.5% Caucasian 6.9% African American 5.6% Hispanic / other Not analysed for ethnicity	Cross-sectional survey (The Behavioral Risk Factor Surveillance System 1998)	Prevalence of nonprescription wt loss product use.	7% of individuals reported nonprescription wt loss product use. Use was especially high for young obese women (28.4%) and prescription wt loss product users (33.8%) 7.9% of normal weight women reported used non –prescription weight loss products. More users than non-users exercised ≥ 30 minutes 5 times per week.	Nonprescription wt loss product users are more likely to be young obese females or individuals already taking prescription drugs for wt loss. Use by normal wt women was relatively high although lower than for overweight or obese individuals.
Pillitteri et al. 2008	3500 US adults Individuals who have made weight loss attempts: n=1444 (620 females) (USA) 75.4% Caucasian 8.9% African American 15.7% Hispanic / other	Cross-sectional survey (telephone survey) (funded by pharmaceutical company)	Dietary supplement (DS) use for wt reduction	33.9% of wt loss attempters had used DS for wt loss. Use was more common among women (44.9%) vs. men (19.8%), young adults (25-34yrs), African Americans (48.7%) & Hispanics vs. Caucasians (31.2%). Use of DS was more common in obese (40.7% vs. overweight (29.1%), those with more wt loss attempts and those who used more wt loss methods. Use was also more common among the less educated & poorer.	Use of dietary supplements is common, especially among obese women, young adults and in individuals who have many wt loss attempts and who have tried a number of wt loss methods. DSs are used by individuals who want greater wt reductions and may be used out of desperation. In the USA, use of DSs for wt loss is higher for African Americans and Hispanics vs. Caucasians and for poorer, less well educated individuals.

Author / year	Sample	Study Design/ objectives	Relevant Indicators	Main Results	Study Conclusions
Tsai et al. 2009	1437 US adults (772 females) (USA) 78.1% Caucasian 9.4% African American 12.5 Hispanic / other	Cross-sectional survey (telephone survey) (funded by pharmaceutical company)	Difference in use of wt loss treatments by ethnic and socio-economic classification.	African Americans & Hispanics were more likely to use exercise or nonprescription DSs for wt loss than Caucasians. African Americans & Hispanics were less likely to use commercial wt loss programmes for wt loss purposes Individuals with more than high school education were less likely to use DSs for wt loss Women, obese individuals and individuals with a number of co-morbidities were more likely to use all dietary regimens except exercise & self-designed regimens. ±50% of individuals believed that DS were safe and effective and had been approved by government legislative bodies.	In the USA, use of DSs for wt loss is higher for African Americans and Hispanics vs. Caucasians and for poorer, less well educated individuals. Exercise is less likely to be used by Caucasians, women, obese individuals and those with co-morbidities. These individuals are also more likely to use a number of dieting aids

4.2. **Weight Reduction Methods**

Recommendations for healthy weight reduction include aiming for a slow, steady weight loss by reducing energy intake while consuming sufficient nutrients and increasing physical activity (Dietary Guidelines for America 2005). In the literature, weight reduction methods have been described as falling into one of three categories: healthy methods, unhealthy methods and extreme weight reduction methods (Nieumark-Sztainer et al. 1996; Nieumark-Sztainer et al, 2006). This section focuses on a discussion of these three categories of weight loss methods and their prevalence, as is evident from Table 2.4.1.

4.2.1. Healthy Weight Loss Methods

Healthy weight loss strategies include reducing energy intake, eating less fat and sugar, increasing the intake of fruit and vegetables, exercising more (especially in conjunction with one of the above strategies) and joining various formal weight loss programmes (Saper et al. 2004; Ikeda et al. 2004; Malinauskas et al. 2006; Nieumark-Sztainer et al. 2006; Wharton et al. 2008).

The majority of the studies in Table 2.4.1 point to a high prevalence of the practice of modifying food intake for weight loss, with most authors estimating the use of these strategies in approximately 90% of individuals who have tried to lose weight. The most common practices include reducing energy intake and eating less fat / sugar (Serdula et al. 1999; Kruger et al. 2004; Bish et al. 2005; Annunziato et al. 2007; Tsai et al. 2009). Increasing fruit and vegetable intake was also mentioned as an important weight loss strategy (Lowry et al. 2002; Kruger et al. 2006). These healthy weight loss practices were more likely to be used by individuals who had higher levels of education (Kruger et al. 2004; Bish et al. 2005; Tsai et al. 2009). Comparisons for ethnicity reveal that a similarly high number of Caucasian and African American women limited dietary fat and sugar intake in order to reduce their energy intake for weight loss (Annunziato et al. 2007). However, Senekal et al. (2001) found that female African students living in South Africa made use of a balanced diet for weight loss but that this was not the most common practice, with skipping meals/eating less between meals being used more often.

Exercise, also a commonly used weight loss method (Serdula et al. 1999; Kruger et al. 2004; Bish et al. 2005; Raynor et al. 2008; Tsai et al. 2009), was used as a strategy for weight control in about 50-75% of subjects across all of the larger studies involving adults. However, fewer individuals (between 6 and 33%) included a reduction in energy intake or exercised at sufficient levels for weight loss (Serdula et al. 1999; Lappalainen et al. 1999; Field et al. 2004; Kruger et al. 2004; Bish et al. 2005; Weiss et al. 2006). Regarding ethnic differences, exercise was commonly

used by African and Caucasian individuals in some studies (Serdula et al. 1999; Annunziato et al. 2007), although other research found that African Americans were more likely than Caucasians to exercise for weight loss and less likely to use a combination of diet and exercise (Bish et al. 2005; Tsai et al. 2009). Little data is available regarding the use of exercise as a weight loss strategy in South African adults. However, a recent study found no association between physical activity and BMI or waist circumference among Africans living in South Africans (Malhotra et al. 2008).

Adolescents and young adults used exercise more often as a weight loss strategy than older adults with the prevalence between 73% and 80% of those attempting weight loss (Malinauskas et al. 2006; Wharton et al. 2008). The use of energy restriction together with exercise was also greater in this group, with 38% - 62% of individuals using both strategies (Lowry et al. 2002; Wharton et al. 2008). However, Malinauskas et al. (2006) reported that whilst exercise was a commonly used strategy, only 19% of these individuals exercised at levels sufficient for weight loss. Two South African studies indicate a greater use of exercise by female Caucasian university students (Cilliers et al. 2006) when compared to a similar group of African students (Senekal et al. 2001). Furthermore, although a balanced weight reduction diet was used by approximately a third of the African females, exercise together with reduced energy intake was only used by 22% of "dieters" in this group.

Factors associated with a reduced likelihood of exercise being used as a weight loss strategy include gender, with women less likely to exercise than men (Tsai et al. 2009), obesity (Serdula et al. 1999; Kruger et al. 2004; Tsai et al. 2009) and weight cycling, with those who have attempted weight loss many times less likely to exercise (Field et al. 2004). Other individuals less likely to exercise have lower educational levels, are elderly (Serdula et al. 1999; Bish et al. 2005) or have obesity related co-morbidities (Bish et al. 2007; Tsai et al. 2009). Body shape dissatisfaction is also associated with a reduced likelihood of the use of exercise for weight reduction (Millstein et al. 2008).

4.2.2. Unhealthy Weight Loss Methods

Weight reduction strategies that may negatively affect health include missing meals, using liquid meal replacements, diets that eliminate specific food groups or foods or require certain combinations of foods, including a large variety of novel diets that are easily accessible to most individuals (Saper et al. 2004; Ikeda et al. 2004; Malinauskas et al. 2006; Nieumark-Sztainer et al. 2006; Wharton et al. 2008). Such diets are used less often than healthy strategies although their

use is still high, with Table 2.4.1 indicating that these methods are used by 13% - 64% of individuals.

The use of unhealthy methods increases with increasing BMI and with an increasing number of "diets" attempted. This is clearly illustrated when examining the prevalence of "missing meals" for weight loss. Firstly, Malinauskas et al. (2006) showed that amongst female college graduates the most common meal missed for weight loss purposes was breakfast, with 27% of normal weight individuals skipping this meal in an attempt to lose weight versus 40% of overweight individuals and 48% of obese individuals. Secondly, the study by Field et al. (2004) showed that individuals who had attempted weight loss numerous times (weight cyclers) used meal skipping in 22% of weight loss attempts whereas in individuals who do not attempt weight loss often (non-weight cyclers), this strategy was only used by 13% of subjects. Kruger et al. (2004) also showed that, while women, especially those who are obese, were more likely to use a number of unhealthy strategies for weight loss than men, men were more likely to skip meals (11%) than women (9%). Since the large epidemiological studies in Table 2.4.1 do not distinguish between ethnicities when reporting weight loss methods used and the study by Annunziato et al (2007) did not assess meal skipping, it is not possible to differentiate between Caucasians and African Americans for meal skipping from this summary. However, South African research shows that African female university students used missing meals and eating less between meals in 46% of weight loss attempts (Senekal et al. 2001). This data is difficult to interpret as "eating less between meals" may mean cutting out high energy, nutrient poor snacks and this could be classified as a healthy strategy. However, the unhealthy practice of missing whole meals was evident.

Other unhealthy strategies such as the use of meal replacement formulae, diet bars and diets that restrict specific foods (e.g. high protein diets) were used in 13%-35% of cases in young adults (Senekal et al. 2001; Malinauskas et al. 2006) vs. 52%-64% in a group of regularly "dieting" obese adult women (Ikeda et al. 2004). This may point to an increasing use of unhealthy strategies as the number of weight loss attempts increase and as BMI increases and may be as a result of a lack of weight reduction success using healthier methods at an earlier age. Regarding differences for ethnicity, Annunziato et al. (2007) found that the use of meal replacement formulae and diet bars were used as often for Caucasian (57%) and African American (58%) women.

4.2.3. Extreme Weight Loss Methods

According to Nieumark-Sztainer et al. (1996) extreme weight loss practices can severely compromise health. These practices include fasting, vomiting, the use of laxatives, diuretics and

amphetamines as well as other over-the counter (OTC) pills and potions (Nieumark-Sztainer et al, 1996; Saper et al. 2004; Ikeda et al. 2004; Wharton et al. 2008).

Table 2.4.1 points to a lower prevalence of use of these strategies in adults (2%-7%) although use was still high among individuals who were desperate to lose weight (Pillitteri et al. 2008), for young obese women, for individuals who use prescription medications for weight reduction (Blanck et al. 2001) and for those who lose and regain weight regularly (Field et al. 2004). In one study of very obese women, between 40% and 45% of individuals reported to having used amphetamines and/or OTC diet supplements / drugs for weight loss (Ikeda et al. 2004). This data suggests that obese individuals who are desperate to lose weight are likely to resort to more extreme practices when other methods of weight loss fail (Saper et al. 2004).

Interestingly, 7.9% of normal weight women reported using OTC drugs for weight loss, which concurs with the earlier observation that weight reduction attempts are common, irrespective of weight status (Field et al. 2004). In the USA, OTC diet pill use was higher amongst African American vs. Caucasian individuals (Annunziato et al. 2007; Tsai et al. 2009) and for poorer and less well-educated individuals (Tsai et al. 2009).

When considering extreme weight loss habits in adolescents and young adults, fasting, the use of diet pills, vomiting and laxatives were used by 32% of girls and 17% of boys attending high school (Lowry et al. 2002). Senekal et al. (2001) found that the use of extreme weight loss methods was also prevalent in African females living in South Africa, including fasting (21% of attempts), appetite suppressant and laxative use (10-15%) and vomiting (12%). When compared with a similar group of Caucasian students (fasting: 8%; appetite suppressant and laxative use: 2-6% and vomiting: 1%) (Senekal 1988), it is clear that the use of these unhealthy weight loss strategies is more common in Africans. Traditional herbal mixtures were used in 1.7% of weight loss attempts in this group of African students. Since traditional herbal preparations are used in South Africa for treating a number of ailments (www.sahealthinfo.org/traditionalmeds.htm), this is not surprising. International research also points to a higher use of “herbal supplements” in African Americans (52%) than Caucasians (19%) and one could speculate that herbal preparations are also more acceptable to Africans living in other parts of the world.

Individuals with inaccurate body weight perceptions and who are at risk of developing eating disorders were also found to be more likely to use these extreme weight loss strategies (Wharton et al. 2008). In a review of OTC products for weight loss, Saper et al (2004) listed the main reasons for the use of dietary supplements for weight control by overweight / obese individuals.

These reasons include the desire for a “magic bullet” for weight loss that does not require demanding lifestyle changes, frustration with previous unsuccessful attempts at dieting and/or exercise, ease of availability and the fact that they are less expensive than seeking professional help. Furthermore, inflated advertised claims and the appeal of a “natural” remedy, where “natural” equals “safe” in many peoples’ minds also influence the use of these products.

While there is little information regarding the use of these extreme practices among South African adult communities, OTC weight loss products and diet pills are available and easily accessible in this country (Puoane et al. 2002). As they have been shown to be used by university students (Senekal et al. 2001), it could be speculated that usage of these products is similar to westernized countries amongst individuals who attempt weight reduction in South Africa.

4.2.4. Summary

In summary, whilst it is important to note the differences in study sample size and age, ethnic composition of the study subjects, study outcomes as well as the different methodologies used for the studies summarized in Table 2.4.1, clear trends are evident. Healthy weight loss practices such as reducing energy and fat intake and exercising more are commonly used, especially by individuals with higher education levels. Reducing energy and fat intake also appears to be similar for both Caucasian and African women. Although it is not possible to determine from the reviewed literature whether specific individuals used healthy methods exclusively or whether these individuals also used less healthy and/or extreme practices, it has been noted that, at least among obese women, a variety of weight loss methods are commonly used . Exercise is frequently used and its use is more common amongst men, young individuals, the less obese, and those whose health is relatively good. However, many individuals, both male and female were found to not be exercising to sufficient levels in order to achieve weight loss and/or were not combining increased exercise with a reduction in energy intake. While exercise was found to be used more often amongst African Americans than Caucasians in USA, some evidence points to the fact that this is not the case in South Africa. It is thus important to consider the potential for differences even among people of the same ethnicity when applying international research results to South African communities.

Less healthy weight loss methods such as skipping meals and using meal replacement diet products were used to a lesser extent than healthy methods. Usage increased with increasing BMI and with the number of diets attempted. While meal replacement use appears to be similar

for Caucasians and individuals of African ancestry, skipping meals and eating less between meals was reported as the most common weight reduction practice.

The use of OTC pills and potions for weight loss was low in total but found to be higher for individuals with lower education levels, those of lower socio-economic status and the obese, especially young obese women. In the USA, use was also higher amongst African Americans than Caucasians, irrespective of educational level. Other extreme practices such as vomiting and laxative use were prevalent in the obese but also especially in young women and those with disturbed body image perceptions. Extreme methods are also used in female African university students.

4.3. **Reasons for Attempting Weight Reduction**

While weight reduction attempts are prevalent for a large number of individuals, the motivations behind attempting weight loss have not been clearly determined. It is clear that the presence of overweight and obesity leads to weight reduction attempts in both men and women (Table 2.4.1) and increases with increasing education levels (Biener & Heaton 1995; Serdula et al. 1999; Bish et al. 2005; Weiss et al. 2006), with differences for weight loss motivation also being evident between the genders.

The assessment of more than 100 000 overweight and obese individuals by Bish et al. (2007) indicated that men were more likely than women to be motivated to lose weight if they perceived their weight to be affecting their health and if they had received medical advice to do so. Men were also less likely to attempt weight reduction if their weight fell within or close to the normal BMI range (Bish et al. 2005). Overweight and obese men were also as likely to do nothing about their weight as to try to lose weight (Serdula et al. 1999). No differences were found for reasons for attempting weight reduction between male Caucasians and African Americans although African American males were less likely to attempt weight loss than Caucasians (OR: 0.84) (Serdula et al. 1999).

Motivation to attempt weight reduction appears to be different for women. Women require time and energy to change their lifestyles and are thus more likely to attempt weight loss if they are in good physical health (Bish et al. 2007). Poorer mental health (stress, depression and emotional issues) is also associated with weight reduction attempts in women. However, it is likely that this mental stress results from unrealistic weight loss expectations and does not act as a motivator to lose weight (Bish et al. 2007). While a high BMI and increasing body weight are very strong

motivators for attempting weight loss in women (Ikeda et al. 2004; Raynor et al. 2008), not all individuals who try to lose weight are actually overweight or obese. Women are more likely to attempt weight loss at lower BMIs than men (Bish et al. 2005) and also exhibit a higher incidence of body size and shape dissatisfaction (Millstein et al. 2008). Body weight/shape dissatisfaction has been identified as a strong motivator for weight loss attempts in adult women, especially for those of normal weight (Millstein et al. 2008). The prevalence of body shape/weight dissatisfaction is lower in the USA among African Americans than Caucasians, even though African Americans are more likely to be overweight (Millstein et al. 2008). Similarly South African women of African ethnicity have been found to be less dissatisfied with their body shape/weight (Kruger et al. 2005; Puoane et al. 2005) and this may explain the lower prevalence of weight loss attempts found in African women compared to Caucasians. Ethnic/cultural body weight norms may influence body shape dissatisfaction, with societal and media pressures that promote slimness as an ideal female form having a strong influence over Caucasian women (Godfrey 2008) and an overweight female form being more acceptable for Africans.

Dissatisfaction with body weight/shape is also prevalent amongst adolescent and young adult females (Cilliers et al. 2006; Millstein et al. 2008; Wharton et al. 2008) and is also less common in Africans (Senekal et al. 2001). However, whilst research amongst rural Zulu adolescent girls indicated that body weight dissatisfaction and resultant eating disorder risk were very low at approximately 3% of individuals (Szabo & Allwood 2004[a]), a very different picture is seen in urban areas where 18.6% of black African girls of varying ethnic groups showed high levels of dissatisfaction and eating disorder risk (Szabo & Allwood 2004[b]). This prevalence is similar to levels of dissatisfaction found in Caucasian adolescents (Lowry et al. 2002) and was confirmed in a study by Caradas et al. (2001) who found that 17.9% of black female adolescents and 21.2% of white female adolescents showed a high risk for eating disorders. It is possible that, with time, attempts at weight reduction by African females living in South Africa will increase as urbanisation increases and the Western norm for a slim body weight becomes internalized, to the point when the prevalence of weight loss attempts is similar to those made by Caucasian females.

In an examination of current dieters, Biener and Heaton (1995) attempted to determine motivations for weight loss attempts amongst normal weight women. Adjusting for education level and age, individuals attempting weight loss saw themselves as being healthier than non-dieters, although there was no difference between the two groups regarding chronic disease prevalence. Almost two thirds of normal weight women trying to lose weight in this study indicated that their main motivation was to improve their health or general level of fitness and 37% said that their

main goal was to improve their appearance or body shape. Malinauskas et al. (2005) added to this research with their distinction between “healthy weight” and “attractive weight”, with normal weight individuals attempting to lose weight in order to become more attractive.

In summary, weight loss is more likely to be attempted by individuals with both perceived and actual overweight or obesity and by those showing high levels of body weight dissatisfaction, irrespective of BMI, although men are less likely to attempt weight reduction at lower BMIs. Women, especially young women, are more likely to try to lose weight as are individuals who have been advised to do so by a physician. Other motivations include improving health and increasing attractiveness. Weight loss attempts are also more common in individuals who have attained higher levels of education and it is possible that these individuals value the health benefits of weight loss and/or have greater demands placed on them to conform to societal norms.

It is important to bear in mind that for Africans living in South Africa, weight loss may be associated with illness and unhappiness (Renzaho, 2004; Kruger et al. 2005) and is less likely to be attempted. However, urban African adolescents are showing body weight dissatisfaction levels similar to South African Caucasians and weight loss attempts may be higher for young, urbanised African women. It is possible that, over time, attempts to lose weight will become more prevalent for black South African women of all age groups and weight classifications.

4.4. **Association between weight cycling and weight gain and obesity development**

While studies have shown that weight loss and energy restriction are safe and that weight loss is beneficial to health for overweight and obese individuals (Walford et al. 2002), the fact that it may be a risk for further weight gain and other negative health outcomes has resulted in the recommendation that weight stability is essential to health and that weight loss maintenance support is thus necessary (Lahti-Koski et al. 2005, Diaz et al. 2005, Rzehak et al. 2007).

Weight cycling can be defined as repeated bouts of weight loss and weight regain (McCargar & Crawford, 1992). In reviewing the literature, it is apparent that there is no internationally recognized set of criteria for defining weight cycling and a variety of definitions have been used. As is reflected in Table 2.4.2, weight cycling definitions vary from intentional weight loss greater than 9kg followed by unintentional weight gain 3 or more times in a 4 year period (Field et al. 2001; Field et al. 2004) to 5 or more weight loss episodes of more than 2.3kg per episode (Van Wye et al. 2007). Some of the research does not define the number or magnitude of weight loss /

regain cycles (Korkeila et al. 1999; Saarni et al. 2006) but assesses weight change over time. When considering the evidence in Table 2.4.2 it is important to bear these differences in mind. Furthermore, the study design and number of subjects in each study varies greatly. Many are sub-studies of large population based cohort studies (e.g. The Nurse's Health Study; the Potsdam EPIC Study) where the study protocols were not originally designed to examine the effect of weight cycling. Many of the studies were not able to distinguish between intentional and unintentional weight loss and other confounding effects such as family weight history, eating behaviour and socio-economic status were not always accounted for. Outcomes may also differ between those who were lean or obese at baseline with only a few of the studies under discussion separating these groups in their analysis. The extent of obesity at baseline, e.g. a BMI of 30kg/m² vs. 45kg/m², was also not considered. Finally, the limitation of self reported data needs to be taken into account when interpreting the results of available research.

Table 2.4.2: Summary of research on the association between weight cycling and obesity development

WtC=weight cycler yrs = years WHR = waist to hip ratio

Author / year	Sample	Study Design	Indicators	Definition of weight fluctuation/cycling	Main Study Conclusions
Effect of Weight Cycling on BMI					
Korkeila et al. 1999	7729 adult twins (4193 female) 18–54 yrs at baseline (Finland) Caucasian	Twin cohort study (6 & 15 yr follow-up) Self-reported data Analysis of twins discordant for weight change	BMI Weight change Confounding factors (activity, smoking, alcohol use, social class, education level)	Undefined. Number of weight loss attempts assessed.	Dieting predicted a higher BMI at baseline for all individuals and at follow-up for older women only. Much of the weight gain following weight loss may be genetically determined. In discordant dieting pairs, the non-dieters had significantly lower BMI's at baseline and at follow-up.
Field et al. 2001	47 515 women 25-43 yrs (USA) Ethnicity not specified	Prospective cohort (6 year follow-up) (from Nurses' Health Study II) Self reported weights	4 self-reported weights over 6 years History of WtC Physical activity Dietary intake Smoking	Severe WtC: intentional wt loss ≥20lbs (~9kg) ≥3 times in 4 years Mild WtC: intentional wt loss ≥10lbs (~4.5kg) ≥3 times in 4 years	Of those who lost ≥ 10% before baseline, more subjects at the low end of the BMI scale regained this weight. Approximately 50% of weight losers regained this weight over the next 4 years Although weight gain after weight reduction was prevalent, weight after 6 years was lower than baseline weight. Thus repeated attempts at weight reduction did result in a positive outcome at the end of the study. Weight loss maintenance is less successful for those with higher initial BMIs and for WtCs. WtCs gained the most weight over the follow-up period.
Jeffery et al. 2002	823 adults (women) 20-45 yrs (USA) Ethnicity not specified	Prospective cohort study (Pound of Prevention Study) (3 yr follow-up)	BMI Dietary restraint Intentional & unintentional weight loss. Weight gain	Large weight gain: ≥ 5% gain in 1 yr typically followed by weight loss in subsequent 2 yrs (linear regression weight history)	Regular dieting at baseline and having lost more wt intentionally in the past were associated with a higher likelihood of a large weight gain. Although regular dieters gained the most weight, they were still below baseline weight at the end of the study.
Kroke et al. 2002	18 001 non-smoking subjects (11 312 women) 24-69 yrs (Germany) Ethnicity not specified	Prospective cohort study (Potsdam [EPIC] Study) (2 year follow-up) Self reported follow-up	Weight gain / loss (intentional & unintentional) WtC Lifestyle habits Disease history and development	Unintentional wt gain with intentional loss ≥ 5kg in the 2 yrs prior to baseline.	WtC predicts the greatest weight gain. WtC history should be assessed for all overweight individuals.
Field et al. 2004	2476 women 25-43 yrs at baseline (USA) Ethnicity not specified	Prospective cohort study (Nurses' Health Study II) Self reported weights	BMI WtC Binge eating Dietary restraint Weight loss (intentional and unintentional)	Severe WtC: intentional wt loss ≥20lbs (~9kg) ≥3 times in 4 years Mild WtC: intentional wt loss ≥10lbs (~4.5kg) ≥3 times in 4 years	Lower levels of exercise and binge eating may partly explain the higher weight gains seen in WtCs.

Author / year	Sample	Study Design	Indicators	Definition of weight fluctuation/cycling	Main Study Conclusions
Hart & Warriner 2005	66 severely obese people involved in a VLCD wt loss programme. (45 women) 18-73 yrs (USA) Ethnicity not specified	Cohort study (weight loss history excluded self-help attempts)	BMI Wt loss history Blood pressure Triglycerides Total Cholesterol Blood glucose	≥ 4 formal wt loss clinics / programmes attended in the last 5 yrs	WC were less likely to benefit from formal weight reduction programmes with respect to the rate and amount of weight lost and the beneficial effects to blood pressure
Van Wye et al. 2007	938 adults (141 women) 20-78 yrs (USA) Ethnicity not specified	Longitudinal study (6 yr follow-up) Subjects self-selected and mainly well educated Caucasians	Weight WC Co-variables (physical activity, smoking habits, age, history of chronic disease, perceived anxiety, marital status)	WC: ≥ 5 episodes of weight loss of ≥2.3kg/episode.	Non-significant differences in wt gain found between WC & non-WC women Dieting was associated with a lower BMI in men. Depression was associated with weight gain.
Effect of Weight Cycling on Body Composition					
Heitmann & Garby 2002	2436 adults (1200 women) 35-65 yrs (Denmark) Caucasian	Longitudinal study (12 yr follow-up) (Danish MONICA study: Monitoring Trends in Cardiovascular Disease)	BMI Body fat (measured using bioelectric impedance) Fat-free mass (FFM) .	Undefined. Weight changes ≥3kg in each 5 yr period were assessed	WC does not change body composition.
Wallner et al. 2004	30 overweight WC women 167 normal weight controls 97 overweight controls 33-55 yrs Ethnicity not specified	Case Control Study	Subcutaneous adipose tissue (SAT) (thickness measured at 15 different sites using an optical lipometer)	WC: Intentional weight loss >4kg≥ 3 times.	Overweight individuals tend to lay down fat on their upper body. Waist circumference had significantly thicker layers of SAT on the abdomen and arms and significantly thinner layers on the legs than the control groups.
Luo et al. 2007	140,057 women 50–79 years (USA) Ethnic distribution not available Waist circumference not analysed for ethnicity	Multi-centre clinical trial and observational study (The Women's Health Initiative)	Waist circumference (Main study goal: Development of renal cell carcinoma.)	Weight loss and gain ≥10lbs (~4.5kg) from 1 to >15 times	Weight cycling is associated with an increase in abdominal girth
Vergnaud et al. 2008	3553 middle aged subjects (2144 women) 41 – 57 yrs (France) Ethnicity not specified	Longitudinal (7 yr follow-up) Self reported baseline weights	BMI Waist circumference	Wt deviation (calculated from lowest weight in cycle and hypothetical weight if no cycle i.e. on straight line between the highest two wts.) Number of deviations	Waist circumference was associated with an increase in abdominal girth Risk of the above was increased with increasing number of weight fluctuations.

It is clear from Table 2.4.2 that weight fluctuation or weight cycling is very prevalent among individuals who are attempting weight reduction, whether obese or normal weight at baseline (Field et al. 2001). What is interesting to note is that while ongoing weight loss and weight regain is common, some of the research suggests that individuals who exhibit this behaviour are likely to have lower BMIs than their non-dieting peers, specifically in the short term and for younger women (Korkeila et al.1999; Field et al. 2001; Jeffrey et al. 2002). Other studies point to an increased risk for weight gain and increasing difficulty in losing weight over time after recurrent weight fluctuations (Jeffrey et al. 2002; Kroke et al. 2002; Ikeda et al. 2004; Hart and Warriner, 2005). It can thus be speculated that while individuals continue to partake in repeated weight control practices, they may be able to compensate for any overall weight gain initially but that this gets more difficult over time.

Other factors that might be associated with weight cycling include unhealthy weight loss practices, dietary disinhibition, depression, binge eating and a lack of exercise (Field et al.2004; Van Wye et al. 2007). Thus individuals who weight cycle may in fact gain weight as a result of binge eating, eating owing to depression or from a lack of exercise, and not necessarily as a direct result of regularly fluctuating weight. It is also important to note that the weight gain seen over time may be as a result of genotype rather than regular weight cycling, although these genetic effects do not mean that lifestyle modifications for body weight control would necessarily fail (Korkeila et al. 1999).

It has been postulated that weight fluctuations over time may result in a reduction in fat free mass, an increase in fat mass and a redistribution of fat to the abdomen, which might put weight cyclers at greater risk for the development of conditions such as diabetes mellitus and heart disease (Wadden et al. 1996; Wallner et al. 2004). The two studies from Table 2.4.2 that specifically analyze body fat content differ greatly with respect to design, sample size and aspects measured and it is difficult to form robust conclusions from their results. They do, however, point to a trend towards a reduction in fat free mass (Heitmann & Garby 2002) and significantly thicker layers of subcutaneous adipose tissue on the abdomen and arms and thinner layers on the legs for weight cyclers when compared to non-weight cycling controls (Wallner et al. 2004). Furthermore, studies that have assessed waist circumference show a significant independent increase in abdominal girth as the number of weight cycles increases (Luo et al. 2007; Vergnaud et al. 2008), supporting the results shown by Wallner et al. (2004). From these results it can cautiously be concluded that repeated fluctuations in weight may

ultimately result in an accumulation of fat on the upper body which, in turn, may impact on the development of conditions such as heart disease, diabetes mellitus and metabolic syndrome.

None of the studies presented in table 2.4.2 analysed the data for ethnicity and thus differences between ethnic groups for the effects of weight cycling are not know. At this point, there is no South African data available.

In summary, it appears that those individuals who most need to reduce their body weight are most likely to fail. Their repeated attempts to lose weight may well result in an increased BMI in the long run although some individuals may benefit in the short term. Weight cycling also appears to result in the accumulation of subcutaneous adipose tissue on the abdomen and an increased waist circumference. While acknowledging the challenges in comparing the studies owing to methodological differences, the literature provides strong evidence to support the need for weight loss maintenance support for those who have successfully reduced their weight in order to reduce weight cycling.

5. Association between eating behaviour (cognitive restraint, disinhibition and perceived hunger) and obesity development

The regulation of energy intake is not only controlled by biological functions such as hunger and satiety but also by a number of complex behavioural traits (Riou et al. 2011). These include cognitive and emotional traits such as cognitive restraint (the conscious control of food intake in order to control body weight), disinhibition (the loss of control over eating resulting from specific cues such as the ingestion of certain foods, alcohol intake or psychological depression) and perceived hunger (food intake in response to feelings and perception of hunger) (Herman & Mack 1975, Stunkard & Messick 1985, Herman & Polivy 2005, Provencher et al. 2007). Numerous studies have examined the effects of these eating behaviours on obesity development using the 51 item Three Factor Eating Questionnaire (TFEQ) developed by Stunkard and Messick (1985). Behaviour - specific subscales have also been developed from each of the TFEQ scales and have become a further focus of research into the association between eating behaviours and obesity development (Westenhoefer et al. 1999, Bond et al. 2001).

Subscales of cognitive restraint (21 items from the TFEQ) include rigid control and flexible control (7 items each) (Westenhoefer et al. 1999) as well as strategic dieting behavior (4 items),

attitude to self-regulation of eating (5 items) and avoidance of fatty foods (4 items) (Bond et al. 2001). Subscales of disinhibition include habitual susceptibility to disinhibition (5 items), emotional susceptibility to disinhibition (3 items) and situational susceptibility to disinhibition (5 items) (Bond et al. 2001). The subscales of perceived hunger include internal and external locus for hunger (6 items each) (Bond et al. 2001).

A summary of relevant research in this regard is presented in Table 2.5.

Table 2.5: Summary of research on the effect of eating behaviour (cognitive restraint, disinhibition & perceived hunger) on obesity development

M: male F: female yr: year wt: weight TFEQ: Three Factor Eating Questionnaire CR: cognitive restraint D: disinhibition H: perceived hunger

Author / year	Sample	Study Design	Select Indicators	Select Results	Select Study Conclusions
Westenhoefer et al. 1999 **(study 1)**	54 517 subjects (46 128 F) Mean BMI: 27.2±3.8kg/m^2 7407 subjects at 1 yr post computer-assisted weight reduction programme Mean age (yrs): 43.6 (F) (Germany) Caucasian	Cross sectional and longitudinal intervention study German version of TFEQ	Eating behaviours: CR, rigid control & flexible control, D BMI at baseline and 1 year follow up Energy intake	F had higher eating behavior scores than M High CR & high flexible control associated with lower BMI, lower energy intake & higher probability of successful wt reduction. Opposite effect found for D Higher rigid control associated with higher BMI and higher energy intake in F. Successful wt losers had increased flexible control at 1 yr Rigid control was associated with a higher BMI and successful wt loss, although its association with wt loss was not considered clinically significant.	High CR & flexible control associated with lower BMI and wt reduction success High D associated with higher BMI and lower wt loss success High rigid control associated with higher BMI & lower wt loss success Successful wt loss associated with higher baseline CR that increased further & lower baseline scores of D that decreased further.
Bond et al. 2001	553 undergraduate women Mean age: 25 yrs (Australia) Ethnicity not reported	Cross-sectional study TFEQ	Eating behavior: CR, D & H and subscales BMI Weight satisfaction	Dissatisfied women had higher CR, D and H scores Dissatisfied women who had high D also had high BMI	Women dissatisfied with their weight had higher BMI's and D scores
Drapeau et al. 2003	75 subjects >18 yrs (45 F) (Quebec family study) (Canada) Caucasian	Longitudinal study Baseline & 6 yrs later French version of TFEQ	Eating behavior: CR, D & H and subscales Weight Weight change	BMI increased over the 6 yrs for F Women were more disinhibited and experienced less perceived hunger than men D score decreased over time indicated by a decrease in habitual susceptibility to increase food intake. High CR seems to promote wt gain in women	Eating behaviours are expressed differently in M & F and this should be considered in clinical interventions. CR appears to be associated with wt gain in F
Provencher et al. 2003	596 individuals (352 F) Mean age: 43.4(M), 42.0(F) (French Canadian) Caucasian	Cross-sectional study French version of TFEQ	Eating behavior: CR, D & H and subscales BMI	Women had higher CR including higher scores for flexible & rigid restraint; higher D including higher scores for habitual & emotional susceptibility to D than men, irrespective of obesity status. M had higher H scores than F. BMI was positively associated with D & H CR was not associated with BMI except for a negative association for non-obese F. For F, rigid restraint was positively associated with BMI, and negatively associated with flexible restraint	F show higher levels of CR & D than M. CR & flexible restraint were associated with lower BMI in F. Rigid restraint was positively associated with a higher BMI in F D & H were positively associated with a higher BMI in M & F.

Author / year	Sample	Study Design	Indicators	Results	Main Study Conclusions
Dykes et al. 2004	1470 F Age 45-68yrs (UK) Ethnicity not reported	Cross sectional study TFEQ	Eating behavior: CR, D & H BMI	H & D were positively associated with a higher BMI. Low R & low D were associated with the lowest BMIs. High D & low R associated with the highest BMIs.	D & H scores associated with all measures of body wt & size Low R - high D were the heaviest and largest. Low R - low D were the lightest and smallest
de Lauzon-Guillain et al. 2006	466 adults (259 F) 271 adolescents/ young adults (14-24yrs) (132 F) (France) Ethnicity not reported	Longitudinal study Measures at baseline & 2 year follow-up TFEQ-R18	CR Uncontrolled eating (UE) (external locus for hunger +situational disinhibition) Emotional eating (EE) (emotional susceptibility to disinhibition) BMI	CR negatively associated with BMI in normal wt but not overweight adults at baseline Baseline CR did not predict change in BMI in all groups High BMI at baseline was associated with a larger increase in CR and BMI over time UE and EE at baseline were not associated with changes in any adiposity measurements in adults & adolescents except for UE & %BF in adolescents.	In normal-weight subjects, restrained eating does not promote weight gain. Restrained eating is associated with weight gain in overweight women The negative effect of highly restrained eating found in obese subjects should not be extrapolated to normal weight subjects.
Hays & Roberts 2008	535 F Age 55-65 yrs (USA) 96% Caucasian Not analysed for ethnicity	Retrospective longitudinal study Measures at baseline and at six prior age intervals TFEQ Prior measures self-reported	Eating behavior: CR, D & H and subscales BMI Weight change	High habitual &/or emotional D scores positively associated with wt gain. Both behaviours plus low flexible restraint resulted in gain of ±22kg vs. ±6kg for low scores. Situational D not associated with weight gain. High habitual & emotional D were most significantly positively associated with current BMI with no added effect for situational D.	BMI & weight gain over time is associated with habitual and emotional susceptibility to over eating. A stronger focus on targeting habitual overeating in the prevention and treatment of adult-onset obesity should be considered.
Savage et al. 2009	163 F (USA) Caucasian	Longitudinal study Measures at baseline, 2, 4 & 6 year follow-up TFEQ	Eating behavior: CR & D Current dieting Intentional weight change	High D was associated with high BMI at baseline and wt gain over time. No effect found on BMI for CR at baseline or follow-up Increase in CR over time was associated with reduction in wt Increased D over time associated with increased wt Increasing CR moderated the effect of D on wt in dieting F only	Dietary restraint is associated with a lower BMI and disinhibition with a higher BMI. Increasing levels of CR may be useful for wt loss / control by reducing the positive association between D and weight in dieting women.
Paradis et al. 2009	326 non-obese individuals with / without a family history of obesity (FHO+ / FHO-) (197 F) (French Canadian) Caucasian	Cross-sectional study French version of TFEQ Anthropometry self-reported	Eating behavior: CR, D & H and subscales Family history of obesity	**For men:** BMI was positively related to CR, rigid control & D FOH+ men had higher levels of CR & rigid control than FOH- men **For women:** BMI was positively related to D FOH+ women had higher levels of D than FOH- women Women with an obese mother had higher levels of CR, rigid control & flexible control than women with a non obese mother.	Eating behaviours of non-obese individuals differ according to the presence or absence of obese family members with D being common to FHO+ men and women. Having an obese mother is associated with a higher CR score in women

Author / year	Sample	Study Design	Indicators	Results	Main Study Conclusions
Konttinen et al. 2009	5024 subjects (2699 F) 25-75 yrs FINRISK study (Finland) Caucasian	Cross-sectional study TFEQ-18	CR, uncontrolled eating (UE) (external locus for H +situational D), emotional eating (EE) (emotional susceptibility to D) Dieting history (current, past, never) BMI Self-control	Overweight/obese subjects scored higher for UE & EE vs. normal weight subjects. Mean score for CR was highest for normal weight subjects. Current & past dieters had higher CR, UE & EE scores than never dieters. Never dieters had highest self-control. Obese current/past dieters had lower CR than normal weight current/past dieters. Obese never dieters had higher CR than normal weight never dieters CR was associated with lower BMI & waist circumference in normal and obese subjects UE & EE were positively associated with BMI and waist circumference in normal and obese subjects	UE & EE were positively associated with obesity. For obese subjects and current / past dieters, higher CR was related to lower BMI, UE & EE. For normal weight subjects and never dieters, higher CR was related to higher BMI, UE & EE. Restrained eating may be related to better weight control for those who need to lose weight and/or are motivated to do so. For others, it may indicate problems with eating.
Bryant et al. 2010	471 subjects 70% F (UK) Ethnicity not reported	Cross-sectional study TFEQ Anthropometry self reported	Eating behavior: CR, D & H Body weight Physical activity	Combination of low Cr and high D associated with wt gain, sedentary behavior and high BMI	Low CR and high D are positively associated with BMI.
Gallant et al. 2010	60 adolescents (30 F) Mean age 15 yrs (French Canadian) Caucasian	Cross-sectional study TFEQ	Eating behavior: CR, D & H and subscales Energy intake Subjects categorized into: High D- High CR; High D- low CR; low D- high CR; low D- low CR	No differences in mean TFEQ scores between M & F except for avoidance of fatty foods (TFEQ-R3). Rigid control, D and emotional susceptibility were positively associated with BMI. High D-high CR subjects had significantly higher BMIs vs. low D-low CR. High D-high rigid control had significantly higher BMIs vs. low D-low rigid control. No significant differences in BMI for flexible control H was positively associated with total energy intake but not BMI	D (habitual, emotional & situational susceptibility) and rigid control were associated with a higher BMI.
Riou et al. 2011	113 post-menopausal F Mean age: 56.7yrs (French Canadian) Caucasian	Cross-sectional study TFEQ	Eating behavior: CR, D & H and subscales BMI Physical activity	No significant differences were found for eating behavior between the high & low physical activity groups **Higher physical activity participation:** BMI lower for F with high CR vs. low CR (25.5±0.5 vs. 30.3±1.7 kg/m^2) **Lower physical activity participation:** BMI lower for F with low external H vs. high external H (27.5±0.8 vs. 32.4±1.1kg/m^2) Emotional D is associated with BMI in this group	Physical activity should be considered when interpreting the association between adiposity & eating behavior traits. Dietary restraint (flexible & rigid) are independent predictors of BMI only in F with high activity levels D is associated with BMI only in F with low physical activity.

It is clear from the information in Table 2.5 that associations are not consistent, which is not unexpected if the variations in study design and methods are considered. Anthropometric assessments are not consistent as some studies use actual weight measurements while others make use of self-reported data. The TFEQ is well researched and widely used (Provencher et al. 2003) but, as is true for all self-reported information, the possibility remains that subjects may misinterpret some of the questions or not be totally honest in their answers. Not all of the studies examined associations for all of the subscales and some have used the TFEQ-18 (Karlsson et al. 2000), a shortened version of Stunkard and Messink's TFEQ, which makes comparison difficult. Furthermore, the small number of questions in some of the behavior-specific sub-scales may reduce the reliability and validity of the data (Bond et al. 2001). Some studies examine body weight and eating behavior changes over time (Westenhoefer et al. 1999; de Lauzon-Guillain et al. 2006; Hays & Roberts 2008; Savage et al. 2009) whereas others report on cross-sectional correlations between eating behaviour and body weight. It must thus be borne in mind that it is not possible to determine whether the eating behaviours are the cause of or result of BMI at a particular point in time (Hill 2004).

The study by Westenhoefer et al. (1999), by virtue of its large sample size, is likely to provide the most valuable insight into the gender aspects of eating behaviours. This research points to the possibility that women appear to score more highly than men for all aspects of the TFEQ. This phenomenon is also shown in other studies for cognitive restraint (Tepper et al. 1996; Provencher et al. 2003; Drapeau et al. 2003) and disinhibition (Provencher et al. 2003; Drapeau et al. 2003; Paradis et al. 2009), irrespective of weight status, although men appear to be more susceptible to perceived hunger than women (Provencher et al. 2003; Drapeau et al. 2003).

Evidence is conflicting regarding the association between cognitive restraint and body weight. While cognitive restraint was found to be associated with a lower BMI in some studies (Westenhoefer et al. 1999; Savage et al. 2009), others have found this association in normal weight but not in overweight/obese individuals (Provencher et al. 2003; Drapeau et al. 2003; de Lauzon-Guillain et al. 2006). In contrast, Konttinen et al. (2009) found that cognitive restraint was associated with lower BMIs in overweight/obese individuals and individuals who had attempted weight loss; and with higher BMIs in normal weight individuals and those who had never dieted. Furthermore, restrained eating was not found to promote weight gain in normal weight individuals whereas it was associated with weight gain in overweight/obese individuals (Drapeau et al. 2003; de Lauzon-Guillain et al. 2006). In one study a gender association was found with cognitive restraint being associated with weight gain in females and weight loss in males (Drapeau et al.

2003). Furthermore, an increase in cognitive restraint over time was associated with weight reduction attempts (Savage et al. 2009; Konttinen et al. 2009).

These inconsistent findings for the relationship between cognitive restraint and BMI led to the development of the subscales of the restraint scale mentioned earlier in this section in order to examine whether specific restrained behaviors have different effects on BMI (Westenhoefer et al. 1999; Bond et al. 2001). Similarly, the subscales for disinhibition and perceived hunger were developed (Bond et al. 2001). It has been suggested that the opposing effects of cognitive restraint in normal weight and overweight/obese individuals may be as a result of the interaction between flexible control (associated with a low BMI) and rigid control (associated with a high BMI) (Westenhoefer et al. 1999). Table 2.5 indicates that high cognitive restraint together with high flexible control are associated with a lower BMI and weight reduction success, whereas rigid control is associated with a higher BMI and weight gain (Westenhoefer et al. 1999; Provencher et al. 2003).

When considering dietary disinhibition, the studies reported in Table 2.5 indicate a strong positive association between disinhibition and BMI (Westenhoefer et al. 1999; Provencher et al. 2003; Dykes et al. 2004; Savage et al. 2009; Paradis et al. 2009; Gallant et al. 2010), weight gain (Hays & Roberts 2008; Savage et al. 2009) and reduced weight loss success (Westenhoefer et al. 1999). These associations were also found for dissatisfied women (Bond et al. 2001) and for women with low levels of physical activity (Riou et al. 2011). This interaction with physical activity suggests that exercise is an important element of weight control.

An examination of the disinhibition subscales by Hays and Roberts (2008) reveals an association between BMI and habitual and emotional disinhibition but no association with situational disinhibition. Thus, overweight/obese women who exhibit highly disinhibited eating behaviours may be able to avoid overeating at social occasions for example, but overeat regularly at other times and when emotionally stressed. For studies that used the shortened TFEQ-18, the scale for uncontrolled eating includes questions from the disinhibition scale of Stunkard and Messink's TFEQ as well as some questions relating to the external locus of control of hunger (TFEQ-H2) from Bond et al. (2001). In the larger study by Konttinen, uncontrolled eating was positively associated with BMI and dieting although de Lauzon-Guillain (2006) only found an association with percentage body fat in adolescents and not with BMI. Emotional eating, comprising all of the questions from the TFEQ-D2 (Bond et al. 2001), was not associated with BMI or weight gain in the study by de Lauzon-Guillain et al (2006) but was found to be strongly associated with BMI in

the study by Konttinen et al.(2009). This positive finding in the latter study supports the findings by Hays and Roberts (2008) mentioned above.

Minimal reporting of perceived hunger is found in the studies in Table 2.5 with little information being available regarding the role of this eating behavior trait in obesity development. What is evident is that perceived hunger is associated with disinhibition (Bond et al. 2001; Provencher et al. 2003; Dykes et al. 2004), and total energy intake (Provencher et al. 2003; Gallant et al. 2010), with women being less likely to have high scores for perceived hunger than men (Drapeau et al. 2003). While some studies found a positive association between perceived hunger and a higher BMI (Provencher et al. 2003; Dykes et al. 2004) the majority of the studies in Table 2.5 did not (Bond et al. 2001; Drapeau et al. 2003; Hays & Roberts 2008; Gallant et al. 2010; Bryant et al. 2010; Riou et al. 2011). The internal locus for hunger was found to negatively correlate with cognitive restraint and this suggests that individuals with high cognitive restraint override or ignore internal feelings of hunger in order to control their food intake (Bond et al. 2001).

It is evident from the discussion above that associations with BMI for cognitive restraint, disinhibition, perceived hunger and their subscales are complex. Different combinations of eating behaviours may associate differently with BMI. Firstly, BMI is positively associated with disinhibition, specifically habitual and emotional disinhibition with no positive associations found for situational disinhibition (Westenhoefer et al. 1999; Provencher et al. 2003). Similarly, a lower BMI is associated with cognitive restraint and flexible control, with rigid control being associated with a higher BMI (Westenhoefer et al. 1999; Provencher et al. 2003). Flexible control also appears to reduce the association between disinhibition and BMI for overweight/obese individuals (Westenhoefer et al. 1999; Hays & Roberts 2008) with the greatest effect seen for habitual disinhibition (Hayes & Roberts 2008). Furthermore, a combination of high restraint and high disinhibition may be associated with disordered eating and low restraint and high disinhibition with a high BMI and sedentary behavior (Bryant et al. 2010). Although not analysed for the restraint subscales, other studies have also found a moderating effect of cognitive restraint on the relationship between disinhibition and BMI so that these behaviours combined result in a reduced BMI (Dykes et al. 2004; de Lauzon-Guillain et al. 2006; Savage et al. 2009). It has been suggested that cognitive restraint and/or flexible control may be useful eating behaviours for weight reduction success (Westenhoefer et al. 1999; Savage et al. 2009).

Since shared family behaviours such as eating behaviours could influence the development of obesity (Savage et al. 2007), Paradis et al. (2009) examined the effects of parental obesity on the eating behavior of non-obese individuals. Eating behaviours were found to differ according to the

presence or absence of a family history of obesity, with disinhibition and cognitive restraint being common to both males and females who had obese parents. Furthermore, higher scores for cognitive restraint, flexible control and rigid control were found for women with obese mothers. It was suggested that both genetic and environmental influences may play a role in the development of these relationships (Paradis et al. 2009).

It is evident from Table 2.5 that most of the research involved Caucasian samples with some of the studies not reporting ethnicity. Furthermore, none of the studies analysed the data for ethnicity separately and so no conclusions can be drawn regarding the effects of eating behaviours on BMI for other ethnic groups. Few studies have been conducted in South Africa to examine these associations among the different ethnicities resident in this country. Senekal et al. (2001) examined cognitive restraint and its association with BMI and weight management in a group of African female university students. The restrained students were found to be more likely to have been continuously gaining weight over time and to have attempted weight reduction in the past. Interestingly, significantly more restrained subjects came from an urban background vs. a rural background. This suggests that the urban subjects may have been more exposed to Western media and advertising resulting in a greater level of adoption of Western norms (acculturation) of slimness as the ideal female form (O'Dea 1995; Senekal et al. 2001), which may have lead to higher levels of restrained behavior.

Hill (2004) comments that it is not possible from the research to prove that cognitive restraint/ rigid control causes weight gain and that it is more likely that being overweight/obese results in cognitive restraint/dieting. However, a long history of dieting has been shown to result in weight gain for women who are not able to maintain their weight (see Section 4.4 on weight cycling) and this may be related to the high levels of dietary disinhibition found in overweight individuals. It must also be remembered that eating behaviours are only part of the aetiology of obesity especially when considering its highly complex nature (Yang et al. 2007; Bouchard et al. 2008; Kumanyika et al. 2008; Huang et al. 2009).

In summary, cognitive restraint and flexible control appear to be associated with a lower BMI and weight loss whereas rigid control and disinhibition, including habitual and emotional susceptibility to disinhibition, are associated with a higher BMI and weight gain. Furthermore, flexible control of eating is associated with weight reduction success. While perceived hunger appears to correlate strongly with disinhibition and energy intake, no direct associations have been found with BMI. It is not possible to speculate at this stage whether these eating behaviours are derived via genetic

inheritance, a shared family environment or as a result of weight gain. However, it is clear that they play a role in determining BMI and in weight loss and weight maintenance success and it may be necessary to consider eating behavior traits when developing strategies to manage overweight/obesity.

6. **Association between taste sensitivity and obesity development**

6.1 **Physiological basis of taste sensitivity**

Taste is one of the chemo-senses and is mediated through taste receptor cells. These cells are specialized epithelial cells that are organized in taste buds in the soft palate, pharynx, larynx and epiglottis and within taste papillae on the tongue. The taste papillae include fungiform papillae found on the anterior tongue, foliate papillae on the posterior lateral tongue and circumvallate papillae across the back of the tongue (Steiner et al. 2001, Duffy 2007). Each taste bud contains between 50 and150 taste receptor cells, some of which have microvilli that extend through the taste bud into the external environment. Chemicals released by substances such as foods and beverages in the mouth dissolve in saliva, cross a mucus layer and reach the microvilli of the taste receptor cells. In these cells they activate ion channels (sour, salty) and G protein coupled receptors (sweet, bitter, umami) and set up impulses in branches of the three cranial nerves that innervate the taste buds. Specific fibres within the taste nerves respond to specific qualities of taste and these impulses are transported to and interpreted by the central nervous system (Drayna 2005; Duffy 2007).

Tongue anatomy also appears to play a role in taste perception as individuals with higher numbers of taste buds and fungiform papillae have the capacity to taste some chemicals more acutely than individuals with fewer taste papillae (Bartoshuk et al 1994; Yackinous & Guinard 2002; Drayna 2005; Yeomans et al. 2007; Hayes & Duffy 2007).

Other sensations further contribute to the perception of flavour. Somatosensory or tactile sensations such as texture and creaminess stimulate mechanoreceptors in the mouth, the temperature of foods and beverages stimulate thermoreceptors and irritants and pungent foods stimulate nociceptors. Furthermore, odours are carried through the nostrils (orthonasal olfaction) and through the oral cavity (retronasal olfaction) to the olfactory nerves behind the bridge of the nose where they stimulate the olfactory nerves to result in a perception of smell. Thus, somatosensations and smell combine with the chemical stimulation of the taste buds to produce a perception of flavour (Duffy 2007).

Hedonic responses to smell are learned through positive (eg. repeated exposure to a specific smell; the association of a specifc smell with other experiences) and negative (eg. flavour aversions) conditioning (Duffy 2007). Taste preferences and liking a particular food are considered the most important determinants of food preference and sensitivity to specific tastes may play an important role here (Tepper & Ullrich 2002; Goldstein et al. 2005; Duffy 2007). However, food preferences and intake are also affected by cultural identity, perceived health benefits, accessibility to foods and food adventurousness or a willingness to try new foods (Ullrich et al 2004; Duffy 2007; Brug et al. 2008).

6.2 **Assessment of Taste Sensitivity**

6.2.1 Markers of Taste Sensitivity

Humans show variations in taste sensitivity to many different substances, much of which is genetically mediated (Drayna 2005). These differences in taste perception appear to play an important role in the dietary choices made by individuals (Tepper et al. 1998; Kirkmeyer et al. 2003; Keller & Tepper 2004). Genetic research has identified a group of genes that encode two main classes of taste G-protein coupled receptors in humans: the TAS1R and TAS2R families. There are approximately 25 TAS2R genes in humans responsible for bitter perception. In contrast, the human TAS1R family contains only 3 genes that serve as sweet receptors (TAS1R2 and TAS1R3) or umami receptors (TAS1R1 and TAS1R3) (Li et al. 2002; Drayna 2005). Receptors for salty and sour tastes are less well understood. It has been proposed that the taste for salt occurs via ion channel transfer and sour tastes by activation of an acid sensor (Drayna 2005).

One of the TAS2R genes (TAS2R38 located on chromosome 7q) responsible for the perception of bitterness involves the taste for 6-*n*-propylthiouracil (PROP) and phenylthiocarbamide (PTC) (Drayna et al. 2003). The PROP / PTC phenotype was first described by Fox in 1931 when some PTC dust was released into the air whilst he was bottling the chemical. A colleague could taste the airborne bitter compound but he was unable to (Fox 1932). This phenomenon has lead to further investigations into genetic variability and taste sensitivity to PTC and PROP (Tepper 1998) and has resulted in PROP being identified as a marker for taste sensitivity.

It has been estimated that approximately 70% of Caucasians in North America and Europe are able to taste PROP and that 30% are not. Approximately 25% of PROP tasters perceive the bitter taste of PROP as extremely bitter and can be further categorized as PROP super-tasters (see Table 2.6.1 for definitions of super vs. medium tasters) with the rest of the PROP tasters categorized as PROP medium tasters (Tepper 1998). Furthermore, the ratio of tasters to non-

tasters may vary globally between racial groups (Guo & Reed 2001; Chang et al. 2006; Lumeng et al. 2008) and between the sexes, with women more likely to be tasters than men (Keller & Tepper, 2004; Hayes & Duffy 2007; Yeomans et al. 2007; Tepper 2008). Genetic analysis has shown that the TAS2R38 haplotype predicts approximately 65% of the variance in PROP phenotype and other factors such as environmental and / or other genetic influences may be involved in its expression (Timpson et al. 2005; Tepper et al. 2008). PROP tasters have been found to have a higher density of fungiform papillae and more taste buds on the tip of the tongue than PROP non-tasters (Tepper & Nurse 1998; Yeomans et al. 2007) and it is possible that alleles controlling taste-bud density and innervation may also play a role in the expression of the PROP phenotype (Timpson et al. 2005; Tepper et al. 2008).

It has been postulated that the PROP taster phenotype enables individuals to identify and avoid toxic bitter substances and that this may have been protective in pre-industrial times (Kim & Drayna, 2004). As the PROP non-taster phenotype has not been removed from the human gene pool through natural selection, it may also serve some function and may be a receptor for some other, as yet unidentified toxic bitter substance (Kim & Drayna 2004).

6.2.2 PROP Screening Methods

A number of different methods for determining PROP sensitivity have been described in the literature. The most commonly used methods for assessing and classifying individuals according to phenotype are summarized in Table 2.6.1 below.

Table 2.6.1: Methodological considerations in PROP screening

PROP phenotype ST= supertaster MT=medium taster NT=non-taster

Test Classification	Tests	Method	Comments	References
PROP screening				
Threshold Methods Assesses the ability of an individual to detect low / moderate concentrations of PROP	a. Single solution test b. Impregnated filter paper method	a. Single solution placed in mouth. Taste intensity rated after approximately 30 seconds b. Impregnated filter paper placed on tongue, allowed to become moist & then the intensity is rated. NaCl impregnated paper (or solution) is rated similarly and is often used as a control (ST experience PROP more intensely than NaCL, MT experience the intensity of both similarly & NT experience NaCl more intensely than PROP	Not predictive of taste intensity at higher concentrations. Low concentrations have been found to effectively separate non-tasters from tasters of PROP. May be difficult to identify MT as some MTs cannot taste PROP at low concentrations but experience PROP as intensely at high concentrations as ST. Moderate concentrations are more effective in separating ST, MT & NT.	Bartoshuk 2000 Tepper et al. 2001 Zhao et al. 2003 Tepper 2008
Supra-threshold Methods Assesses the ability to taste PROP at higher concentrations.	a. Single solution test b. Various PROP solutions from very low to very high concentrations (3, 5 or 7 solutions most commonly used)	a. As above b. Various concentrations are tested one at a time with the individual rinsing his / her mouth with filtered water between each solution. Intensity of each is rated and tracked. The highest reading or a mid-point of all readings is used for classification purposes. NaCl solutions may be used as a control as discussed above.	a. Single solutions with high PROP concentrations may be tasted similarly by both medium and super tasters of PROP b. Multiple solution test is a complicated procedure. Care must be taken to ensure that samples are not mixed up while performing the test.	Bartoshuk 2000 Tepper et al. 2001 Zhao et al. 2003 Tepper et al. 2008
Rating Scales for Taster Status Classification				
Category Scales	Defined scale e.g. rate intensity from 0-9 where 0 is very weak or no sensation and 9 is very strong	PROP taste intensity is rated according to the scale e.g. Very weak-very strong, not bitter – very bitter. Generally classification is done by comparing PROP & NaCl ratings. i.e. ST rates PROP higher than NaCl MT rate PROP similarly to NaCl NT rate NaCl higher than PROP	These scales tend to limit the taste intensity rating of individuals who taste PROP as intensely bitter so that both medium and supertasters rate taste intensity similarly	Kaminski et al. 2000 Drewnowski et al. 2001 Keller et al. 2002 Tepper et al. 2008
Labelled Magnitude Scale (LMS)	Label descriptors are arranged in semi log intervals along the length of the scale (normally 100mm long or measured as 100 units) Descriptors range from "barely detectable" to " strongest imaginable oral sensation"	Subjects mark the scale according to their perceived taste. Classified according to cutoffs on LMS: e.g. ST mark their perception of PROP higher up the scale than 67units/mm (some researchers use 51 units/mm) MT mark PROP between 15 & 67units/mm NT mark of PROP lower than 5units/mm NaCl ratings are used as a control & to assist with classification in borderline cases	LMS gives subjects more freedom to express their perceptions. Recently, the general labeled magnitude scale (gLMS) was developed, which expands the top of the scale to include all sensations including the strongest pain, sound and light to allow even greater flexibility for ST. Both LMS & gLMS have been used successfully to identify taster groups.	Green et al. 1996 Bartoshuk 2000 Tepper et al. 2001 Tepper et al. 2008
Numerical cut-off scores	Taste phenotype assigned according to Mendelian proportions i.e. 25% ST, 50% MT, 25% NT	Subjects rate PROP according to one of the scales mentioned above. Numerical scores are divided so that the lowest 25% of the scores are NT, the highest 25% are ST and the middle 50% are MT	PROP phenotype varies according to race & gender. In mixed gender / mixed race samples, it is unlikely that populations would stick rigidly to Mendelian proportions	Guo & Reed 2001 Chang et al 2006 Drewnowski et al. 2007 Lumeng et al. 2008 Tepper et al. 2008

From the table it is clear that methodological differences between the studies might result in differences in classification of PROP phenotype, complicating comparisons between studies. According to Tepper (2008), these differences may have contributed to the lack of consensus surrounding the body of research into PROP phenotype and body weight (see section 6.3).

6.3 **The Association between Taste Sensitivity and BMI**

6.3.1 PROP phenotype and food choices

Recent research has shown that the PROP phenotype is associated with variance in perceptions of a variety of foods (Drewnowski et al. 1997; Tepper 1998; Kirkmeyer & Tepper 2003; Dinehart et al. 2006; Bell & Tepper 2006; Tepper et al. 2009). In comparison to PROP non-tasters, PROP tasters perceive more fattiness in foods such as salad dressings and dairy products (Tepper et al. 1997; Keller et al. 2002; Kirkmeyer & Tepper 2003). PROP non-tasters are less able to detect the fat in foods, and therefore show greater preferences for some high fat foods such as full cream milk, fatty meats and cheeses (Keller & Tepper 2004; Hayes & Duffy 2008). It has been suggested that these individuals, who may have lower numbers of fungiform papillae on their tongues than PROP super tasters, may be less able to use oral sensory cues as a control mechanism to avoid over-consuming fatty foods and beverages (Hayes & Duffy 2008).

PROP non-tasters have also been shown to have a higher preference for sweet foods than super tasters in some studies (Chang et al. 2006; Yeomans et al. 2007; Hayes & Duffy 2008; Hedge & Sharma 2008; Villarino et al. 2009) but not in others (Drewnowski et al. 1997; Prescott et al. 2004; Drewnowski et al. 2007). Super tasters have also been found to eat fewer kilojoules than non tasters (Drewnowski et al. 2007; Goldstein et al. 2007). Furthermore, a study by Sitton and Sullivan (2007) that did not assess PROP phenotype, but counted taste bud numbers on the tongue, found that individuals with the highest taste bud counts (found in PROP super tasters) consumed the least amount of energy.

Passive overeating refers to eating high energy diets where the quantity of food is not excessive but the kilojoule content is (Prentice 2001). Such high fat / high energy diets may play a role in the development of obesity. Goldstein et al. (2005) hypothesized that if PROP non-tasters prefer high fat / high energy diets, and eat more kilojoules than PROP super-tasters, they may be at an increased risk for weight gain.

6.3.2 PROP Phenotype and BMI

There is a large body of research that reports on the association between PROP phenotype and body weight (Table 2.6.2). However, the role of the PROP phenotype in determining BMI is highly

controversial and has resulted in ongoing debate in the literature (Drewnowski et al. 2007; Tepper 2008; Lumeng et al. 2008). Differences in methodology for testing PROP status, in defining taster groups and in sample selection and size have been blamed for the lack of consensus surrounding this research (Tepper 2008). A wide range of subject ages, from pre-school children to adults have been used in published studies. PROP screening of children may present difficulties in the understanding of the tests by the subjects. This may impact on the interpretation and PROP phenotype classification in research on children (Lumeng et al. 2008). Furthermore, obesity is a highly complex condition resulting from a multitude of environmental, socio-cultural and genetic influences (Yang et al. 2007; Bouchard et al. 2008; Kumanyika et al. 2008; Huang et al. 2009). These many variables make it very difficult to effectively isolate individual factors when conducting obesity research. Furthermore, other issues that motivate food intake should be considered when assessing the effect of PROP phenotype on BMI. Factors such as cognitive restraint (the conscious control of eating) and disinhibition (the loss of control over eating), both considered important factors in the determination of body weight (Tepper & Ullrich 2002), may confound the PROP phenotype-BMI association if they have not been controlled for (Tepper 2008).

Bearing these methodological limitations in mind, an integrated perspective on the information summarized in Table 2.6.2 is provided in the following two sections.

Table 2.6.2: Summary of research on the association between PROP phenotype and obesity development

PROP-P= PROP phenotype ST=super taster MT= medium taster NT= non-taster T=taster yrs = years f=female m=male WC = waist circumference WHR= waist-hip ratio BMI= body mass index

Author / year	Sample	PROP test & TS classification	Indicators	Controlled for dietary restraint & disinhibition	Main Results	Relevant Study Conclusions
PROP-BMI associations in pre-school children						
Keller et al. 2002	67 pre-school children Aged 3-4 yrs (33f, 34m) (USA) 97% Caucasian	Single solution of 0.56mmol PROP (Lawless 1980) Rated on 8 point scale: 0=no taste, 7=very strong taste NT: no NT: yes, tastes good T: yes, tastes bad etc.	PROP sensitivity Ht, wt, weight for height Food acceptability	No	Raw broccoli & American cheese was less acceptable to T than NT for both girls & boys. T girls liked full fat milk less than NT girls and consumed 2-3 more servings of fats than T girls & T & NT boys No differences were found between T & NT for weight or height measurements	This study found no association between PROP-P & body weight. NT girls consumed more fat servings than T girls and all boys
Keller & Tepper 2004	53 pre-school children Aged 4-5 yrs (26f, 27m) (USA) 93% Caucasian	10ml solution in mouth. Questioned "do you taste anything" NT: no NT: yes, tastes good T: yes, tastes bad etc	PROP sensitivity: T & NT Ht, wt, weight for height Maternal PROP-P & BMI	No Maternal restraint / disinhibition measured	NT boys had higher wt for ht percentiles than T boys (77^{th} vs. 56^{th} percentile) For girls, this relationship was opposite Child wt status was not affected by maternal BMI, restraint, disinhibition or PROP phenotype Dietary energy intake was similar for both groups	T boys had lower BMIs than NT boys T girls had higher BMIs than NT girls The reason for these differences requires further research
Lumeng et al. 2008	81 pre-school children in a poverty relief govt. funded school Age ± 5yrs (48f, 33m) (USA) 47% Caucasian 53% African American / Hispanic / other Not analysed for ethnicity	5ml solution in mouth. Questioned "does it taste like water or anything else" NT: tastes like water NT: tastes "yummy" T: tastes "yucky"	PROP sensitivity: T & NT BMI Maternal BMI	No Controlled for age, gender, race, maternal education & maternal BMI	Taster children were more likely to be overweight (31.8%)than NT children (5.6%) No differences were found between the groups for reported dietary intake No significant differences were found for BMI between T & NT for gender or race Maternal BMI was significantly associated with child BMI	T boys and girls had higher BMIs than NT boys and girls.
PROP-BMI associations in children aged 7-18						
Goldstein et al. 2007	65 children 7-11 years old (29f, 36m) (USA) 92% Caucasian	Filter paper method (Zhao et al. 2003) LMS: ST> 67 mm MT: 15-67 mm NT: <15mm	PROP sensitivity BMI Energy intake (Maternal adiposity: BMI, Triceps skin fold, WC, hip circumference as predictors of child's weight & energy intake)	Disinhibition & restraint measured in mothers Not controlled for in children	No significant differences in PROP-P for age or gender NT children consumed 293kcal/day more than ST's but this did not affect BMI BMI tended to increase with increasing PROP sensitivity so that ST had higher BMIs than NT, but this was not significant. Maternal BMI, food restriction and concern for child's weight were positively correlated with child's BMI	NT children had a higher energy intake No association was found between PROP-P and BMI.

Author / year	Sample	PROP test & TS classification	Indicators	Controlled for dietary restraint & disinhibition	Main Results	Study Conclusions
Hedge & Sharma 2008	500 healthy Indian children age 8-12y (245f, 255m) (India) Indian	Filter paper method Greens LMS (135mm in length)(1993) ST>60mm MT 12-60mm NT< 12mm	PROP sensitivity BMI Sweet & fat preferences Dental Caries (oral hygiene not controlled for)	No	80.6% of ST did not prefer sweet & fatty foods 73.6% of NT preferred sweet & fatty foods As PROP-P moved from ST to NT through the MT group, there was an increasing preference for sweet & fatty foods NT were significantly more likely to be overweight (34.6%) or obese (20.8%) vs. ST (17.7% & 6,7% respectively) NT children had significantly more dental caries than MT & ST	PROP-ST had significantly higher BMIs than PROP-NT. There is a strong association between PROP-P and dietary preferences. There is a strong inverse association between PROP-P and dental caries in this population of Indian children (data not controlled for oral hygiene practices)
Baranowski et al. 2009	813 children aged 9-10yrs 738 children aged 17-18yrs (USA) 25.4% Caucasian, 31.8% African-American, 42.8% Hispanic/other Not analysed for ethnicity	PROP & NaCl impregnated disks: filter paper method (Zhao et al. 2003) LMS ST>51mm MT 15-51mm NT<15mm	PROP sensitivity BMI Household income	No	As income increased, BMI decreased No significant differences were found when comparing the association between PROP-P and BMI between ethnic groups No significant association was found between age-group & PROP-P A significant association was found between PROP-P and income PROP-P had a significant BMI effect in the upper-income group only: NT had the lowest average BMI percentiles (52.1±2.78) vs. MT (63.2±1.84) & ST (64.7±2.06)	PROP-BMI relationship was only found in the upper income group with NT having the lowest BMIs and ST, the highest. Other factors in the lives of the lower-income individuals may have a stronger effect on BMI than PROP-P. These were not related to gender or age but might include food insecurity or dietary restraint.
PROP-BMI associations in adults						
Tepper & Nurse 1998	150 adults 25 ST, 25 MT & 25 NT gender not specified (USA) Ethnicity not specified	5 solution method (Bartoshuk et al. 1994) ST: rated PROP higher than NaCl MT: rated PROP & NaCl similarly NT: rated NaCl higher than PROP	PROP sensitivity BMI Food preferences	No	BMI was negatively related to PROP sensitivity but this relationship was not statistically significant BMI was not related to PROP-P in women ST & MT perceive more fat in food than NT NT preferred high fat salad dressing while MT & ST showed no preference	PROP sensitivity may be associated with liking for fat. PROP-P link with BMI requires further study.
Kaminski et al. 2000	63 young women (USA) 73% Caucasian Not analysed for ethnicity	Filter paper method & 7 PROP solutions 9 point scale 1= not at all bitter 9= extremely bitter PROP-T classification not indicated but assessed T & NT only	PROP sensitivity BMI Food acceptability	No	No difference was found between PROP T & NT for BMI values PROP tasters showed a lesser preference for bitter vegetables such as broccoli, brussel sprouts and spinach than NT	No associations found between PROP-P and BMI.

Author / year	Sample	PROP test & TS classification	Indicators	Controlled for dietary restraint & disinhibition	Main Results	Study Conclusions
Yackinous & Guinard 2002	183 college students (114f, 69m) (USA) Ethnicity not specified	5 solution method (Bartoshuk et al. 1994) Classification according to 16 point category scale: 0=no sensation 15= intense sensation ST: rated PROP higher than NaCl MT: rated PROP & NaCl similarly NT: rated NaCl higher than PROP	PROP sensitivity BMI Number fo fungiform papillae on the tongue Energy intake	No	No significant differences in BMI were found between PROP-P groups ST had significantly higher average taste papillae counts per cm2 (165.2±34.2) vs. MT (126.5±33.0) & NT (116.8±29) although there was some overlap. Some ST had fewer papillae than some NT. No significant differences were found between the groups for PROP-P for energy intake	No association was found between PROP-P and BMI or energy intake Dietary patterns in college students may be influenced by other factors such as social practices.
Tepper & Ullrich 2002	86 middle aged women (USA) 90% Caucasian	3 solution method (Tepper et al. 2001) ST: rated PROP higher than NaCl MT: rated PROP & NaCl similarly NT: rated NaCl higher than PROP	PROP sensitivity BMI Dietary restraint & disinhibition	Restraint & disinhibition controlled for	Dietary disinhibition was strongly positively associated with BMI, irrespective of PROP-P No differences in BMI between taster groups were found for restrained individuals. Adjusting for dietary restraint revealed that NT and MT were heavier than ST by 6 and 4 BMI units respectively	Eating behaviour modifies the inverse association between PROP-P and BMI in middle aged women. Controlling for dietary disinhibition & restraint reveals that PROP T had significantly lower BMIs than PROP NT in this group of women
Timpson et al. 2005	3383 women (British Heart & Health study) (UK) Ethnicity not specified	Genetic testing No PROP sensitivity tests done	BMI WH ratio Serum HDL, LDL, triglycerides Diabetes TAS2R38 genotyping PROP phenotype not determined	No	No relationship found between predicted PROP-P and BMI, CHD, WHR and serum lipids Diabetes was more prevalent amongst predicted PROP tasters (p=0.05)	PROP-P was not actually measured No association was found between TAS2R38 genotype and BMI
Goldstein et al. 2005	40 women whose children all attend the same pre-school (USA) 93% Caucasian	Filter paper method (Zhao et al. 2003) LMS: ST> 67 mm MT: 15-67 mm NT: <15mm	PROP sensitivity BMI Body fatness Triceps skin fold WC	Restraint & disinhibition controlled for	BMI was 6.2 units higher in NT women vs ST women MT women were not significantly different from the other two groups WC showed a non-significant negative association with PROP-P Controlling for dietary restraint did not affect the results Disinhibition was associated with a higher BMI	PROP-T had significantly lower BMIs than PROP- NT Controlling for dietary restraint did not affect the results in this homogenous group of mothers.

Author / year	Sample	PROP test & TS classification	Indicators	Controlled for dietary restraint & disinhibition	Main Results	Study Conclusions
Yeomans et al. 2007	60 adults (40f, 20m) (UK) Ethnicity not specified	0.032, 0.32 and 3.2 mmol/l PROP solutions 0.01, 0.1 and 1.0 mol/l NaCl solutions 3 solution method (Tepper et al. 2001) ST: rated PROP higher than NaCl MT: rated PROP & NaCl similarly NT: rated NaCl higher than PROP	PROP sensitivity BMI TFEQ Fungiform papillae density	Sweet liking controlled for dietary restraint but not BMI	PROP-P correlates with Fungiform papillae density with NT having the lowest count (32.7±3.9) vs MT (42.8±3.2) and ST (52.6±3.8) Dietary restraint was more common in women than men Disinhibition was similar for all PROP-P groups No significant relationships were found between PROP-P & BMI	Dietary restraint was similar for all PROP-P groups No relationship was found between BMI and PROP-P
Drewnowski et al 2007	179 female breast cancer patients prior to medical intervention & 179 cancer-free controls (USA) 92% Caucasian	5 PROP solutions (Drewnowski et al. 1999) Classification based on 25:50:25 split of summed bitterness ratings	PROP sensitivity BMI Skin fold measurements WHR Food preferences Serum cholesterol & triglycerides	No	Distribution of PROP-P was similar for cases & controls & data was pooled into a single group No statistically significant differences were found for food preferences between ST, MT & NT PROP responders were younger than non-responders No significant differences were found between ST, MT & NT for BMI, skinfold measurements , WHR, dietary fat intake or plasma lipids. ST consumed significantly less energy (1 629kcal) than NT (1 801kcal, p=0.04)	PROP sensitivity may decline with age PROP-P has no influence on BMI or measures of body fatness PROP NT consumed more energy than MT & ST but this had no significant impact on body weight.
Hayes & Duffy 2007	79 adults (36f, 43m) (USA)	5 solution method (Bartoshuk et al. 1994) LMS Classification using strongest PROP solution ST>51mm MT 22-51mm NT <22mm	PROP sensitivity Fungiform papillae density BMI Taste perception of sugar-fat mixtures	No	BMI did not differ significantly between the PROP-P groups. BMI did not differ for fungiform papillae density Fungiform papillae density & PROP-P were strongly correlated ST found sugar fat solutions significantly more sweet than NT Fungiform papillae density was less predictive of detecting creaminess than PROP-P	No relationship was found between BMI and PROP-P or fungiform papillae density

Author / year	Sample	PROP test & TS classification	Indicators	Controlled for dietary restraint & disinhibition	Main Results	Study Conclusions
Tepper et al. 2008	540 individuals age 15-89 years (324f, 216m) (Genetically isolated village in S Italy) Caucasian	Filter paper method (Zhao et al. 2003) LMS: ST> 67 mm MT: 15-67 mm NT: <15mm	PROP sensitivity BMI WC TAS2R38 genetic analysis (Modified TFEQ used)	Yes	Polymorphisms in TAS2R38 explained 65% of the variance in PROP taste intensity scores. For females, BMI & WC were higher for NT(29.5±0.6; 90.7±1.6) than MT (26.8±0.6; 85.6±1.5) & ST (26.3±0.7; 82.7±1.6). For males, no relationship was found. The relationship between PROP-P and BMI is increased when controlling for dietary restraint. There is no relationship between PROP-P and BMI or WC in restrained eaters. No interactions were found for males	PROP-T had significantly lower BMIs and smaller WC than PROP-NT in women Dietary restraint appears to mask this interaction between BMI and PROP-P in women No association between PROP-P and BMI or WC were found for men
Villarino et al. 2009	100 adults (82f, 18m) (Philippines) Philippino	3 solution method (Tepper et al. 2001) LMS: classification not specified	PROP sensitivity BMI	No	A high proportion of MT (45% of total sample) & ST (43% of total sample) were found in all BMI classes. NT had lowest average BMI (21.9±6.0) vs. MT (26.0±6.8) & ST (24.3±6.0)	No association was found between PROP-P and BMI MT may have a greater risk for the development of obesity
Bajec et al. 2010	127 university staff & students (84 f, 43m) (USA) 79.5% Caucasian Not analysed for ethnicity	20 ml volume of 0.32 mM PROP solution Intensity rated using the labeled magnitude scale (LMS) PROP-P cut off points not specified	PROP sensitivity BMI WC	No	No association was found between PROP taster status and BMI or WC for the whole group For the females, MT's average BMI was 24.3±0.7, WC: 81.7 ±1.6; NT's BMI: 26.4±1.7, WC: 87.8±2.3 & ST's BMI:26.2±1.7, WC:86.5±3.6 BMI & WC were significantly correlated with one another	PROP taster status was not associated with BMI or WC

6.3.2.1 PROP Phenotype and BMI in Children and Teenagers

Table 2.6.2 shows conflicting results regarding the association between PROP phenotype and BMI in pre-school children. In the study by Keller et al. (2002) no differences in body weight were found between PROP phenotypes, whilst Keller and Tepper (2004) found an inverse relationship between PROP phenotype and weight for height percentile in boys but an opposite effect for girls. Thus, PROP super taster boys were leaner and PROP supertaster girls were the least lean. Both studies were conducted amongst predominantly lean individuals, with very little difference in BMI between the children. The lack of overweight children in the sample may have affected these findings (Keller & Tepper 2004). While the results for the girls in the latter study were unexpected, it was proposed that taste preferences change as one matures so that, while child PROP tasters were shown to eat more sweet snacks, as they matured, their perception of sweet foods would increase to a level where they started avoiding these foods (Keller & Tepper, 2004).

A more recent study of pre-school children examined a mixed-race low income group of children where obesity prevalence was high (Lumeng et al. 2008). As with the previous two studies, the children were classified as either PROP tasters or PROP non-tasters without further distinction between PROP medium- and super-tasters. The results, controlled for a number of variables (Table 2.6.2), showed that the PROP tasters were significantly more likely to be overweight or at risk for overweight than PROP non-tasters, although no differences could be seen in the dietary intakes of the two groups. When comparing this study with the two studies of pre-school children mentioned earlier, there appears to be some agreement with the results shown for girls in the Keller and Tepper (2004) study, although there was no agreement for boys or for the earlier study by Keller et al. (2002). However, these two earlier studies were conducted in wealthy white communities where the children were predominantly lean, the parents well educated and where the food-environment is likely to have been different. Owing to the complex nature of obesity, the differences in environmental influences between the Caucasian studies and the study by Lumeng et al. (2008) necessitate the use of extreme care when comparing and interpreting the results. Furthermore, difficulties in PROP screening in such young children may have resulted in misclassification of PROP phenotype for some subjects and this would have influenced the findings.

Studies in older children and teenagers have also produced conflicting results. A study of 500 healthy Indian children between the ages of 8 and 12 years indicated a very strong association between BMI and PROP phenotype (Hedge & Sharma 2008). PROP non-taster

children were significantly more likely to be overweight or obese and more likely to prefer sweet and fatty foods.

Other studies have not, however, produced such convincing results. Goldstein et al. (2007) found no difference in BMI between the PROP phenotypes in a group of financially secure Caucasian children (average age 9yrs). However, PROP non-taster children in this study did have higher energy intakes than PROP super-tasters and showed a preference for dietary fat over carbohydrate, possibly predisposing PROP non-taster children to food choices that could result in weight gain during adulthood.

Baranowski et al. (2009) conducted a much larger study in a multi-ethnic group of children between the ages of 9 and 18 years. PROP phenotype distribution was significantly different between the ethnic groups, but no differences were found for the association between PROP phenotype and BMI. For children in the upper income group that included all ethnic groups, PROP non-tasters had the lowest BMIs and PROP super-tasters the highest. This is in line with the results for the girls from the study by Keller and Tepper (2004) and in the mixed race study of pre-school children by Lumeng et al. (2008), but the reverse of the Indian study (Hedge & Sharma 2008). One could speculate that as children from low socio-economic backgrounds mature, other environmental factors such as food insecurity or dietary disinhibition may overwhelm the PROP phenotype-BMI relationship resulting in a reversal of the association (Tepper, 2008; Baranowski et al. 2009). Furthermore, the Indian children were selected whilst attending regular preventative dental check-ups, which may imply that they were relatively wealthy and thus food secure.

In drawing conclusions from these studies one should consider the difficulties associated with conducting this type of research on children and the multitude of factors that influence BMI, including maternal influence on the child as well as the effect of poverty and food insecurity (Hui et al. 2003; Davey Smith et al. 2007; Goldstein et al. 2007; Lumeng et al. 2008; Baranowski et al. 2009). Interestingly, most of the studies pointed to a BMI effect opposite to the expected effect with half of the studies showing an increase in BMI for PROP tasters vs. non-tasters in some or all groups of children (Keller & Tepper, 2004; Lumeng et al. 2008; Baranowski et al. 2009). It has been suggested that the effect of PROP phenotype on BMI may appear later in the lifecycle in some communities (Keller & Tepper, 2004; Goldstein et al. 2007).

6.3.2.2 PROP Phenotype and BMI in Adults

Much of the earlier research into PROP status and BMI in adults was conducted using lean individuals. In a study of college students, Tepper and Nurse (1998) reported a small inverse association between PROP phenotype and BMI in men (greater taste sensitivity was associated with a lower BMI), but not in women. Yackinous and Guinard (2002) also used a sample of college students and found no association between BMI or energy intake with taster status. In fact, in the latter study, the PROP super tasters had a higher intake of dietary fat than the other two groups. No significant findings were reported in another study of lean young women (Kaminski et al. 2000). It was suggested that psycho-social issues among teenagers and young adults may have had a greater influence on body weight than food preferences or PROP phenotype (Yackinous & Guinard, 2002) and that cognitive factors such as restrained eating and dietary disinhibition may have influenced the result in women in the study by Tepper and Nurse (1998).

Studies in older women with body weights across the BMI spectrum have shown more convincing results. Tepper and Ullrich (2002) examined the effect of dietary disinhibition and cognitive restraint on PROP phenotype and body weight by making use of the restraint and disinhibition scales of the Three Factor Eating Questionnaire (TFEQ) (Stunkard & Messick, 1984). In this study it was hypothesized that food choices in restrained eaters would be motivated more by weight concerns than taste and that this would disrupt the PROP phenotype – BMI relationship. Furthermore, it was assumed that dietary disinhibition would cancel out the PROP phenotype effect. The results showed that disinhibition was strongly correlated with a high BMI but not with PROP phenotype, even before controlling for dietary restraint. Individuals who had high disinhibition scores had body weights of five BMI units greater than those individuals with low scores for disinhibition. After adjusting for disinhibition, women with high dietary restraint (49%) showed no differences in BMI between PROP phenotypes. However in non-restrained eaters (51%), a significant association was found, with PROP non-tasters being almost six BMI units heavier than PROP super-tasters, and PROP medium tasters four BMI units heavier. The authors noted that among women with low cognitive restraint, PROP non-tasters and PROP medium tasters were borderline obese (i.e. ≥30 kg/m²), while PROP super-tasters fell within the healthy range (i.e. 18.5–24.9 kg/m²). This study was the first to control for eating behaviour and, while the sample was relatively small (86 women) and exercise was not assessed, it provided strong evidence of a possible link between the ability to taste PROP and BMI.

The TFEQ was also used to assess cognitive restraint and disinhibition and its interaction with PROP phenotype, BMI and adiposity in a study of 40 middle aged women by Goldstein

et al. (2005). This study showed that PROP non-tasters had significantly higher BMI, skin fold thicknesses and body fat percentages than PROP super-tasters and that there was a non-significant trend towards a higher waist circumference, even before controlling for eating behaviours. As with the study discussed previously (Tepper & Ullrich 2002), PROP super-tasters weighed approximately six BMI units less than PROP non-tasters. Dietary disinhibition was also associated with a high BMI and increased adiposity. Controlling for dietary disinhibition in order to assess the relationship between cognitive restraint, PROP phenotype and adiposity did not increase the strength of the associations and the authors suggested that the homogeneity of this group of women may have weakened the influence of cognitive variables on the results. However, while the study pointed to a strong link between PROP taster status and adiposity, it is important to note that in this small group of moderately overweight women there were only eight individuals classified as non-tasters.

In a well designed study by Tepper et al. (2008) a significant relationship was found between PROP phenotype and BMI. After controlling for disinhibition, mean BMI values for PROP supertasters were 3.2 units less than PROP non tasters. When cognitive restraint was included in the analysis, the association was stronger with a further 1.7 unit decrease in BMI between PROP non-tasters and PROP tasters. However, no relationship was shown between the PROP phenotype and BMI in men.

The study by Tepper et al. (2008) thus provides evidence suggestive of a strong influence of PROP phenotype on BMI in adult women. However, not all of the research supports this association. Research by Hayes and Duffy (2007), Villarino et al. (2009) and Drewnowski et al. (2007) showed no association between PROP phenotype and BMI. Unlike the results found for some of the studies on children in Table 6.2, none of the adult studies found an association between the PROP super taster phenotype and a high BMI.

A number of methodological issues may have contributed to the different results found in the studies mentioned above. None of these studies controlled for eating behaviour when interpreting the association between PROP phenotype and BMI. In the study by Hayes and Duffy (2007), cut off scores used for the classification of PROP phenotype were lower for PROP super-tasters when compared to other studies (>51mm vs. >67mm) and higher for PROP non-tasters (<22mm vs. <15mm). Furthermore, individuals were classified according to hypothetical Mendelian frequencies of 25:50:25 for PROP non-tasters, PROP medium tasters & PROP super-tasters in the study by Drewnowski et al. (2007). Thus, some individuals may have been misclassified for taster status, especially in the study on women by Drewnowski et al. (2007) since most authors agree that the super-taster phenotype is

expressed more frequently in females (Keller & Tepper, 2004; Hayes & Duffy, 2007; Yeomans et al. 2007; Tepper 2008). Furthermore, cognitive factors such as cognitive restraint may have masked any association that was present between PROP phenotype and BMI.

In summary, bearing in mind the mentioned methodological limitations and the complex nature of obesity, it appears that for moderately overweight middle aged women there is an association between increased sensitivity to PROP (PROP super taster phenotype) and a low BMI and that this association may be masked by restrained eating. Restrained eating may be much more prevalent in teenagers and young adults where societal pressures to remain slim are strong and body dissatisfaction is high (Cilliers et al. 2006; Millstein et al. 2008; Wharton et al. 2008) and this may be one reason why the PROP – BMI association is difficult to find in this group of individuals.

The discussed information also points to a possible difference in effect between males and females. No clear explanation for this difference is evident at this stage, with genetic and / or environmental influences most probably contributing (Timpson et al. 2005; Tepper et al. 2008). Ethnic differences in PROP phenotype have also been suggested (Guo & Reed 2001; Chang et al. 2006; Lumeng et al. 2008, Hedge & Sharma 2008) but there is currently insufficient data to draw any robust conclusions regarding the relationship between PROP phenotype and body weight for different ethnic groups. Furthermore, there is no published data on the influence of PROP phenotype on BMI for South Africans although one might assume that the association may be different for the different ethnic groups resident in this country.

Therefore, the clinical usefulness of PROP taste sensitivity as a method of screening to identify individuals at risk for weight gain at this stage appears to be limited (Drewnowski et al. 2007).

7 Final Summary of Main Trends

Obesity is a highly complex condition resulting from a multitude of heterogeneous and interdependent factors. The dynamic interactions between genes, behaviour and socio-environmental factors (such as those related to food, physical, cultural or economic environments that promote or restrict human behaviour) have been blamed for the current global obesity epidemic.

This review included a brief overview of the aetiology of obesity but focused mainly on the association between personal and parental weight history, body weight and shape satisfaction, weight management practices, eating behaviour as well as taste sensitivity and weight with a focus on ethnic differences that may be apparent.

Bearing in mind all the mentioned research limitations, it is clear that parental BMI and even the BMI of one's grandparents can have an impact on weight status, with this impact being cumulative such that obesity risk for an individual with two obese parents is greater than for an individual with only one parent being obese. This suggests a strong inherited component to body weight, although it is not possible to determine from the literature whether this inheritance was genetically mediated or as a result of learned behaviours and a shared environment. It is most likely that both have an interactive effect on obesity development. In some cultures there may also be a gender link for obesity inheritance, further suggesting inherited or socio-cultural influences that may differ between various ethnic groups.

Furthermore, once overweight, an individual is likely to remain overweight or move up a BMI category and become obese, since weight tracking has been clearly shown to exist. Weight tracking is strongest from adolescence to adulthood and especially for individuals who are already overweight or obese. Weight tracking has also been demonstrated in African Americans, especially for obesity, with African American girls and overweight boys more likely than Caucasian Americans to remain overweight as they move through the life cycle stages. In contrast, maternal influences on infant and childhood food and activity environments appear to influence body weight in young children more strongly, at least for Caucasian populations. Although weight tracking is convincingly demonstrated, many individuals who are normal weight in early adulthood become overweight or obese as older adults and this is clearly illustrated by the exponential growth in obesity throughout the world. There is currently no South African data available regarding weight tracking in our ethnically diverse population.

Eating behavior also plays a role in obesity development via the regulation of energy intake. However, associations with BMI between cognitive restraint, disinhibition and perceived hunger and the various aspects of each of these behaviours are complex and inconsistent. While cognitive restraint and flexible control appear to be associated with a lower BMI and weight loss, rigid control and disinhibition, including habitual and emotional susceptibility to disinhibition, are associated with a higher BMI and weight gain. Furthermore, flexible control of eating has been found to be associated with weight reduction success in some studies. Perceived hunger appears to correlate strongly with disinhibition and energy intake although

no direct associations have been found with BMI. While most of the available data relates to Caucasian populations, an association has been found between cognitive restraint, weight gain, weight loss attempts and urbanization in young African women living in South Africa, suggesting acculturation taking place with exposure to Western influences. At this stage it is not possible to speculate whether these eating behaviours are derived via genetic inheritance, a shared family environment or as a result of weight gain.

With increasing rates of obesity, weight loss attempts are prevalent although long term success is not evident. Attempts at weight reduction are not limited to the overweight or obese as many normal weight individuals, especially young women, also try to reduce their weight in order to conform to western societal ideals of slimness. Dissatisfaction with body weight and shape appears to play a role in the motivation behind weight loss attempts and has been found to be high in both overweight/obese and normal weight Caucasian women. Body weight and shape dissatisfaction is lower in African American women and African women living in South Africa and may contribute to the lower prevalence of weight loss attempts found for this ethnic group.

As far as weight loss methods are concerned, while healthy methods are commonly used, using a combination of healthy dietary methods and sufficient exercise is not common. Dietary adaptation is the most common approach. Exercise as a weight reduction strategy is seldom used by obese individuals with African Americans using exercise more often than American Caucasians, although this was not found for Caucasians and Africans living in South Africa. The use of unhealthy strategies for weight loss is more common amongst regular dieters, the very obese and the youth, with over-the-counter product usage more prevalent in poorer, less educated individuals and in African American and Hispanic communities in the USA. A greater use of these methods, including the use of traditional herbal mixtures has also been demonstrated for African communities in South Africa, with skipping meals being the most common weight loss practice for young African females.

Very interestingly, the literature points to a short term benefit of weight cycling (reflected by repeated weight loss attempts) whereby body weight is maintained at lower levels than it would have been without dieting. However, long term weight cycling appears to result in increased weight, abdominal fat and waist hip ratios and to have some adverse effects on health. Weight cycling is associated with depression, binge eating, unhealthy weight loss practices and lack of exercise and it is possible that one or more of these factors result in the increases in body weight seen in these individuals rather than as a result of weight cycling. None of the studies analysed the data for ethnicity.

Food preferences may also have an impact on body weight and individuals who prefer sweet and fatty foods may be at higher risk for weight gain. Some evidence suggests that PROP non-tasters have a higher risk of being overweight or obese although the relationship between PROP phenotype and BMI is currently inconclusive. Strong associations were found in some children, with maternal influence on body weight stronger than the PROP phenotype in others. The relationship between PROP phenotype and BMI in middle aged women was shown to be confounded by disinhibition and cognitive restraint which may be why there is little agreement in the literature, as not all of the research controlled for these factors. The literature illustrates that there may be ethnic differences in the PROP phenotype-BMI relationship, although there is insufficient data to thoroughly examine this. There is no South African data available on PROP sensitivity and no conclusions can be drawn in this regard.

CHAPTER 3

METHODS & PROCEDURES

3.1 Study design

This study followed a case control design. The study was a sub-study of a parent study that examined the association between weight loss success and genotype in overweight/obese Caucasian and Zulu subjects. The subjects included in the mentioned parent study were included as the overweight/obese cases in the sub-study. Normal weight controls were subsequently recruited for the purposes of the sub-study (see Figure 3.1 for detail).While it had been the intention to ensure that the controls were age matched to within two years of the cases, it was necessary to accept every individual who met the study criteria owing to the difficulties experienced in recruiting the normal weight volunteers. Age was thus controlled for in the analyses.

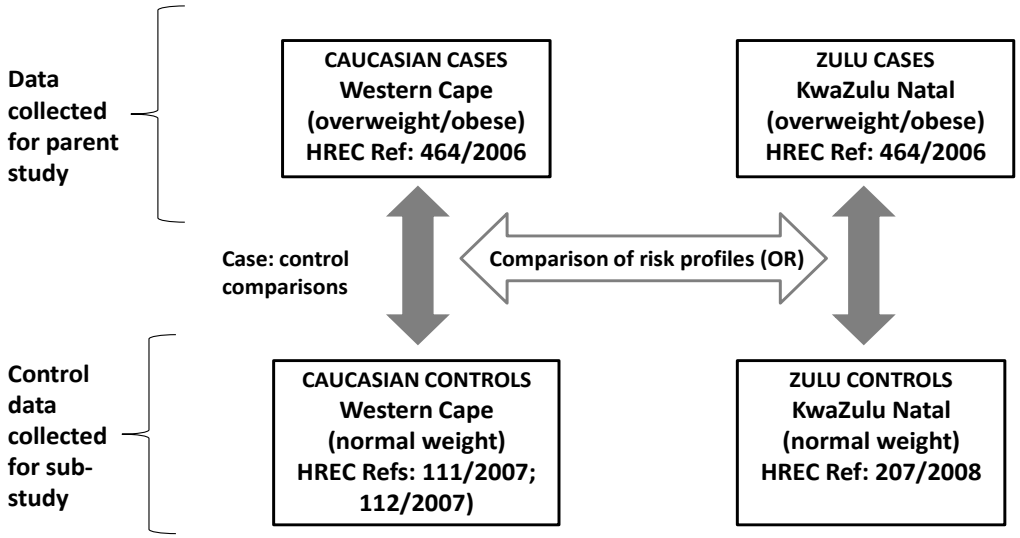


Figure 3.1 Study Design

3.2 Study population and sample

For the Caucasian group, the cases were selected from subjects who voluntarily entered a conservative weight loss programme (parent study) either in Cape Town or Stellenbosch between 2007 and 2008. Cases for the Zulu study were selected from Pietermaritzburg and Durban in Kwazulu-Natal between 2008 and 2010 where the second part of the parent study was being conducted. Controls were recruited between August and October 2008 (Caucasians) and between February 2009 and June 2010 (Zulus) from the same

geographical areas as the cases. The study sample included 92 overweight/obese cases and 102 normal weight controls in the Caucasian group and 94 overweight/obese cases and 86 normal weight controls in the Zulu group. Post-hoc power estimation revealed a statistical power of ≥90% for this study sample.

Selection criteria were the same for both the Caucasian and Zulu groups of women. Cases and controls had to be aged between 23 years and 40 years, from the middle to upper income socio-economic groups and were required to have at least basic English language skills in order to understand and complete the self-administered questionnaires. Cases had to have a BMI ≥ 28kg/m^2 up to a maximum of 50kg/m^2 and controls had to fall within the BMI range of 18.5-24.9kg/m^2. Further criteria for the controls included weight stability with no more than a two kilogram fluctuation in weight in the previous six months as well as a maximum of three hours per week of organized (recreational or competitive) physical activity. This limit on physical activity was imposed to ensure that the controls were not normal weight owing to very high physical activity levels.

Exclusion criteria for both cases and controls included pregnancy and lactation, debilitating disease, psychiatric disorders and addictions, conditions affecting taste perception, current participation in a weight loss programme or the use of weight loss products or drugs in the four weeks prior to recruitment for the study. Furthermore, controls were excluded if they experienced substantial weight loss for reasons other than dieting, for example owing to a chronic illness such as retroviral disease (see screening questionnaire in Addendum A). Individuals unwilling to sign the consent form and those suffering from Graves' disease were also excluded. Individuals diagnosed with Graves' disease were excluded on the basis that the chemicals used in the taste perception test are also part of the treatment regime for this condition.

3.3 Subject recruitment

Overweight and obese cases were recruited by means of advertisements in local newspapers and University bulletins and by word of mouth. On first contact, potential subjects were given a broad outline of the study following which a screening questionnaire was administered (Addendum A). Separate screening questionnaires were developed for the Caucasian cases and the Zulu cases. While both questionnaires were similar, the Zulu questionnaire further screened for weight gain associated with medication use, such as is common when using anti-retroviral medications. These potential subjects were excluded from this study. The screening questionnaires, which were reviewed by a panel of experts before being finalised, were developed to identify potential subjects who met the inclusion

criteria for the studies. Those potential overweight/obese subjects who met the study requirements were invited to participate in the parent studies.

Normal weight controls were also recruited using advertisements in university bulletins and by word of mouth. Snowball sampling was also applied with individuals who had responded to the advertisements being asked whether they knew other women who could be requested to enrol in the study. Nursery schools and companies were also approached and subjects were recruited at these venues. Owing to the difficulties in recruiting Zulu controls, qualified dietitians employed at some hospitals in Durban and Pietermaritzburg were trained and standardized to assist with recruiting from the staff at their places of work and at local churches. Potential subjects were given a broad outline of the study and completed the screening questionnaire specifically developed for the controls. This screening questionnaire was completed either telephonically or face-to-face to ensure eligibility for the study. Those potential normal weight subjects who met the study requirements were invited to participate.

Overweight/obese and normal weight individuals who met the study criteria and had agreed to participate were then asked to sign a consent form (Addendum B) after having the study explained to them in detail. Baseline anthropometric assessments were then conducted and the research questionnaires administered.

3.4 Anthropometric measurements

Heights and weights were measured in order to determine Body Mass Index (BMI). This simple index, computed as weight(kg)/height(m)^2, has been used extensively in epidemiological studies and has been recommended for use in clinical practice as a guide for weight management (WHO 1995; NIH/NHLBI 1998). Table 3.1 illustrates the classification of weight status according to BMI. This classification was used to ensure that the subjects fell within the BMI ranges specified for case and control groups.

Table 3.1: BMI classification

Classification	BMI (kg/m^2) cut off points
Underweight	< 18.50
Normal weight	18.50 – 24.99
Overweight	25.00 – 29.99
Obese	≥ 30.00
Obese class I	30 – 34.99
Obese class II	35 – 39.99
Obese class III	≥ 40.00

Adapted from: WHO, 1995

Weights (kg) were measured in light clothing without shoes to the nearest 0,2kg using an electronic scale. Subjects were measured while standing in the middle of the scale without support, their weight evenly distributed between both feet and while looking forward. Heights (m) were measured to the nearest 0.1cm without shoes using a stadiometer. Subjects stood on the base plate of the stadiometer with their feet together and their heels, buttocks, scapulae and back of the head touching the vertical bar of the stadiometer (Centres for Disease Control and Prevention, 2009).

3.5 Research questionnaire

A self-administered questionnaire (Addendum C) developed specifically for the parent study was used to obtain information on socio-demographic variables, weight history and weight loss practices. For the development of this questionnaire a theoretical framework was constructed from which the core concepts to be covered in the questionnaire were finalized. Subsequently the questions were developed and a draft questionnaire compiled. This was reviewed by a panel of experts and then pilot tested on a group of overweight/obese subjects. These steps were followed to ensure construct, content and face validity of the final questionnaire. This questionnaire was then adapted for the Zulu parent study by firstly being reviewed by a panel of Zulu speaking dietitians for comprehension and then pilot tested on a group of overweight/obese Zulu subjects.

Socio-demographic questions used for the purposes of this study included age, home language spoken (English, Afrikaans, Zulu, other), marital status (unmarried, married, divorced, separated, widowed, living together), home situation (living alone, with friends, with husband/partner, with husband/partner and children, with parents, other) and highest education levels achieved (matric, college certificate/diploma, technikon diploma/degree, university degree, other).

Questions regarding personal weight history included maximum, minimum and stable weights attained, the time period that these weights were maintained (<1 month, 1-6 months, >6 months), perception of current weight, weight during childhood, adolescence and early adulthood as well as perceived current parental weight and parental weight during the subject's childhood (responses included: underweight, normal weight, overweight, obese). Comparison of perceived weight in adolescence vs. their friends was also requested (weighed more than them, the same as them, less than them, don't know). Other questions included dissatisfaction with current weight (very much dissatisfied, somewhat dissatisfied, completely satisfied) and with individual body parts (yes/no) as well as fear of weight gain (very much afraid, somewhat afraid, not afraid at all). During the pilot test of the

demographic and health questionnaire in the Zulu population, it was found that Zulu cases were likely to not be able to supply detail regarding maximum, minimum and stable weights. This group of women were given the alternative option to answer in terms of dress size.

Weight management questions included weighing practices (at least once a day, 1-2 times a week, 3-6 times a week, 1-3 times a month, a few times a year, rarely if ever), weight goals (completely satisfied with present weight, gain some weight, lose 1-5kg, lose 6-10kg, lose 11-15kg, lose 16-20kg, lose>20kg), previous weight loss attempts (yes/no) the methods used (healthy methods: balance slimming diet, increase in physical exercise, eat less/nothing between meals, Weigh-Less, Weight Watchers; unhealthy methods: skipping meals, fasting, low carbohydrate and high protein diet, quick-loss diets, diet formulas/milkshakes/powders; extreme methods: diuretics, appetite suppressants, laxatives, vomiting, herbal mixtures, machines that break down fat, injections that break down fat, surgery, other), the most successful weight loss method used, most amount of weight lost and weight loss maintenance success (kept the weight off for at least 1 year, gained some of it before a year passed, gain all of it before a year passed, never lost weight on a diet).

In this study, self-reported weights and perceived weight were used as a proxy for weight history. Studies have shown that self-reported heights and weights provide sufficiently accurate data (Reed & Price 1998; Hill & Roberts 1998; Bolton-Smith et al. 2000; Kuczmarski et al. 2001) although there is a trend towards under-reporting of body weight, especially in Caucasian women (Jeffrey 1996; Black et al. 1998). However, a review of 29 studies by Gorber et al. (2007) found that using self-reported data for BMI determination was sufficiently accurate when compared to measured values and could be used in epidemiological studies. Regarding perceived weight, studies have shown that retrospective recall of weight in childhood, adolescence and young adulthood (Munoz et al. 1996, Koprowski et al. 2001, Must et al. 2002) and perception of weight relative to peers during early adolescence (Casey et al. 1991) was accurate for women. Other studies show that the correlations between perceived and measured weight are moderately strong, especially for overweight/obese Caucasian women, with normal weight women being more likely to overestimate their weight (Paeratakul et al. 2002; Linder et al. 2010). Overweight African American women are also more likely than Caucasian women to perceive themselves as being normal weight (Williamson et al. 2000; Paeratakul et al. 2002), a phenomenon found in Africans living in South Africa (Senekal et al. 2001; Mchiza et al. 2005). However, accuracy of perceived weight is also associated with higher income and education levels (Paeratakul et al. 2002; Puoane et al 2005) and, as the samples in this study were draw from the middle to upper income groups with many subjects having relatively high education levels, the use of perceived weight as a proxy for actual weight is likely to be relatively accurate, especially

for the Caucasian sample. For the Zulu sample, the possibility of inaccuracies were taken into account in the interpretation of the results.

3.6 Eating behaviour assessment

In this study eating behaviour was assessed using the *Three-Factor Eating Questionnaire* (TFEQ) developed by Stunkard and Messick (1985) (Addendum D). This questionnaire is used to measure cognitive dietary restraint, defined as the tendency of some persons to restrict their food intake in order to control their body weight (Herman 1975), dietary disinhibition, defined as the loss of control over eating resulting from specific cues such as the ingestion of specific foods, alcohol intake or psychological depression (Stunkard & Messick 1985) and perceived hunger, defined as food intake in response to feelings and perception of hunger / lack of satiety (Provencher et al. 2007).

The response options for the 51 questions on the TFEQ ranged from true/false to a variety of likert scales e.g. rarely/sometimes/often/always. Each of the three scales has been divided into subscales as follows:

The cognitive restraint scale (TFEQ-R)

- Rigid dietary restraint (TFEQ-RC7): 7 questions that reflect dichotomous all or nothing approach to eating, dieting and weight (Westenhoefer et al. 1999);
- Flexible dietary restraint (TFEQ-FC7): 7 questions that reflect gradual approach to eating, dieting and weight in which high energy foods are eaten in limited quantities without feeling guilty (Westenhoefer et al. 1999);
- Strategic dieting behavior (TFEQ-R1): 4 questions that reflect specific weight control behaviours (Bond et al. 2001);
- Attitude to self-regulation of eating (TFEQ-R2): 4 questions that reflect overall perspective on eating and weight control (Bond et al. 2001);
- Avoidance of fattening foods (TFEQ-R3): 4 questions that reflect behavioural aspects of food selection (Bond et al. 2001).

The disinhibition scale (TFEQ-D)

- Habitual susceptibility to disinhibition (TFEQ-D1): 4 questions that reflect behaviours that may occur when circumstances predispose to recurrent disinhibition;
- Emotional susceptibility to disinhibition (TFEQ-D2): 3 questions that reflect disinhibition associated with negative affective states;

- Situational susceptibility to disinhibition (TFEQ-D3): 4 questions that reflect disinhibition initiated by specific environmental cues (Bond et al. 2001).

The hunger scale (TFEQ-H)

- Internal locus for hunger (TFEQ-H1): 6 questions that reflect hunger interpreted and regulated internally;
- External locus for hunger (TFEQ-H2): 6 questions that reflect hunger triggered by external cues (Bond et al. 2001).

Responses to each of the questions are given a score of 0 or 1 and are totalled for each scale and subscale. Total scores were then used to classify each eating behaviour as restrained/unrestrained, disinhibited/not disinhibited or hungry/not hungry. In order to determine risks for overweight/obesity (odds ratios), the scores for the scales and subscales of the TFEQ were dichotomised. This was done according to the method recommended by Tepper et al. (1996) for cognitive restraint and disinhibition. The method used for dicotomizing all other scales and subscales was specifically designed for this study. The scales and subscales of the TFEQ, including their interpretation are summarised in Table 3.2.

Table 3.2: Three Factor Eating Questionnaire scales and subscales

	Scales	Subscales	No. of Items	Interpretation
TFEQ 51 items	**Cognitive Restraint TFEQ-R**		**21**	Comparison of means** ≥ 10: restrained eater * < 10:unrestrained eater *
		Flexible control (TFEQ-FCR7)	**7**	Comparison of means*** ≥4: restrained <4: unrestrained
		Rigid control (TFEQ-FCR7)	**7**	Comparison of means*** ≥4: restrained <4: unrestrained
		Strategic dieting behaviour (TFEQ-R1)	**4**	Comparison of means** ≥3: restrained <3: unrestrained
		Attitude to self-regulation (TFEQ-R2)	**5**	Comparison of means** ≥3: restrained <3: unrestrained
		Avoidance of fatty food (TFEQ-R3)	**4**	Comparison of means** ≥3: restrained <3: unrestrained
	Disinhibition TFEQ-D		**16**	Comparison of means** ≥ 8: disinhibited eater * <8: not disinhibited *
		Habitual susceptibility (TFEQ-D1)	**5**	Comparison of means** ≥3: disinhibited <3: not disinhibited
		Emotional susceptibility (TFEQ-D2)	**3**	Comparison of means** ≥2: disinhibited <2: not disinhibited
		Situational susceptibility (TFEQ-D3)	**5**	Comparison of means** ≥3: disinhibited <3: not disinhibited
	Perceived Hunger TFEQ-H		**14**	Comparison of means** ≥ 7: hungry <7: not hungry
		Internal locus for hunger (TFEQ-H1)	**6**	Comparison of means** ≥3: disinhibited <3: not disinhibited
		Internal locus for hunger (TFEQ-H2)	**6**	Comparison of means** ≥3: disinhibited <3: not disinhibited

***** Tepper et al. (1996) ** Bond et al. (2001) *** Westenhoefer et al. (1999)

The TFEQ has been shown to be a reliable method of determining eating behaviour in both obese and normal weight Caucasians (de Lauzon et al. 2004). However, its use in South African populations has not been extensively researched although Senekal et al. (2001) found that the internal reliability of the restraint scale was moderate (Cronbach's alpha = 0.56) for a group of female African university students which allowed cautious interpretation of the results. Cronbach's alpha in the current study is illustrated in Table 3.3.

Table 3.3: Cronbach's Alpha for the Three Factor Eating Questionnaire

	Number of items	Caucasian Sample		Zulu Sample	
		True / False	Likert Scale	True / False	Likert Scale
Total TFEQ	51				
Cronbach's alpha		0.75	0.75	0.8	0.74
(number of items)		(36)	(15)	(36)	(15)
Cognitive restraint Scale: TFEQ-R	21				
Cronbach's alpha		0.27	0.70	0.42	0.76
(number of items)		(12)	(8)	(12)	(8)
Disinhibition Scale: TFEQ-D	16				
Cronbach's alpha		0.63	0.77	0.69	0.66
(number of items)		(13)	(3)	(13)	(3)
Perceived Hunger Scale: TFEQ-H	14				
Cronbach's alpha		0.77	0.01	0.80	0.05
(number of items)		(11)	(3)	(11)	(3)

Since a reliability co-efficient of >0.6 is often considered to have met internal consistency requirements (Thiessen 1993), the use of the TFEQ in this study is appropriate for measuring disinhibition. When considering the restraint scale however, Cronbach's alpha for the true/false questions (consisting of 12 questions) was low for the Caucasian sample and moderately low for the Zulu sample, indicating that the results from this section of the restraint scale may be questioned. However, the likert scale of the restraint scale (consisting of 8 questions) shows good reliability and it is possible that the results from the combined sections may be valid if interpreted with caution. With regards to the perceived hunger scale, while the true/false section shows good reliability, Cronbach's alpha for the likert scale section is very poor. As there are only three questions in the latter section, the true/false section of the hunger scale (11 questions) may be a more important indicator of internal reliability for this scale. Nevertheless, results from the perceived hunger scale should also be interpreted with caution. Cronbach's alpha was not computed for the TFEQ sub-scales owing to the small number of questions in each.

3.7 Taste Sensitivity Test

The internationally recognized filter paper method developed by Zhao et al. (2003) was used to classify individuals according to their PROP phenotype. This method uses the Labelled Magnitude Scale (LMS) (Addendum E) to rate the intensity of taste experienced when the impregnated filter paper is placed on the tongue (Green et al. 1996). The LMS is a 100mm semi-logarithmic scale with label descriptors ranging from "barely detectable" at the one extreme to "strongest imaginable" at the other. Firstly, the subject rinses out her mouth and then places a sodium chloride (NaCl) impregnated disk on the tongue and leaves it there

until it is wet. The intensity of the taste is then rated according to the LMS and the procedure repeated using the PROP impregnated filter paper (Goldstein et al. 2005).

In this study subjects were trained on how to interpret the LMS using sour sweets and lemon juice before completing the taste sensitivity test. Prior to training, subjects were given examples as to what sensations might be rated as "strongest imaginable". Examples included the pain experienced when looking into the sun or when a jet aeroplane takes off in close proximity to the individual. After rinsing the mouth with water subjects placed a "sour jelly tot" (Tiger Consumer Brands, South Africa) in their mouths and chewed it. The intensity of the sour taste was rated on the LMS. Subjects rinsed their mouths again, ensuring that no residual jelly was left and then tasted a small piece of "sour worm" (Manhattan Jellyland, Kraft Foods, South Africa) and repeated the intensity rating. After rinsing a third time, a teaspoon of fresh lemon juice was placed in the mouth and the intensity rated. The mouth was then rinsed again. In order to reduce the possibility of residual taste lingering in the mouth and affecting the PROP taste test, individuals were requested to complete the questionnaires after this initial training before undergoing the actual PROP taste test.

Subjects were classified into three groups according to empirically derived cut off scores for PROP intensity (Zhao et al. 2003). These include PROP "non-tasters" who are not able to taste the bitter PROP taste (or submitted a score of less than15mm on the LMS), PROP "medium tasters" who scored the intensity of bitterness only moderately (scores between 15 and 67mm on the LMS) and PROP "super tasters" who rated PROP bitterness as "strongest imaginable" (submitted LMS scores greater than 67mm). Sodium chloride (NaCl) is used as a reference standard since taste sensitivity to this compound does not vary by PROP taster status in this method (Zhao et al. 2003). PROP non-tasters give lower ratings to PROP than to NaCl and PROP super tasters give much higher ratings to PROP than NaCl. PROP medium tasters give similar ratings to both compounds (Goldstein et al. 2007). Thus, if an individual gave a borderline rating to PROP, the NaCl rating was used in the final classification of that individual.

It has been suggested that cognitive factors such as eating behaviour may confound the relationship between PROP phenotype and BMI (Tepper & Ullrich, 2002) and should be controlled for during data analysis. For the purposes of this study, only the disinhibition and dietary restraint sections of the TFEQ were used, in line with other research into this phenomenon (Tepper & Ullrich, 2002, Goldstein et al. 2005, Tepper 2008).

3.8 Data collection and fieldworkers

As indicated in the section on subject recruitment, data collection for the cases was conducted during the introductory sessions for the weight management programme as part of the parent studies. This included anthropometric assessment, the PROP taste test and the completion of questionnaires. These sessions were conducted at various centres including the Department of Human Biology at the University of Cape Town and at the University of Stellenbosch (Caucasian data) or at various centres in Durban and Pietermaritzburg (Zulu data). Caucasian and Zulu control data was collected at the same centres used for the cases as well as at other private locations, churches, hospitals and businesses. For both cases and controls, heights and weights were measured, the PROP taste test conducted in a private area and the questionnaires were self-administered under supervision.

The Caucasian overweight/obese data was collected by the principle researcher and Honours students in Nutrition and Dietetics. Caucasian control data was collected by the same Honours students and by the principle researcher for the case control study. Data for both Zulu cases and controls was collected by the principle researcher for the Zulu parent study and by three Zulu speaking dietitians. All fieldworkers were trained and standardised to ensure consistency.

3.9 Data processing and statistical analysis

3.9.1 Data capturing and cleaning

After data collection, the primary researcher checked the questionnaires for completeness. If any data was missing, the subjects were requested to fill in the missing information, either in person or telephonically if possible. Despite these measures, missing data points were still recorded for some measures. For this reason there is some variability in subject numbers for variables included in the results. Data was captured on Excel spreadsheets and cleaned.

3.9.2 Conversion of dress size to a BMI equivalent

As a large number of Zulu cases recorded only dress sizes during data collection (Table 3.4), the dress size data was converted to BMIs > 25kg/m^2 and <25kg/m^2.

Table 3.4: Dress size vs. weight data reported by Zulu cases

	Maximum weight	Minimum weight	Stable weight
Dress size n (%)	48 (49%)	53 (62%)	14 (30%)
Weight n (%)	49 (51%)	32 (38%)	32 (70%)
Total n	97	85	46

Data from subjects who provided both dress size and a weight when answering questions on minimum/maximum/stable weight (26 data points) was used to investigate the association between dress size and BMI (Table 3.5). With the exception of two data points, the height of the women who provided both dress size and weight fell within the range of 1.52.-1.62 (total sample mean for Zulu cases: 1.59, 95%CI: 1.58-1.60). Thus, the two data points from taller women (both 1.8m) were not further considered.

Table 3.5: BMI category estimation from actual weight and dress size data

DRESS SIZE	32	34	36	38	40	42	44	46	48
Reported Weights (kg)	55	56 55 65 63 56 63 60	68 70	75 86 (ht:1.8 BMI 26.5 excluded)	85 79	90 110 85 97	106 98 90 104 110	110 131 (ht:1.8 BMI 40 excluded)	135
Average weight/weight used	55	60	69	75	82	96	102	110	135
BMI range for heights 1.53m-1.62m	21-23	22.8-25.4	26-29	28.6-32	31-35	34-38.4	38.7-43	42-47	51-58

A BMI range was determined from the average weight for each dress size where possible. A height of 1.55m is the minimum height for which a dress size of 34 equates to a BMI<25kg/m^2 from this data. Therefore, the cut-off measurements for a BMI<25kg/m^2 or > 25kg/m^2 was dress size 34 at a height of 1.55m. Subjects shorter than 1.55m who reported a dress size of 34 were recorded as having a BMI>25kg/m^2 whereas subjects 1.55m or taller were recorded as having a BMI<25kg/m^2. Subjects with dress sizes smaller than 34 (size 32 or smaller) were recorded as having a BMI<25kg/m^2 and dress sizes larger than size 34 (size 36 or larger) were recorded as having a BMI>25kg/m^2 as long as the subject's height fell within the range 1.55m-1.62m.

Four subjects were taller than 1.62m and were assessed as follows: two subjects (height: 1.71m and 1.69m) stated that their maximum weight equated to dress sizes of 50 and 48 respectively. As their measured weights at the time of data collection were 145kg (BMI 49.6kg/m^2) and 134kg (BMI 47kg/m^2), they were both assigned a BMI >25kg/m^2 for their maximum weight. Neither woman provided information for their minimum or stable weight and these were recorded as missing data. One woman (height 1.73m, measured weight 149kg, BMI 49.8kg/m^2) reported a maximum and stable weight dress size of 48 and was assigned a BMI >25kg/m^2 for both measures. This subject's minimum weight dress size was 36. As it was difficult to *accurately* assign a BMI for this measure, it was recorded as missing

data. The last subject (height: 1.64, measured weight 98kg, BMI 36kg/m^2) recorded a maximum and stable weight dress size as size 40 and size 38 respectively. Both were recorded as a BMI >25kg/m^2 since her BMI for dress size 38 and size 40 was >25kg/m^2 when calculated using the average weight for this dress size.

As this method was determined from a small database, inaccurate assignment of BMI categories may have occurred in some cases. It is thus important to bear this in mind when interpreting the results for maximum, minimum and stable weight from the Zulu sample. It is also important to note that analysis of actual BMIs (maximum, minimum and stable weight BMI) was limited to only those women who reported an actual weight.

3.9.3 Analyses

Statistical analysis was conducted using Statistica 9 (Statsoft Inc. Tulsa, USA) and Stata 11.0 (Stata Inc. Texas, USA).

Primary aim:

The following hypotheses were formulated to guide the statistical analysis to achieve the primary aim:

$H_0$1: There is no association between Caucasian cases and controls for all variables.
$H_0$2: There is no association between Zulu cases and controls for all variables.

The following analyses were conducted to test these hypotheses:

- Shapiro Wilks tests were conducted to determine normality of numerical data.
- Descriptive statistics including frequencies for categorical variables and mean (± SD) / median (IQR) for numerical variables were conducted.
- Comparison of cases and controls for categorical variables using Pearson's Chi-squared tests or Fishers exact tests where there was an expected frequency of less than 5 in cells of 2x2 tables. Multivariate regression analysis using a generalized linear model (GLM) was used for the comparison of numerical variables in order to control for demographic variables that differed between cases and controls (Caucasians: age, language, education; Zulus: age, education, marital status).
- Odds ratios were computed using logistic regression (Stata) for variables that differed significantly between cases and controls. Odds ratios were controlled for socio-demographic variables that differed significantly between cases and controls (Caucasians: age, language, education; Zulus: age, education, marital status). PROP phenotype odds ratios were also controlled for cognitive restraint and dietary disinhibition as recommended by Tepper & Ullrich (2002)

The analyses conducted to meet the primary aim of this study were conducted for each data set separately (Caucasian cases vs. controls; Zulu cases vs. controls).

Secondary aim:

The following hypotheses were formulated to guide the statistical analysis to achieve the secondary aim:

$H_0$3: There is no association between Caucasian cases and Zulu cases for all variables.

H_0 4: There is no association between Caucasian controls and Zulu controls for all variables.

The following analyses were conducted to test these hypotheses:

- Shapiro Wilks tests were conducted to determine normality of numerical data.
- Descriptive statistics including frequencies for categorical variables and mean (± SD) / median (IQR) for non-categorical variables were conducted.
- Comparison of cases and controls for categorical variables using Pearson's Chi-squared tests or Fishers exact tests where there was an expected frequency of less than 5 in cells of 2x2 tables. Multivariate regression analysis using a generalized linear model (GLM) was used for the comparison of numerical variables in order to control for demographic variables that differed between cases and controls (*Case* comparisons and *control* comparisons: age, education, marital status). PROP phenotype odds ratios were controlled for dietary restraint and dietary disinhibition as recommended by Tepper & Ullrich (2002).

The analyses conducted to meet the secondary aim of this study were conducted for each data set separately (Caucasian vs. Zulu *cases*; Caucasian vs. Zulu *controls*).

A summary of all of the analyses is shown in Table 3.6. In all of the statistical analyses, a p-value of <0.05 was considered statistically significant.

Table 3.6: Summary of Statistical Analysis of Variables

Study Objective	Variables	Descriptive Statistics	Analytical statistics	
			Comparative	Odds Ratios*
Personal weight history #	Child: 2-10 years (normal wt;overweight/obese) Adolescent: 11-19 years (normal wt;overweight/obese) Young adult: 20-25 years (normal wt;overweight/obese) Adolescent (more than peers; less than/same as peers)	Frequencies	Chi square / Fisher's exact tests	√
	Maximum weight (kg) / BMI (kg/m^2) Minimum weight (kg) / BMI (kg/m^2) Stable weight (kg) / BMI (kg/m^2)	Mean ±SD 95%CI	GLM♦	X
	BMI at maximum wt (<25 kg/m^2;>25 kg/m^2) BMI at minimum wt (<25 kg/m^2;>25 kg/m^2) BMI at stable wt (<25 kg/m^2;>25 kg/m^2) Time at maximum wt (<6 months;>6 months) Time at minimum wt (<6 months;>6 months)	Frequencies	Chi square / Fisher's exact tests	√
Parental weight history #	Perceived mother's weight in childhood (normal wt;overweight/obese) Perceived father's weight in childhood (normal wt;overweight/obese) Perceived mother's current weight (normal wt;overweight/obese) Perceived father's current weight (normal wt;overweight/obese)	Frequencies	Chi square / Fisher's exact tests	√
Weight management practices #	Previous dieting (yes;no) Weight regain (kept wt off for > 1 year; regained wt in 1 year) Successful diet (balanced/exercise; other; none successful) Most successful diet (balanced/exercise; other method)	Frequencies	Chi square / Fisher's exact tests	√
	Type of diet (18 categories)	Frequencies Histograms	Chi square / Fisher's exact tests	X
	Age of first diet (yrs) Most weight lost on a diet (kg) Number of different diet strategies Current goal weight (kg)	Median (IQR)	GLM♦	X
Weight perception & satisfaction #	Weight perception (overweight/obese; normal/underweight) Afraid of weight gain (yes;no) Satisfaction with weight (yes; no) Frequency of weighing (daily; weekly; rarely) Gain vs. lose weight (gain; lose) Weight loss goal (to lose < 5kg; to lose > 5kg) Body part dissatisfaction: arms, stomach, middle, hips, buttocks, thighs, calves (yes; no)	Frequencies	Chi square / Fisher's exact tests	√
Eating behaviour	TFEQ-R Cognitive Restraint (0-21) TFEQ-FCR7 Flexible Restraint (0-7) TFEQ-RC7 Rigid Restraint (0-7) TFEQ-R1 Strategic Dieting Behaviour (0-4) TFEQ-R2 Attitude to self-regulation (0-5) TFEQ-R3 Avoidance of fattening foods (0-4) TFEQ-D Dietary disinhibition (0-16) TFEQ-D1 Habitual susceptibility (0-5) TFEQ-D2 Emotional susceptibility (0-3) TFEQ-D3 Situational susceptibility (0-5) TFEQ-H Perceived Hunger (0-14) TFEQ-H1 Internal locus for hunger (0-6) TFEQ-H2 External locus for hunger (0-6)	Means±SD 95%CI	GLM♦	X
	TFEQ-R Cognitive Restraint:0-21 (≥10 R;<10 not R) # TFEQ-FCR7 Flexible Restraint:0-7 (4-7 R; 0-3 not R) TFEQ-RC7 Rigid Restraint:0-7 (4-7 R; 0-3 not R) TFEQ-R1 Strategic Dieting Behaviour: 0-4 (3-4 R; 0-2 not R) TFEQ-R2 Attitude to self-regulation:0-5 (3-5 R; 0-2 not R) TFEQ-R3 Avoidance of fattening foods:0-4 (3-4 R; 0-2 not R) TFEQ-D Dietary disinhibition:0-16 (≥8 D; <8 not D) # TFEQ-D1 Habitual susceptibility:0-5 (≥3D; <3 not D) TFEQ-D2 Emotional susceptibility:0-3 (≥2 D; <2 not D) TFEQ-D3 Situational susceptibility:0-5 (≥3D; <3 not D) TFEQ-H Perceived Hunger:0-14 (≥ 7 H; <6 not H) # TFEQ-H1 Internal locus for hunger:0-6 (≥4 H; <4 not H) TFEQ-H2 External locus for hunger:0-6 (≥4 H; <4 not H)	Frequencies	Chi square / Fisher's exact tests	√
Taste sensitivity #	PROP sensitivity (supertaster, medium taster, non-taster)	Frequencies	Chi square / Fisher's exact tests	X
	PROP taster (supertaster) PROP non-taster (medium taster; non-taster)	Frequencies	Chi square / Fisher's exact tests	√**

Variables included in secondary analysis for ethnicity Wt: weight R: restrained D: disinhibited

***** Odds ratio's controlled for significantly different demographic variables:
Caucasian data controlled for: age, education and language Zulu data controlled for: age, education and marital status

♦ Comparisons controlled for significantly different demographic variables:
Caucasian data controlled for: age, education and language Zulu data controlled for: age, education and marital status
Cases vs. cases controlled for: age, education and marital status Controls vs. controls controlled for: age, education and marital status

****** Odds ratio's controlled for cognitive restraint and disinhinbition

All Odds ratios controlled using logistic regression analysis (Stata 11.0: Stata Inc. Texas, USA)

3.10 Ethical Issues

Ethical approval for this research as an addendum to the parent study was obtained from the Faculty of Health Sciences Human Research Ethics Committee, University of Cape Town. This study was conducted in a manner that is in accordance with the principles of the Declaration of Helsinki (Williams 2008), the ICH Good Clinical Practices (GCP) and the laws of South Africa. All participants signed an informed consent form (Addendum B) after the investigator provided a full and adequate verbal and written explanation of the study and its risks and had the right to withdraw at any time without having to provide a reason. The information was coded and subjects' names removed from the database before analysis in order to maintain confidentiality at all times. Furthermore, participants have not been named in any publications.

CHAPTER 4

RESULTS

4.1 Socio-demographic information

Caucasian (cases vs. controls)

The baseline characteristics of Caucasian cases (n=89) and controls (n=102) are shown in Table 4.1a. Weight and BMI were significantly higher in the cases than the controls. The mean age of the control group was significantly lower than for the cases, although this difference was only two years.

Controls were significantly more likely to be English speaking and have a tertiary degree, while the cases were more likely to be Afrikaans speaking. No differences were found between the two groups for smoking or marital status.

Since age, language and education differed significantly between cases and controls, group comparisons (cases vs. controls) were adjusted for these variables in the statistical analysis.

Zulu (cases vs. controls)

The baseline characteristics of Zulu cases (n=94) and controls (n=86) are shown in Table 4.1b. Weight and BMI were significantly higher in the cases than the controls. The mean age of the control group was significantly lower than for the cases.

Cases were significantly more likely to be married or living together and have a tertiary qualification. No differences were found between the two groups for smoking or for home situation with most people sharing accommodation with at least one other individual.

Since age, marital status and education differed significantly between cases and controls, group comparisons (cases vs. controls) were adjusted for these variables in the statistical analysis.

Differences between Caucasian and Zulu samples

Significant differences were found between Caucasian (n=89) and Zulu (n=94) *cases* for age (p=0.008), education (p=0.008) and marital status (p=0.04). These variables were adjusted for in the statistical analysis of the *cases*.

Significant differences were found between Caucasian (n=102) and Zulu (n=86) *controls* for age, education, BMI and marital status (all p<0.001). Age, education and marital status were adjusted for in the statistical analysis of the *controls*.

Table 4.1a: Socio-demographic and anthropometric characteristics of Caucasian cases and controls

	Cases (n= 89)	Controls (n= 102)	p value
Age: mean(SD)years	33.1(4.2)	31.1(5.56)	0.006[a]
95% CI	27.4-38.0	26.2-37.5	
Weight: mean(SD) kg	99.7(20.6)	69.98(6.2)	<0.001[a]
95% CI	81.7-123.8	64.5-77.2	
Height: mean(SD) m	1.66(0.1)	1.66(0.1)	0.76[a]
95% CI	1.6-1.73	1.6-1.73	
BMI: mean(SD) kg/m²	36(6.7)	22.0(1.7)	<0.001[a]
95% CI	29.3-42.7	20.5 - 23.9	
Marital Status (Column %)			0.067[b]
Unmarried	30.3	43.1	
Married / Living together	69.7	56.9	
Language (Column %)			<0.001[b]
English	14.6	72.6	
Afrikaans	85.4	27.5	
Education (Column %)			<0.001[b]
Matric	34.8	10.8	
Post-Matric	65.2	89.2	
Smoking			0.678[b]
% Yes reported	25.8	23.2	

[a] Paired t test [b] Chi-Square test

SD: Standard deviation 95% CI: 95% confidence interval

Table 4.1b: Socio-demographic and anthropometric characteristics of Zulu cases and controls

	Cases (n= 94)	Controls (n= 86)	
Age: mean(SD)years 95% CI	31.6(5.35)* 30.5-32.7	27.3(4.24)** 26.3-28.2	<0.001[a]
Weight: mean(SD) kg 95% CI	96.1(20.35) 91.9-100.3	59.7(5.54) 58.6-60.9	<0.001[a]
Height: mean(SD) m 95% CI	1.59(0.06)# 1.58-1.60	1.61(0.06)** 1.59-1.62	0.14[a]
BMI: mean(SD) kg/m² 95% CI	37.8(7.22) 36.3-39.3	23.1(1.38)** 22.9-23.4	<0.001[a]
Marital Status (Column %)			0.03[b]
Unmarried	66*	85**	
Married / living together	34	15	
Education (Column %)			<0.001[b]
Matric	18*	45**	
Post-Matric	82	55	
Smoking			0.93[c]
% Yes reported	2	2	

[a] Paired t test [b] Chi-Square test [c] Fisher's exact test

* Cases (Caucasian vs. Zulu) differ significantly: all p<0.05

** Controls (Caucasian vs. Zulu) differ significantly: all p<0.001

Cases (Caucasian vs. Zulu) differ significantly: all p<0.001

SD: Standard deviation 95% CI: 95% confidence interval

4.2 Personal Weight History

4.2.1 Self reported maximum, minimum and stable weight

Caucasian (cases vs. controls)

The self reported maximum, minimum and stable weight of Caucasian cases and controls are presented in Table 4.2a. Significant differences were evident for all variables except time spent at maximum weight. Cases had higher maximum, minimum and stable weight BMIs than the controls and these BMIs were more likely to be >25kg/m^2.

Zulu (cases vs. controls)

The self reported maximum, minimum and stable weight of Zulu cases and controls is presented in Table 4.2b. Significant differences were evident for all variables except time spent at maximum weight. In the sub-analysis that includes only subjects who had reported actual weights, cases had higher maximum, minimum and stable weight BMIs than the controls and these BMIs were more likely to be >25kg/m^2. BMI at maximum weight for a third of the controls was in the overweight/obese group.

Differences between Caucasian and Zulu samples

Significant differences were found between Caucasian and Zulu *cases* for self reported maximum weight BMIs (p=0.018), with the Zulu *cases* reporting higher maximum weight BMIs. No significant differences were found for minimum and stable weight BMI after controlling for demographic variables that differed. Caucasian *cases* were also significantly taller than Zulu *cases* (p<0.001). No differences between Caucasian and Zulu *cases* were found for being normal weight or overweight/obese for maximum, minimum and stable weight. Time spent at maximum, minimum and stable weight was also not different between the groups except for time spent at minimum weight, with the Caucasian *cases* more likely than the Zulu *cases* to have spent less than 6 months at this weight (p<0.001).

Significant differences were found between Caucasian and Zulu *controls* for self reported minimum weight BMIs (p=0.01), with the Caucasians weighing less. Caucasian *controls* were also significantly taller than Zulu *controls* (p<0.001). However, no differences were found between Caucasian and Zulu *controls* for maximum or stable weight BMIs, for being normal weight or overweight/obese or for time spent for each of these weight measures.

Table 4.2a: Association between self reported weight history (maximum, minimum and stable weight) and overweight/obesity for Caucasian women

	Cases (n= 89)	Controls (n= 102)	p value	Odds ratio (95% CI)	Adjusted Odds ratio (95% CI)
Maximum weight: mean(SD) kg 95% CI	100.1(21.7) 95.4-104.8	64.7(7.4) 63.3-66.2	<0.001[a]	NA	NA
Maximum BMI : mean(SD) kg/m² 95% CI	36.1(7.1) 34.6-37.6	23.4(2.3) 22.9-23.8	<0.001[a]	NA	NA
Minimum weight: mean(SD) kg 95% CI	70.8(12.5) 68.2-73.5	55.4(6.5) 54.1-56.7	<0.001[a]	NA	NA
Minimum BMI: mean(SD) kg/m² 95% CI	25.6(4.2) 24.7-26.5	20(1.6) 19.6-20.3	<0.001[a]	NA	NA
Stable weight: mean(SD) kg 95% CI	83.3(18.6) 79.2-87.3	58.5(6.2) 57.3-59.7	<0.001[a]	NA	NA
Stable BMI: mean(SD) kg/m² 95% CI	30(5.9) 28.8-31.4	21.1(1.5) 20.8-21.4	<0.001[a]	NA	NA
BMI at max weight: (Column %)					
< 25 kg/m²	0	78.4	<0.001[b]	*	*
> 25 kg/m²	100	21.6			
Time at max weight: (Column %)					
> 6 months	47	43	0.063[c]	–	–
< 6 months	53	57			
BMI at min weight: (Column %)					
< 25 kg/m²	52.3	100	<0.001[b]	*	*
> 25 kg/m²	47.7	0			
Time at min weight: (Column %)					
> 6 months	57.5	38.6	0.004[c]	1.17 (0.63-2.2) P=0.59	1.69 (0.87-4.13) P=0.18
< 6 months	42.5	61.4			
BMI at stable weight: (Column %)					
< 25 kg/m²	24.1	100	<0.001[b]	*	*
> 25 kg/m²	75.9	0			

[a] GLM adjusting for demographic variables (age, education, demographic variables) [b] Fisher's exact test [c] Chi-Square test

* odds ratios cannot be calculated as one or more frequencies equal zero

NA Not applicable SD: standard deviation 95% CI: 95% confidence interval

Table 4.2b: Association between self reported weight history: (maximum, minimum and stable weight) and overweight/obesity for Zulu women

	Cases	Controls (n= 70)		Odds ratio (95% CI)	Adjusted Odds ratio (95% CI)
Maximum weight: mean(SD) kg 95% CI	(n=48) ** 99.1 (18.3) 93.8-104.4	62.3 (7.52) 60.5-64.1	<0.001[a]	NA	NA
Maximum BMI : mean(SD) kg/m² 95% CI	(n=47) ** 39 (6.63) [#] 37.1-41	24.1 (2.29) 23.6-24.6	<0.001[a]	NA	NA
Minimum weight: mean(SD) kg 95% CI	(n=31) ** 72.1 (14.76) 66.7-77.5	54.5 (6.18) 53.1-56	<0.001[a]	NA	NA
Minimum BMI: mean(SD) kg/m² 95% CI	(n=29) ** 27.7 (5.3) 25.7-29.7	21.2 (2.07) ♦ 20.7-21.7	<0.001[a]	NA	NA
Stable weight: mean(SD) kg 95% CI	(n=31) ** 74.7 (17.24) 68.4-81.1	56.6 (6.34) 55.1-58.1	<0.001[a]	NA	NA
Stable BMI: mean(SD) kg/m² 95% CI	(n=31) ** 27 (9.4) 23.6-30.5	21.9 (1.83) 21.5-22.3	<0.001[a]	NA	NA
BMI at max weight: (Column %)	(n=85)				
< 25 kg/m²	0	70	<0.001 [b]	*	*
> 25 kg/m²	100	30			
Time at max weight: (Column %)	(n=42)				
> 6 months	50	56	0.51[c]	–	–
< 6 months	50	44			
BMI at min weight: (Column %)	(n=76)				
< 25 kg/m²	39.5	100	<0.001 [b]	*	*
> 25 kg/m²	60.5	0			
Time at min weight: (Column %)	(n=90) [#]				
> 6 months	90	39	<0.001[c]	14.07 (0.027-0.172) p<0.001	0.1 (0.04-0.24) p<0.001
< 6 months	10	61			
BMI at stable weight: (Column %)	(n=45)				
< 25 kg/m²	28	93	<0.001 [b]	35.8 (10.56-135.17) p<0.001	43.7 (10.03-190.5) p<0.001
> 25 kg/m²	72	7			

[a] GLM adjusting for demographic variables (age, education, marital status) [b] Fisher's exact test [c] Chi-Square test

* odds ratios cannot be calculated as one or more frequencies equal zero

** sub-analysis: only includes data from cases who provided actual weights

NA Not applicable SD: standard deviation 95% CI: 95% confidence interval

[#] Cases (Zulu vs. Caucasian) differ significantly p<0.05 ♦ Controls (Zulu vs. Caucasian) differ significantly p<0.05

4.2.2 Perceived weight status through the lifecycle

Caucasian (cases vs. controls)

The perceived weight status through the lifecycle of Caucasian cases and controls is presented in Table 4.3a. Cases were significantly more likely to have perceived themselves as having been overweight as a child (OR: 8.24), as an adolescent (OR: 13.3), as a young adult (OR: 62.4) and to have perceived that their weight was higher than that of their peers as an adolescent (OR: 22.32).

Zulu (cases vs. controls)

The perceived weight status through the lifecycle of Zulu cases and controls is presented in Table 4.3b. Cases were significantly more likely to have perceived themselves as having been overweight as a child (OR: 20.1), as an adolescent (OR: 17.39), as a young adult (OR: 95.17) and to have weighed more than their peers (OR: 10.42). Two controls indicated that they had been overweight/obese both as children and as adolescents and 8 controls were overweight/obese at one lifecycle stage.

Differences between Caucasian and Zulu samples

No differences were found between Caucasian and Zulu *cases* or *controls* for perceived weight status through the lifecycle.

Table 4.3a: Association between perceived weight status through the lifecycle and overweight/obesity for Caucasian women

	Cases (n= 89)	Controls (n=102)	P value	Odds ratio (95% CI)	Adjusted Odds ratio (95% CI)
Perceived weight: Childhood 2-10 years (Column %)					
Normal weight	59.6	94.1	<0.001[a]	10.98 (4.17-33.54) p<0.001	8.24 (2.7-25.1) p<0.001
Overweight / obese	39.4	5.9			
Perceived weight : Adolescence11-19 years (Column %)					
Normal weight	47.2	94.1	<0.001[a]	8.1 (6.89-54.88) p<0.001	13.3 (4.76-37.42) p<0.001
Overweight / obese	52.8	5.9			
Perceived weight: Young adult 20-25 years (Column %)					
Normal weight	30.3	95.1	<0.001[a]	45 (15.7-153.51) p<0.001	62.4 (17.32-224.64) p<0.001
Overweight / obese	69.7	4.9			
Perceived adolescent weight (Column %)					
More than peers	66.7	10.3	<0.001[a]	17.6 (7.52-43.18) p<0.001	22.32 (7.76-64.14) p<0.001
Less /same as peers	33.3	89.7			

[a] Paired t test 95% CI: 95% confidence interval
Wide CIs do not indicate wide individual variability but result from the actual values used to calculate the ORs

Table 4.3b: Association between perceived weight status through the lifecycle and overweight/obesity for Zulu women

	Cases (n= 85)	Controls (n= 86)	P value	Odds ratio (95% CI)	Adjusted Odds ratio (95% CI)
Perceived weight: Childhood 2-10 years (Column %)					
Normal weight	66	97	<0.001 [a]	14.3 (4.08-75.94) p<0.001	20.1 (4.9-82.3) p<0.001
Overweight / obese	34	3			
Perceived weight: Adolescence 11-19 years (Column %)					
Normal weight	55	93	<0.001 [b]	10.96 (4.1-33.76) p<0.001	17.39 (5.59-54.1) p<0.001
Overweight / obese	45	7			
Perceived weight: Young adult 20-25 years (Column %)					
Normal weight	40	98	<0.001[a]	63.63 (14.9-555.25) p<0.001	95.17 (18.05-501.66) p<0.001
Overweight / obese	60	2			
Perceived adolescent weight (Column %)					
More than peers	57	12	<0.001[b]	10.22 (4.23-26.31) p<0.001	10.42 (3.91-27.81) p<0.001
Less /same as peers	43	88			

[a]Fisher's exact test [b]Chi-Square test 95% CI: 95% confidence interval

Wide CIs do not indicate wide individual variability but result from the actual values used to calculate the ORs

No significant differences between Zulu vs. Caucasian *cases* or Zulu vs. Caucasian *controls*.

4.3 Parental Weight History

Caucasian (cases vs. controls)

Caucasian subjects' perception of the weight status of their parents is depicted in Table 4.4a. It is evident that reporting to have had an overweight/obese mother during childhood increases the likelihood of being overweight (OR 3.2). No associations were found for subjects' perception of the current weight of their mother's and their father's past and current weight.

Zulu (cases vs. controls)

Zulu subjects' perception of the weight status of their parents is depicted in Table 4.4b. It is evident that reporting to have an overweight/obese mother during childhood increases one's likelihood of being overweight (OR 2.56). No associations were found for subjects' perception of the current weight of their mother's and their father's past and current weight.

Differences between Caucasian and Zulu samples

No differences were found for the *cases*' perception of past and current weight status of their mothers. However, significant differences were found for *cases*' perception of the past and current weight status of their fathers, with the fathers of Caucasian *cases* more likely to be overweight/obese than the fathers of their Zulu counterparts for both measures (father's past perceived weight: $p=0.001$; father's current perceived weight: $p<0.001$).

No differences were found for the *controls'* perception of past and current weight status of their mothers or past weight of their fathers. However, significant differences were found for the *controls*' perception of current weight status of their fathers, with Caucasian *controls* more likely to perceive their fathers as overweight/obese than their Zulu counterparts ($p=0.001$).

Table 4.4a: Association between perceived past and current weight status of parents and overweight/obesity for Caucasian women

	Cases	Controls	P-Value	Odds Ratio (95% CI)	Adjusted Odds ratio (95%CI)
Mother's weight status in childhood (column %)	**n= 89**	**n= 102**			
Normal weight	56.2	75.5	0.009[a]	2.4 (1.24-4.67) p=0.005	3.2 (1.42-7.21) p=0.003
Overweight / obese	43.8	24.5			
Father's weight status in childhood (column %)	**n= 86**	**n= 98**			
Normal weight	55.8	62.6	0.376[a]	–	–
Overweight / obese	44.2	37.4			
Mother's current weight status (column %)	**n= 83**	**n= 94**			
Normal weight	44.6	65.2	0.004[a]	2.34 (1.22-4.48) p=0.006	2.04 (0.98-4.24) p=0.056
Overweight / obese	55.4	34.8			
Father's current weight status (column %)	**n= 65**	**n= 87**			
Normal weight	46	48.9	0.729[a]	–	–
Overweight / obese	54	51.1			

[a]Chi-Square test 95% CI: 95% confidence interval

NOTE: variation in subject numbers (n) owing to presence / absence of living parents at the two time points.

Table 4.4b: Association between perceived past and current weight status of parents and overweight/obesity for Zulu women

	Cases	Controls	P-Value	Odds Ratio (95% CI)	Adjusted Odds ratio (95%CI)
Mother's weight status in childhood (column %)	**n= 81**	**n=80**			
Normal weight	42	64	0.006[a]	2.4 (1.23-4.82) p=0.006	2.56 (1.22-5.39) p=0.013
Overweight / obese	58	36			
Father's weight status in childhood (column %)	**n= 74**	**n= 73**			
Normal weight	80 *	78	0.81[a]	–	–
Overweight / obese	20	22			
Mother's current weight status (column %)	**n= 79**	**n= 77**			
Normal weight	53	57	0.62[a]	–	–
Overweight / obese	47	43			
Father's current weight status (column %)	**n= 74**	**n= 61**			
Normal weight	78 *	74 **	0.53[a]	–	–
Overweight / obese	22	26			

[a] Chi-Square test 95% CI: 95% confidence interval

NOTE: variation in subject numbers (n) owing to presence / absence of living parents at the two time points.

* Cases differ significantly: p≤0.001 ** Controls differ significantly: p<0.001

4.4 Weight Management Practices

Caucasian (cases vs. controls)

Weight management practices of Caucasian cases and controls are presented in Table 4.5a. It is evident that dieting is a very common practice, with a large percentage of both groups reporting to have dieted to reduce weight (98% of cases; 68% of controls). The prevalence of dieting differs significantly between cases and controls and a dieting history is associated with a significant likelihood of being overweight/obese (OR: 30.2, 95% CI: 5.3-172.13, p<0.001; data not included in the table). Similarly, weight regain within a year of having dieted is associated with an increased likelihood of being overweight / obese (OR 5.8). The most weight lost, number of diet strategies attempted and goal weights also differed significantly between the groups, with cases reporting higher values for all measures (all p<0.001). Controls were more likely to report that their most successful weight loss strategy was a healthy strategy that included a balanced diet and/or exercise. There was no difference between cases and controls for the age of first dieting attempt.

Zulu (cases vs. controls)

Weight management practices of both cases and controls are presented in Table 4.5b. It is evident that the prevalence of dieting differs significantly between cases (85% dieted) and controls (28% dieted) and that a dieting history is associated with a significant likelihood of being overweight/obese (OR: 12.02, 95% CI:5.27-27.4, p<0.001; data not included in the table). Weight regain within a year of having dieted and the most successful diet were not significantly different for cases and controls. However, 10% of the cases who reported to have attempted weight loss did not find any strategy successful.

The amount of weight lost, number of diet strategies attempted and weight loss goals differed significantly between the groups, with cases more likely to have lost more weight with a single dieting attempt, to have employed a wider variety of strategies and to have higher goal weights than the controls.

Differences between Caucasian and Zulu Samples

Significant differences were found between Caucasian and Zulu *cases* for the age of first diet, number of different diet strategies (both p<0.001) and most weight lost on a diet (p=0.004) with the Caucasians initiating dieting at a younger age, having tried a greater variety of weight loss strategies and reporting to have lost more weight with a single dieting attempt. Zulu *cases* were more likely to report that their most successful weight loss strategy was a healthy strategy although 10% of Zulu *cases* reported that they had not been

successful on any diet. Caucasian *cases* were also more likely to have a higher goal weight than Zulu *cases* ($p=0.029$).

No differences were found between Caucasian and Zulu *controls* for age of first diet and current goal weight. However, Caucasian *controls* were significantly more likely than Zulu *controls* to have previously attempted weight reduction ($p<0.001$), to have lost more weight on a diet ($p=0.03$) and to have attempted more weight reduction strategies ($p=0.006$).

Table 4.5a: Association between weight management practices and overweight/obesity for Caucasian women

Subjects who answered Yes to dieting	Cases (n= 87)	Controls (n= 69)		Odds Ratio (95% CI)	Adjusted Odds ratio (95% CI)
Weight regain (column %)					
Kept weight off for >1yr	21.8	50.8	<0.001[a]	3.47 (1.61-7.51) p<0.001	5.8 (2.1-15.76) p<0.001
Regained weight within 1yr	78.2	49.2			
Most successful diet (column %)					
Balanced diet / increased physical activity	41	69	<0.001[a]	3.23 (1.53-6.89) p<0.001	2.8 (1.1-7.11) p=0.003
Other method	59	31			
None successful	0	0			
Age of first diet: median (IQR) yrs	17 (15-24)	20 (16-22)	0.32[b]	NA	NA
Most weight lost: median (IQR) kg	12 (8-20)	5 (3-8)	<0.001[b]	NA	NA
No. of different diet strategies: median (IQR)	6 (4-10)	3 (2-6)	<0.033[b]	NA	NA
Current goal weight: median (IQR) kg	70 (65-80)	57 (54-60)	<0.001[b]	NA	NA

[a] Chi-Square tests [b] GLM controlled for demographic variables (age, education, marital status)
NA Not applicable yr: year IQR: Inter-quartile range 95% CI: 95% confidence interval

Table 4.5b: Association between weight management practices and overweight/obesity for Zulu women

Subjects who answered Yes to dieting	Cases (n= 78)	Controls (n= 24)		Odds Ratio (95% CI)	Adjusted Odds ratio (95% CI)
Weight regain (column %)					
Kept weight off for >1yr	29	50	0.072[a]	–	–
Regained weight within 1yr	71	50			
Most successful diet (column %)	(n 67)	(n21)			
Balanced diet / increased physical activity	60	52			
Other method	30	48	0.15 [a]	–	–
None successful	10	0			
Age of first diet: median (IQR) yrs	(n=71) 25 (20-30) *	(n=22) 22 (18-25)	0.75 [b]	NA	NA
Most weight lost: median (IQR) kg	(n=62) 7 (4-12) **	(n=18) 3 (1-5) #	<0.018 [b]	NA	NA
No. of different diet strategies: median (IQR)	(n=77) 3 (2-5) *	(n=24) 2 (1-3) #	<0.001 [b]	NA	NA
Current goal weight: median (IQR) kg	(n=83) 65 (60-75) **	(n=62) 58 (54-62)	<0.001 [b]	NA	NA

[a] Chi-Square tests [b] GLM controlled for demographic variables (age, education, marital status)
NA Not applicable yr: year IQR: Inter-quartile range 95% CI: 95% confidence interval
* Cases differ significantly: p<0.001 # Controls differ significantly: p <0.05
** Cases differ significantly: p<0.05

4.5 Weight Management Strategies

Caucasian (cases vs. controls)

Actual weight management strategies used by Caucasian cases and controls are illustrated in Figure 4.1a. Most strategies were reportedly used by both groups, with the most common strategy for cases being the use of a well balanced energy restricted diet followed by eating nothing between meals. For the controls, exercise was the most common practice, with a well balanced diet being the second most common strategy for this group. Controls were also more likely to report that their most successful weight loss strategy was a healthy strategy.

Enrolment in commercial weight loss programmes that offer energy restricted diets and group support such as Weigh-Less ($p<0.001$) and Weight Watchers ($p=0.035$) , was more common for overweight/obese individuals.

The cases also employed significantly more unhealthy weight reduction methods such as the use of a low carbohydrate diet and liquid diet formulas (both $p<0.001$). Extreme methods were also used more often by the cases and included "quick fix" diets that promise almost instant weight loss ($p=0.012$), herbal mixtures ($p=0.008$), passive exercise machines that are supposed to break down fat, appetite suppressants and injections (all $p<0.001$). None of the women included in this study had undergone surgery for weight loss.

Zulu (cases vs. controls)

Actual weight management strategies used by Zulu cases and controls are illustrated in Figure 4.1b. Most strategies were reported by both groups although no controls used diuretics, vomiting, low carbohydrate diets or passive exercise machines for weight loss. The most common strategy for the cases was the use of exercise, with skipping meals and the use of a balanced weight loss diet the next two most popular methods. For the controls, skipping meals was the most common practice with exercise being the second most common strategy for this group.

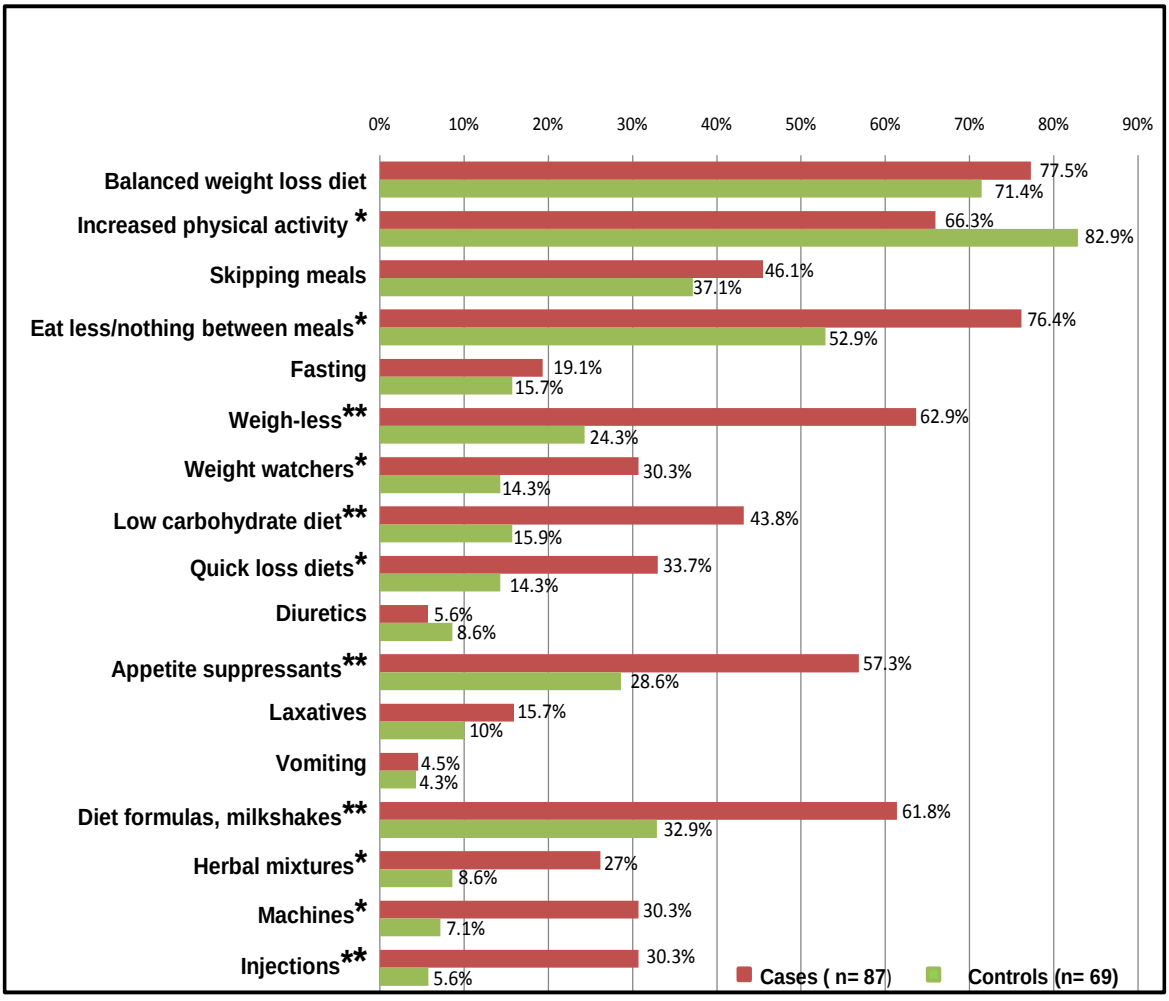
Significantly more cases made use of a low carbohydrate diet ($p=0.019$). Extreme methods were also used more often by the cases and included appetite suppressants ($p=0.006$) and passive exercise machines that are supposed to break down fat ($p=0.05$). None of the women included in this study had undergone surgery for weight loss.

Differences between Caucasian and Zulu samples

Significant differences were found between Caucasian and Zulu *cases* for actual dieting strategies with Caucasian *cases* more likely to use a balanced weight loss diet, to increase

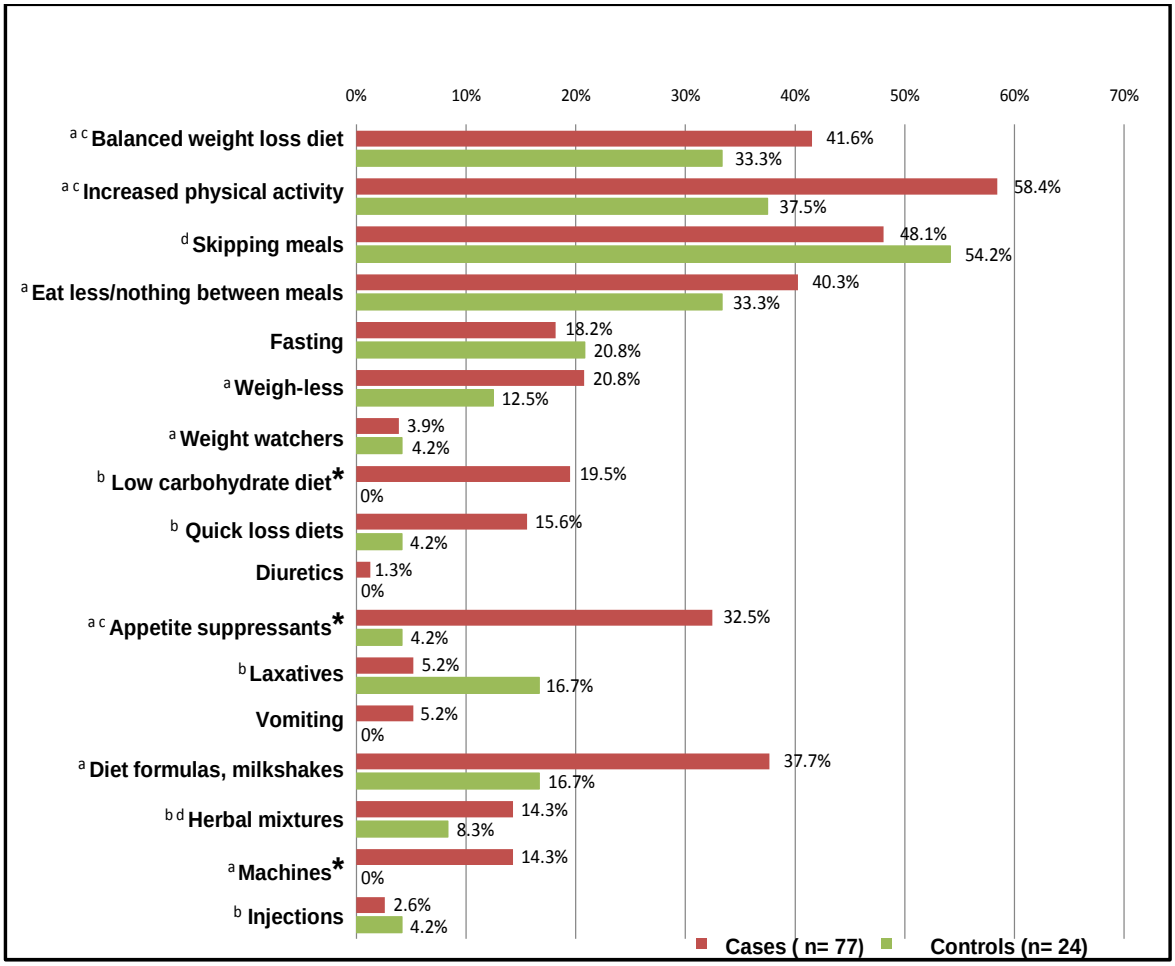
physical activity, to eat less or nothing between meals, to enrol in commercial weight loss programmes such as Weigh-Less and Weight Watchers, to use appetite suppressants, diet formulas/milkshakes and machines that are supposed to break down fat (all p<0.001). Caucasian *cases* were also more likely than Zulu *cases* to use low carbohydrate and quick-loss diets as well as herbal mixtures and injections for weight loss (all p<0.05). Zulu *cases* were more likely than Caucasian *cases* to use laxatives for weight loss (p=0.028).

Caucasian *controls* were significantly more likely to use a balanced diet, exercise, appetite suppressants (all p<0.001) and diet formulas/milkshakes (p=0.027) for weight loss than Zulu *controls*. Zulu *controls* were more likely than Caucasian *controls* to skip meals in order to lose weight (p=0.016).



Chi squared tests: *p<0.05 **p<0.001

Figure 4.1a: Prevalence of use of various weight management methods for Caucasian cases and controls.



Chi squared tests: *p<0.05
[a] Cases differ significantly: p<0.001
[b] Controls differ significantly: p<0.05
[c] Controls differ significantly: p<0.001
[d] Controls differ significantly: p<0.005

Figure 4.1b: Prevalence of use of various weight management methods for Zulu cases and controls.

4.6 Body Dissatisfaction

4.6.1 Current weight perception and satisfaction

Caucasian (cases vs. controls)

Table 4.6a illustrates current weight perceptions and satisfaction for Caucasian cases and controls. The cases were more likely to perceive themselves as being overweight/obese and the controls as being normal weight/underweight. However, 13.7% of the controls perceived themselves as being overweight. Dissatisfaction with body weight and fear of weight gain is evident in both groups, although the cases showed significantly more dissatisfaction (OR: 74.88) and fear of weight gain (OR: 9.89). Weigh loss goals were also significantly higher for the cases with the majority wanting to lose more than 5kg compared with the majority of controls wanting to lose less than 5kg (OR not calculated owing to very high values expected

based on the selection criteria for the case-control study). No differences were found for frequency of weighing.

Zulu (cases vs. controls)

Table 4.6b illustrates current weight perceptions and satisfaction of Zulu cases and controls. The cases were more likely to perceive themselves as being overweight/obese and the controls as being normal weight/underweight. There was no difference between cases and controls for having an accurate perception of body weight, with 8% of cases perceiving themselves to be normal weight and 10% of controls perceiving themselves as being overweight. Dissatisfaction with body weight and fear of weight gain is evident in both groups, although the cases showed significantly more dissatisfaction (OR: 27.45) and fear of weight gain (OR: 19.82). However, 37% of the controls reported that they were not totally satisfied with their weight and 77% were afraid of gaining weight. Weigh loss goals were significantly lower for the controls with the majority of those women wanting to lose weight reporting that they wanted to lose less than 5kg compared to the majority of the cases wanting to lose more than this amount. Almost a quarter of the controls and one of the cases indicated that they wanted to gain weight.

Differences between Caucasian and Zulu samples

No differences were found between Caucasian and Zulu *cases* for accuracy of weight perception, frequency of weighing, fear of weight gain, weight satisfaction and whether they wanted to gain or lose weight. Differences were found for weight loss goals, with Caucasian *cases* more likely to want to lose more than 5kg than Zulu *cases* ($p=0.029$). This data was not controlled for demographic variables that differed between the groups.

Uncontrolled data for Caucasian and Zulu *controls* reported similarly accurate perceptions of weight status and no differences were found for fear of weight gain and for wanting to lose less than or more than 5kg. However, Caucasian *controls* were significantly more dissatisfied with their current weight ($p=0.003$) and Zulu *controls* were more likely to want to gain weight ($p<0.001$).

Table 4.6a: Association between current weight perception and satisfaction and overweight/obesity for Caucasian women

	Cases (n= 89)	Controls (n=102)	P-Value	Odds Ratio (95% CI)	Adjusted Odds ratio (95% CI)
Weight perception (column %)					
Perceived overweight/obesity	97.7	13.7	0.004[a]	#	#
Perceived normal/underweight	2.3	86.3			
Afraid of weight gain (column %) *	97.8	83.3	0.001[a]	8.60 (1.93-78.29) p=0.001	9.89 (1.83-53.53) p=0.008
Satisfaction with weight (column %) *	1.1	37.3	<0.001[a]	51.45 (8.12-2107.49) p<0.001	74.88 (8.57-654.20) p<0.001
Frequency of weighing (column %)					
Daily	10.1	8.8	0.130[b]	NA	NA
Weekly	49.4	36.3			
Rarely	40.5	54.9			
Gain vs. lose weight (%)		**n= 64**			
Gain	0	0	1.0 [a]	NA	NA
Lose	100	100			
Weight loss goal (column %)		**n=102**			
To lose <5kg	1.1	97.1	<0.001[a]	#	#
To lose >5kg	98.9	2.9			

[a]Fisher's exact tests [b]Chi-Square tests * % Yes, balance represents No

ORs not calculated owing to very high values expected based on selection criteria for the case-control study

NA Not applicable kg: kilograms

Table 4.6b: Association between current weight perception and satisfaction and overweight/obesity for Zulu women

	Cases (n= 90)	Controls (n= 86)	P-Value	Odds Ratio (95% CI)	Adjusted Odds ratio (95% CI)
Weight perception (column %)					
Perceived overweight/obesity	92	10	<0.001 [a]	**	**
Perceived normal/underweight	8	90			
Afraid of weight gain (column %) *	98	77	<0.001 [b]	10.17 (2.23-93.11) p<0.001	19.82 (3.40-115.5) p=0.001
Satisfaction with weight (column %) *	3	62.7 ϡ	<0.001 [b]	31.83 (9.19-166.04) p<0.001	27.45 (7.42-101.54) p<0.001
Frequency of weighing (column %)					
Daily	8 [$]	13	0.079 [a]	NA	NA
Weekly	30	42			
Rarely	62	45			
Gain vs. lose weight (%)		(n= 72)			
Gain	1	28 [#]	<0.001 [b]	33.65 (4.6-1445.31) p<0.001	22.76 (2.55-203.31) p=0.005
Lose	99	72			
Weight loss goal (column %)	(n= 89)	(n= 59)			
To lose <5kg	11 ♦	92	<0.001 [a]	**	**
To lose >5kg	89	8			

[a] Chi-Square tests [b] Fisher's exact tests * % Yes, balance represents No

** ORs not calculated owing to very high values expected based on selection criteria for the case-control study

NA Not applicable kg: kilograms

[$] Cases differ significantly: p<0.001 [#] Controls differ significantly: p<0.001

♦ Cases differ significantly: p<0.05 ϡ Controls differ significantly: p<0.05

4.6.2 Body part satisfaction

Caucasian (cases vs. controls)

Body part satisfaction of Caucasian cases and controls is presented in Table 4.7a. Dissatisfaction with all body parts is evident in both groups although the cases showed significantly *more dissatisfaction for all measures.* The greatest levels of dissatisfaction were found for the stomach for cases and thighs for the controls, although about twice as many cases reported dissatisfaction than controls for all body parts, resulting in significant odds ratios (see Table 4.7a). The lowest levels of dissatisfaction were found for arms and calves.

Zulu (cases vs. controls)

Body part satisfaction of Zulu cases and controls is presented in Table 4.7b. Dissatisfaction with individual body parts is evident in both groups although the cases showed significantly *more dissatisfaction for all measures.* The greatest levels of dissatisfaction were found for

the stomach for both groups, although about twice as many cases reported dissatisfaction, resulting in significant odds ratios. Dissatisfaction levels for their thighs were almost as high as levels reported for their stomachs. For the controls, apart from dissatisfaction with the stomach (48%), far lower levels of dissatisfaction were reported for all other body parts. The lowest levels of dissatisfaction were found for calves for both groups.

Differences between Caucasian and Zulu samples

Significant differences were found between Caucasian and Zulu *cases* for all body parts except for arms, with Caucasians more likely than Zulus to be dissatisfied with their stomach ($p=0.001$), middle ($p<0.001$), hips ($p<0.001$), buttocks ($p<0.001$), thighs ($p=0.002$) and calves ($p<0.001$).

Caucasian *controls* were also more likely than Zulu *controls* to be dissatisfied with their middles ($p<0.001$) and thighs ($p<0.001$).

Table 4.7a: Association between body part dissatisfaction and overweight/obesity for Caucasian women

Dissatisfaction*	Cases (n= 89)	Controls (n=102)	P -Value	Odds Ratio (95% CI)	Adjusted Odds ratio (95% CI)
Arm (%)	69.7	25.5	<0.001[a]	6.8 (3.45-13.50) p<0.001	8.17 (3.52-18.96) p<0.001
Stomach (%)	97.8	44.1	<0.001[c]	53.9 (12.97-466.92) p<0.001	57.93 (11.89-282.26) p<0.001
Middle (%)	87.6	34.3	<0.001[a]	13.20 (5.95-30.66) p<0.001	13.49 (5.4-33.70) p<0.001
Hips (%)	84.3	36.3	<0.001[a]	9.16 (4.36-19.81) p<0.001	7.86 (3.40-18.19) p<0.001
Buttocks (%)	85.4	46.1	<0.001[a]	6.97 (3.30-15.28) p<0.001	8.76 (3.53-21.75) p<0.001
Thighs (%)	91	49	<0.001[a]	10.32 (4.35-26.93) p<0.001	12.55 (4.65-33.88) p<0.001
Calves (%)	61.8	18.8	<0.001[a]	7.07 (3.50-14.44) p<0.001	6.44 (2.84-14.63) p<0.001

[a]Chi-Square tests [c] Fisher's exact tests * % Dissatisfied, balance represents Satisfied
95% CI: 95% confidence interval

Table 4.7a: Association between body part dissatisfaction and overweight/obesity for Zulu women

Dissatisfaction*	Cases (n= 92)	Controls (n= 84)	P -Value[a]	Odds Ratio (95% CI)	Adjusted Odds ratio (95% CI)
Arm (%)	63	15	<0.001	9.16 (4.20-20.54) p<0.001	11.48 (4.74-27.78) p<0.001
Stomach (%)	82 **	48	<0.001	4.85 (2.35-10.20) p<0.001	5.05 (2.26-11.30) p<0.001
Middle (%)	41 **	13 #	<0.001	4.67 (2.09-11.00) p<0.001	9.49 (3.59-25.10) p<0.001
Hips (%)	52 **	27	<0.001	2.89 (1.47-5.73) p<0.001	3.12 (1.49-6.54) p=0.003
Buttocks (%)	53 **	26	<0.001	3.21 (1.63-6.40) p<0.001	2.84 (1.37-5.90) p<0.001
Thighs (%)	73 ♦	18 #	<0.001	12.33 (5.67-27.27) p<0.001	11.63 (5.04-26.85) p<0.001
Calves (%)	24 **	8	<0.001	3.51 (1.33-10.27) p=0.005	4.09 (1.45-11.55) p=0.008

[a] Chi-Square tests * % Dissatisfied, balance represents Satisfied

** Cases differ significantly: p<0.001 # Controls differ significantly: p<0.001

♦ Cases differ significantly: p<0.05 95% CI: 95% confidence interval

4.7 Eating Behaviour: (Cognitive Restraint, Disinhibition and Perceived Hunger)

Caucasian (cases vs. controls)

Table 4.8a presents mean (±SD) values for cognitive restraint, disinhibition and perceived hunger and their subscales. No differences were found between cases and controls for cognitive restraint and the subscales of the restraint scale, except for attitude to self-regulation (TFEQ-R2). Mean values for disinhibition and perceived hunger and all their subscales were significantly different, with higher values for cases for all measures.

Zulu (cases vs. controls)

Table 4.8b presents mean (±SD) values for cognitive restraint, disinhibition and perceived hunger and their subscales. Differences were found between cases and controls for cognitive restraint and flexible restraint, with means (±SD) for these measures being higher for cases than controls. Significant differences were also found for disinhibition, including habitual, emotional and situational susceptibility to disinhibition and for perceived hunger, including internal and external locus for hunger with all means (±SD) being higher for cases for all measures.

Differences between Caucasian and Zulu samples

No significant differences were found between Caucasian and Zulu *cases* or *controls* for means (±SD) of total scores for cognitive restraint, disinhibition and perceived hunger and their subscale scores.

Table 4.8a: Eating behaviour characteristics of cases and controls (means of total scores): Caucasian

	Cases (n= 89)			Controls (n= 67)*			P-Value [a]
	Mean	SD	95% CI	Mean	SD	95% CI	
TFEQ-R Cognitive Restraint (0-21)	7.77	3.60	3.12-4.25	7.76	4.74	4.05-5.71	0.99
TFEQ-FCR7 Flexible Restraint (0-7)	2.34	1.69	1.46-1.99	2.61	1.83	1.57-2.21	0.35
TFEQ-RC7 Rigid Restraint (0-7)	2.5	1.59	1.38-1.88	2.49	1.66	1.42-2.01	0.98
TFEQ-R1 Strategic Dieting Behaviour (0-4)	0.91	1.11	0.97-1.32	1.00	1.26	1.07-1.51	0.66
TFEQ-R2 Attitude to self-regulation (0-5)	2.18	1.21	1.05-1.43	1.76	1.30	1.11-1.57	0.04
TFEQ-R3 Avoidance of fattening foods (0-4)	2.01	1.46	1.27-1.73	2.31	1.31	1.12-1.57	0.19
TFEQ-D Dietary disinhibition (0-16)	11.27	3.49	3.02-4.12	5.33	2.96	2.53-3.56	<0.001
TFEQ-D1 Habitual susceptibility (0-5)	2.93	1.54	1.33-1.82	0.61	0.98	0.84-1.19	<0.001
TFEQ-D2 Emotional susceptibility (0-3)	2.38	1.04	0.90-1.23	1.01	1.17	1.00-1.42	<0.001
TFEQ-D3 Situational susceptibility (0-5)	3.72	1.28	1.11-1.51	2.31	1.61	1.38-1.94	<0.001
TFEQ-H Perceived Hunger (0-14)	7.59	3.60	3.12-4.25	5.40	3.04	2.60-3.66	<0.001
TFEQ-H1 Internal locus for hunger (0-6)	3.05	1.87	1.62-2.20	2.34	1.61	1.38-1.94	0.015
TFEQ-H2 External locus for hunger (0-6)	3.44	1.74	1.51-2.05	2.07	1.49	1.27-1.80	<0.001

[a] GLM adjusting for demographic variables (age, language, education) SD: standard deviation 95% CI: 95% confidence interval

* lower n owing to some TFEQ data only captured as total scores for restraint and disinhibition

Table 4.8b: Eating behaviour characteristics of cases and controls (means of total scores): Zulu

	Cases (n= 91)			Controls (n= 85)			P-Value [a]
	Mean	SD	95% CI	Mean	SD	95% CI	
TFEQ-R Cognitive Restraint (0-21)	9.19	4.28	3.73-5.01	7.45	4.49	3.90-5.29	0.009
TFEQ-FCR7 Flexible Restraint (0-7)	3.25	1.81	1.58-2.12	2.32	1.66	1.44-1.95	<0.001
TFEQ-RC7 Rigid Restraint (0-7)	2.44	1.78	1.55-2.08	1.98	1.72	1.49-2.02	0.08
TFEQ-R1 Strategic Dieting Behaviour (0-4)	1.49	1.26	1.10-1.47	1.18	1.14	0.99-1.34	0.08
TFEQ-R2 Attitude to self-regulation (0-5)	2.46	0.99	0.87-1.16	2.21	1.16	1.0-1.36	0.13
TFEQ-R3 Avoidance of fattening foods (0-4)	1.60	1.33	1.16-1.56	1.25	1.31	1.14-1.54	0.075
TFEQ-D Dietary disinhibition (0-16)	9.13	3.54	3.09-4.14	5.65	2.66	2.31-3.13	<0.001
TFEQ-D1 Habitual susceptibility (0-5)	2.43	1.55	1.35-1.82	1.18	1.26	1.10-1.49	<0.001
TFEQ-D2 Emotional susceptibility (0-3)	1.97	1.22	1.06-1.42	1.11	1.19	1.03-1.40	<0.001
TFEQ-D3 Situational susceptibility (0-5)	2.95	1.35	1.18-1.58	1.91	1.14	0.99-1.34	<0.001
TFEQ-H Perceived Hunger (0-14)	7.2	3.6	3.14-4.22	2.14	1.51	1.31-1.77	<0.001
TFEQ-H1 Internal locus for hunger (0-6)	2.91	1.88	1.64-2.20	1.81	1.60	1.39-1.88	<0.001
TFEQ-H2 External locus for hunger (0-6)	3.15	1.73	1.51-2.02	2.14	1.51	1.31-1.77	<0.001

[a] GLM adjusting for demographic variables (age, marital status, education) SD: standard deviation 95% CI: 95% confidence interval

No significant differences between Zulu vs. Caucasian *cases* or Zulu vs. Caucasian *controls*.

4.8 Eating behaviour characteristics (dichotomised data)

Caucasian (cases vs. controls)

Table 4.9a presents dichotomised data for the TFEQ scales and subscales for Caucasian cases and controls. No significant odds ratios were found for the restraint scale and subscales of this scale, including attitude to self-regulation (TFEQ-R2). Significant odds ratios were found for disinhibition and hunger and the sub-scales thereof (TFEQ-D1) (OR: see table 4.9a).

Zulu (cases vs. controls)

Table 4.9b presents dichotomised data for the TFEQ scales and subscales for Zulu cases and controls. Subjects who had higher scores for flexible control and for the disinhibition and perceived hunger scales and their sub-scales were significantly more likely to be overweight/obese (OR: see table 4.9b).

Differences between Caucasian and Zulu samples

No significant differences were found between Caucasian and Zulu *cases* or *controls* for cognitive restraint, disinhibition and perceived hunger and their subscale scores.

Table 4.9a: Association between eating behaviour characteristics and overweight/obesity for Caucasian women (dichotomised data)

	Cases column % (n= 89)	Controls column % (n= 67)*	P-Value	Odds Ratio (95% CI)	Adjusted Odds ratio (95% CI)
TFEQ-R Cognitive Restraint (0-21)					
Restrained (≥10)	35.4	40.4	0.487[a]	_	_
Unrestrained (<10)	64.6	59.6			
TFEQ-FCR7 Flexible Restraint (0-7)					
Restrained (4-7)	18	30	0.1[a]	_	_
Unrestrained (0-3)	82	70			
TFEQ-RC7 Rigid Restraint (0-7)					
Restrained (4-7)	28	27	0.87[a]	_	_
Unrestrained (0-3)	62	73			
TFEQ-R1 Strategic Dieting Behaviour (0-4)					
Restrained (3-4)	11	16	0.33[a]	_	_
Unrestrained (0-2)	89	84			
TFEQ-R2 Attitude to self-regulation (0-5)					
Restrained (3-5)	41	30	0.14[a]	_	_
Unrestrained (0-2)	59	70			
TFEQ-R3 Avoidance of fattening foods (0-4)					
Restrained (3-4)	38	46	0.3[a]	_	_
Unrestrained (0-2)	62	54			
TFEQ-D Dietary disinhibition (0-16)					
Disinhibited (≥8)	81.7	20.2	<0.001[a]	17.64 (7.9-39.97) p<0.001	19.85 (7.14-50.4) p<0.001
Not disinhibited (<8)	18.3	79.8			
TFEQ-D1 Habitual susceptibility (0-5)					
Disinhibited (3-5)	61	4	<0.001[b]	33.33 (9.40-175.35) p<0.001	43.64 (9.23-206.21) p<0.001
Not disinhibited (0-2)	39	96			
TFEQ-D2 Emotional susceptibility (0-3)					
Disinhibited (2-3)	83	36	<0.001[a]	8.70 (3.82-20.15) p<0.001	14.46 (4.72-44.28) p<0.001
Not disinhibited (0-1)	17	64			
TFEQ-D3 Situational susceptibility (0-5)					
Disinhibited (3-5)	83	43	<0.001[a]	6.36 92.83-14.57 p<0.001	8.32 (2.94-23.59) p<0.001
Not disinhibited (0-2)	17	57			
TFEQ-H Perceived Hunger (0-14)					
Hungry (7-14)	62	34	<0.001[a]	3.15 (1.52-6.54) p<0.001	3.16 (1.26-7.93) p=0.014
Not hungry (0-6)	38	66			
TFEQ-H1 Internal locus for hunger (0-6)					
Hungry (4-6)	41	25	0.04[a]	2.08 (0.98-4.51) p=0.04	1.77 (0.68-4.60) p=0.24
Not hungry (0-3)	59	75			
TFEQ-H2 External locus for hunger (0-6)					
Hungry (4-6)	63	31	<0.001[a]	3.80 (1.82-7.99) p<0.001	2.89 (1.19-7.01) p=0.19
Not hungry (0-3)	37	69			

[a] Chi-Square tests [c] Fisher's exact test

* lower n owing to some TFEQ data only captured as total scores for restraint and disinhibition

Table 4.9b: Association between eating behaviour characteristics and obesity for Zulu women (dichotomised data)

	Cases (n= 91) %	Controls (n= 85) %	P-Value[a]	Odds Ratio (95% CI)	Adjusted Odds ratio (95% CI)
TFEQ-R Cognitive Restraint (0-21)					
Restrained (≥10)	44	31	0.09	_	_
Unrestrained (<10)	56	69			
TFEQ-FCR7 Flexible Restraint (0-7)					
Restrained (4-7)	40	21	0.008	2.36 (1.15-4.90) p=0.011	2.47 (1.13-5.41) p=0.024
Unrestrained (0-3)	60	79			
TFEQ-RC7 Rigid Restraint (0-7)					
Restrained (4-7)	26	21	0.42	_	_
Unrestrained (0-3)	74	79			
TFEQ-R1 Strategic Dieting Behaviour (0-4)					
Restrained (3-4)	23	14	0.12	_	_
Unrestrained (0-2)	77	86			
TFEQ-R2 Attitude to self-regulation (0-5)					
Restrained (3-5)	42	42	0.94	_	_
Unrestrained (0-2)	58	58			
TFEQ-R3 Avoidance of fattening foods (0-4)					
Restrained (3-4)	30	21	0.94	_	_
Unrestrained (0-2)	70	79			
TFEQ-D Dietary disinhibition (0-16)					
Disinhibited (≥8)	67	27	<0.001	5.57 (2.8-11.2) p<0.001	5.5 (2.57-11.78) p<0.001
Not disinhibited (<8)	33	3			
TFEQ-D1 Habitual susceptibility (0-5)					
Disinhibited (3-5)	46	15	<0.001	4.59 (2.13-10.24) p<0.001	5.33 (2.27-12.51) p<0.001
Not disinhibited (0-2)	54	85			
TFEQ-D2 Emotional susceptibility (0-3)					
Disinhibited (2-3)	67	35	<0.001	3.54 (1.82-6.92) p<0.001	4.17 (1.97-8.80) p<0.001
Not disinhibited (0-1)	33	65			
TFEQ-D3 Situational susceptibility (0-5)					
Disinhibited (3-5)	66	29	<0.001	4.43 (2.24-8.79) p<0.001	4.40 (2.10-9.21) p<0.001
Not disinhibited (0-2)	34	71			
TFEQ-H Perceived Hunger (0-14)					
Hungry (7-14)	51	31	0.007	2.23 (0.29-1.19) p=0.01	2.14 (1.04-4.41) p=0.04
Not hungry (0-6)	49	69			
TFEQ-H1 Internal locus for hunger (0-6)					
Hungry (4-6)	40	15	<0.001	3.51 (1.62-7.85) p<0.001	3.57 (1.55-8.26) p=0.003
Not hungry (0-3)	60	85			
TFEQ-H2 External locus for hunger (0-6)					
Hungry (4-6)	47	18	<0.001	4.04 (1.93-8.68) p<0.001	4.56 (2.03-10.22) p<0.001
Not hungry (0-3)	53	82			

[a] Chi-Square tests
No significant differences between Zulu vs. Caucasian *cases* or Zulu vs. Caucasian *controls*.

4.9 Taste Sensitivity

4.9.1 PROP phenotype distribution

Caucasian (cases vs. controls)

Table 4.10a presents the PROP phenotype of Caucasian cases and controls. There was no significant difference between the groups for taster status, although there were more non-tasters amongst the cases than the controls.

Zulu (cases vs. controls)

Table 4.10b presents the PROP phenotype of Zulu cases and controls. Significant differences were found between the groups for taster status with more non-tasters amongst the cases than the controls.

Differences between Caucasian and Zulu samples

No significant differences were found between Caucasian and Zulu *cases* or *controls* for PROP phenotype distribution.

Table 4.10a: PROP phenotype distribution of Caucasian cases and controls

	Cases (%) (n= 89)	Controls (%) (n= 99)	P-Value
Non-Tasters	24.4	15.2	**0.257**[a]
Medium Tasters	35.6	42.4	
Super-Tasters	40	42.4	

[a]Chi-Square test

Table 4.10b: PROP phenotype distribution of Zulu cases and controls

	Cases (%) (n= 94)	Controls (%) (n= 80)	P-Value
Non-Tasters	21	5	<0.001 [a]
Medium Tasters	45	36	
Super-Tasters	34	59	

[a] Fisher's exact test

No significant differences between Zulu vs. Caucasian *cases* or Zulu vs. Caucasian *controls*.

4.9.2 Association between PROP phenotype and overweight/obesity

Caucasian (cases vs. controls)

When comparing Caucasian PROP super tasters with PROP medium- and non-tasters, no significant association could be found between PROP phenotype and overweight/obesity

(Table 4.11a) even when controlled for age, language, education and eating behaviours (cognitive restraint and disinhibition). Comparison of only the PROP supertasters and PROP non-tasters, while excluding the PROP medium tasters showed the same non-significant association (data not included in a table).

Zulu (cases vs. controls)

When comparing Zulu PROP super tasters with PROP medium- and non-tasters, a significant association was found between PROP phenotype and overweight/obesity (Table 4.11b) after controlling for age, marital status and education (OR: 2.13). However, this association was no longer significant after further adjusting for eating behaviours. Comparison of only the PROP supertasters and PROP non-tasters, while excluding the PROP medium tasters showed the same non-significant association (data not included in a table).

Differences between Caucasian and Zulu samples

No significant differences were found between Caucasian and Zulu *cases* or *controls* for PROP phenotype after adjusting for age, education, marital status and eating behaviours.

Table 4.11a: Association between PROP taster status and overweight/obesity for Caucasian women

	Cases (n= 89)	Controls (n= 99)	P-Value	Odds Ratio (95% CI)	Adjusted Odds ratio* (95% CI)	Adjusted Odds ratio** (95% CI)
PROP Phenotype (%)						
Super-Tasters	40	42.4	0.108[a]	-	-	-
Non-Tasters	60	57.6				

[a] Chi-Square test
* odds ratios adjusted for demographic variables (age, language, education)
****** odds ratios adjusted for demographic variables, cognitive restraint & disinhibition

Table 4.11b: Association between PROP taster status and overweight/obesity for Zulu women

	Cases (n= 94)	Controls (n= 80)	P-Value	Odds Ratio (95% CI)	Adjusted Odds ratio* (95% CI)	Adjusted Odds ratio** (95% CI)
PROP Phenotype (%)						
Tasters	34	59	0.001 [a]	2.76 (1.4-5.36) p=0.001	2.13 (1.05-4.35) P=0.037	2.16 (0.97-4.8) p=0.06
Non-Tasters	66	41				

[a] Chi-Square test
* odds ratios adjusted for demographic variables (age, education, marital status)
****** odds ratios adjusted for demographic variables and eating behaviours, cognitive restraint & disinhibition

No significant differences between Zulu vs. Caucasian *cases* or Zulu vs. Caucasian *controls*.

CHAPTER 5
DISCUSSION AND CONCLUSIONS

The primary aim of this study was to investigate risk factors for obesity development in South African Caucasian and Zulu women focussing on personal and parental weight history, weight management practices, eating behaviour and taste sensitivity. A case-control design was used for these purposes, comparing Caucasian cases with Caucasian controls as well as Zulu cases with Zulu controls for the mentioned variables. The secondary aim was to compare Caucasian cases with Zulu cases and Caucasian controls with Zulu controls in order to investigate some of the fundamental differences that may exist between Caucasian and Zulu women for the mentioned variables. An integrated discussion of these results relating to both the primary and secondary aims is presented for each of the main concepts investigated, followed by a summary of core conclusions and other evident trends.

5.1 Personal weight history

An in-depth analysis of the literature indicated that two trends regarding the association between personal weight history and obesity development could be expected. Firstly, a positive relationship can be expected between childhood (>1 year), adolescent and adult BMI (Power et al. 1997; Laitinen et al. 2001; Guo et al. 2002; Laitinen et al. 2004; Engeland et al. 2004; Juonala et al. 2005; Freedman et al. 2005[b]; Singh et al. 2008). Secondly, the literature points to the fact that the majority of overweight/obese adults are not likely to have been overweight/obese in childhood or adolescence (Power et al. 1997; Laitinen et al. 2001; Guo et al. 2002; Freedman et al. 2005[a]; Freedman et al. 2005[b]; Juonala et al. 2005; Deshmukh-Taskar et al. 2006) and that weight gain during early adulthood is a risk for the development of overweight/obesity (Power et al. 1997; Deshmukh-Taskar et al. 2006). Thus, weight tracking from childhood through adolescence into adulthood as well as weight gain during early adulthood could be present in a sample of overweight/obese subjects.

In this study, perception of weight at different lifecycle stages was used as a proxy for actual weight at each time point. Perception of weight at particular life stages has been found to be a sufficiently accurate measure of weight history in Caucasian women (Casey et al. 1991; Munoz et al. 1996, Koprowski et al. 2001, Must et al. 2002) although this has not been established in Zulu women, with the possibility existing that these women may underestimate their weight (Senekal et al. 2001; Mchiza et al. 2005). Nevertheless, the results of this study clearly indicate that perceiving oneself as having been overweight during childhood increases the likelihood of being overweight/obese in adulthood for both Caucasian (OR: 8.2) and Zulu (OR: 20.1) subjects. The same is true for perceiving oneself as having been overweight/obese during adolescence (Caucasian OR: 13.3; Zulu OR: 17.4). Thus perceived weight in adolescence seems to carry a greater risk for overweight/obesity in adulthood for Caucasians and perceived weight in childhood a greater risk for Zulus. If it is

assumed that perceived weight reflects actual weight at these lifecycle stages, these results indicate that weight tracking is present in both ethnic groups.

While there is very little information available for weight tracking in Africans, our results for Caucasians are in line with the literature, with the strongest association between childhood, adolescent and adult weight being found for adolescents (Power et al. 1997; Laitinen et al. 2001; Guo et al. 2002; Laitinen et al. 2004; Juonala et al. 2005; Freedman et al. 2005[b]). For the Zulu women, one could speculate that the more prominent tracking between childhood weight and overweight/obesity in adulthood may be as a result of the fact that an overweight baby and young child is considered to be healthy in many African cultures (Onywera 2010). This may promote rather than address overweight in a child, with the higher body weight continuing into adolescence and adulthood. This possibility is supported by the work of Freedman et al. (2005[a]) who found that weight tracking into adulthood was prominent for obese African American children (ages 5-14). The latter study also showed that weight gain was prominent in overweight children, with 84% of overweight girls also becoming obese in adulthood.

Perceiving oneself to have weighed more than one's peers in adolescence appears to indicate a greater risk of being overweight/obese in adulthood for Caucasian women than Zulu women (Caucasian OR: 22.3; Zulu OR: 10.4). This result may have been expected since Kwazulu Natal has the highest prevalence of overweight in adolescents in South Africa, with this prevalence being particularly high amongst Zulu girls (Reddy et al. 2010). Since more of the overweight/obese Zulu women may have had peers who were also overweight/obese when compared to their Caucasian counterparts, fewer Zulu women would have weighed more than their overweight/obese peers as adolescents. This may have resulted in the Zulu women being more likely to report that they weighed the same as their peers in adolescence, thereby reducing the size of the odds ratio for the Zulu women. This argument is further supported by the fact that the identification of normal weight Zulu women for this study was particularly challenging.

Perceiving oneself to have been overweight/obese as a young adult seems to denote the highest risk of being overweight/obese in adulthood for both Caucasian (OR: 62.4) and Zulu (OR: 95.2) women. However, many of the subjects fell within the 23-26 year age group at the time of the study (22% of Caucasians, 31% of Zulus), with reported perceived weight at age 20-25 years thus being a reflection of the current situation and this could have exaggerated these odds.

Nevertheless, for both Zulu and Caucasian *cases*, 30-40% of women reported to have been normal weight in young adulthood and 24-28% indicated that their stable weight BMI was

within the normal range. These results thus support the above mentioned possibility that weight gain in adulthood is an important risk factor in the development of obesity in these two groups. This association is strongly supported by the literature (Laitinen et al. 2001; Guo et al. 2002; Freedman et al. 2005[a]; Freedman et al. 2005[b]; Juonala et al. 2005; Deshmukh-Taskar et al. 2006) and is also reflected in the increasing global prevalence of overweight/obesity (WHO 2011). The work by Deshmukh-Tasker et al. (2006) in the USA for example, indicates that 20-40% of individuals moved up into the next BMI quartile in adulthood, while 21% moved up two quartiles.

From the odds ratios reported above, it appears that the risk for obesity development may be greater for Zulu women than Caucasian women if they perceived themselves as overweight/obese during childhood and adolescence. Furthermore, the risk for obesity development may be especially high for Caucasians if they are overweight/obese as young adults, whereas for Zulu women this risk appears to be high throughout the lifecycle stages. One could speculate that the tolerance for a larger body size shown amongst South Africans of African ethnicity may explain this greater risk throughout the lifecycle for Zulu women, possibly owing to a reduced perceived need to lose weight.

For both Zulu and Caucasian *controls* tracking of normal weight into adulthood was evident, although 22% of Caucasian women and 30% of Zulu women reported a maximum weight BMI greater than 25kg/m^2. One could speculate that these women may have been better able to manage this weight gain by implementing appropriate weight management strategies.

A comparison of the Caucasian and Zulu *cases* and Caucasian and Zulu *controls* for BMI related variables reveals a number of interesting differences. Zulu *cases* reported significantly higher values for maximum BMI than Caucasian *cases*. Caucasian *controls* reported significantly lower values for minimum BMI than Zulu *controls*. These findings may be explained by the fact that overweight and obesity is more prevalent in African women than Caucasian women (SADHS 2003). The tolerance for a larger body size in the African culture has been linked to the increase in overweight/obesity prevalence in general in African populations (Kruger et al. 2005). One could also speculate that the lower minimum BMIs reported by the Caucasian *controls* resulted from the significantly higher prevalence of previous weight reduction attempts/dieting reported by these normal weight women (see section on weight management for detail). This could be linked to the pressure experienced by these women to conform to the slim western body shape ideal (Godfrey 2008). The fact that 28% of the Zulu *controls* wanted to gain weight and may have been trying to do so,

supports the presence of acceptance of a larger body size in our sample of normal weight Zulu women.

Based on the above discussion of the results pertaining to personal weight history, it can be concluded that:

- Perceived overweight/obesity during childhood as well as adolescence is a risk for overweight/obesity in Caucasian and Zulu women.
- Perceiving one self to have weighed more than one's peers in adolescence is a risk for overweight/obesity in Caucasian and Zulu women.
- Weight tracking from childhood and adolescence into adulthood is evident in overweight/obese Caucasian and Zulu women.
- Perceived overweight/obesity in young adulthood is a risk for overweight/obesity in Caucasian and Zulu women.
- Overweight/obese Zulu women reach higher maximum weight BMIs.

The following trends are worth mentioning and should be considered when developing weight management programmes:

- Based on the size of the odds ratios, weight tracking of overweight/obesity from childhood and adolescence through into adulthood appears to be greater for Zulu women.
- Based on the size of the odds ratios for perceived overweight/obesity in young adulthood, the greatest risk for overweight/obesity for Caucasian women appears to be weight gain in adulthood.
- Based on the size of the odds ratios, perceiving one self to weigh more than one's peers appears to be a greater risk for the development of overweight/obesity for Caucasian women.
- Weight tracking from childhood and adolescence into adulthood is evident for normal weight Caucasian and Zulu women.
- Normal weight Caucasian and Zulu women experience periods of being overweight.
- Normal weight Caucasian women reach lower minimum weight BMIs.

5.2 Parental weight history

According to Whitaker et al. (1997) parental weight may influence offspring weight as a result of shared environmental factors including dietary habits and family lifestyle, as well as inherited genetic factors. While there is little South African data available on the influence of family history on obesity, Senekal et al. (2003) showed that having at least one obese parent

was a risk factor for obesity for economically active South Africans of all ethnicities. An association between parental weight and offspring weight could therefore be expected to be present in a sample of overweight/obese Caucasian and Zulu women.

The results of this study show that having a "perceived overweight" mother during childhood is a significant risk factor for overweight/obesity for both Caucasian (OR: 3.2) and Zulu (OR: 2.6) women. However, no association was found for currently having a "perceived overweight" mother or father or a "perceived overweight" father during childhood for either the Caucasian or Zulu groups. While no significant effect was found for currently having a "perceived overweight" mother in the controlled data for Caucasian women, there was a strong trend towards significance, which may become so with a larger sample size.

When interpreting the Zulu data it is important to bear in mind that whilst the current research screened for retroviral disease and anti-retroviral treatment in the study participants themselves, no assessment of parental HIV status was undertaken. Since the untreated disease may result in substantial weight loss on the one hand and anti-retroviral treatment may result in weight gain on the other hand (Koethe & Heimburger 2010), this may have confounded these results. Considering that Kwazulu Natal has the highest prevalence of HIV infections in South Africa, with 27% of women aged 15-47 and 13.5% of males aged 15-54 years being infected with the disease (Welz et al. 2007), the data relating to parental weight history should be interpreted with caution.

Nevertheless, other studies have also shown that the effect of maternal weight on offspring weight is significantly greater than the paternal effect (Hui et al. 2003; Lawlor et al. 2007). Associations between the weight status of fathers and sons have been shown in two Greek studies (Savva et al. 2002, Mihas et al. 2009), while no studies reported associations between fathers and daughters. Many studies have reported a positive association between the weights of mothers and their daughters (Burke et al. 2001; Hui et al. 2003; Trudeau et al. 2003; Savva et al. 2003; Lawlor et al. 2007; Mihas et al. 2009), while there are no clear associations between the weights of mothers and their sons in the literature (Burke et al. 2001; Trudeau et al. 2003; Savva et al. 2003; Mihas et al. 2009).

The exact reasons for the association between maternal weight and offspring weight are unclear, although it has been suggested that this phenomenon may be related to the "foetal over-nutrition" hypothesis, which implies that over-eating by the pregnant mother results in a greater delivery of nutrients to the developing foetus. This high nutrient load may result in permanent epigenetic changes in appetite control, neuroendocrine functioning or energy metabolism and may lead to obesity (Lawlor et al. 2007; Sullivan & Grove 2010). However,

further research is needed to determine how maternal overnutrition results in these epigenetic modifications (Sullivan & Grove 2010). The fact that the association is evident for mothers and daughters but not sons in many of the studies (Burke et al. 2001; Hui et al. 2003; Trudeau et al. 2003; Savva et al. 2003; Lawlor et al. 2007; Mihas et al. 2009), refutes the possibility that foetal overnutrition is a primary determinant of obesity. Other genetic and epigenetic effects that play a role in body weight regulation and may be passed from mother to daughter have been reported and support a physiological basis for this association (Lawlor et al. 2007). As with all phenotype outcomes, the effect of environmental factors cannot be negated. Stunkard et al. (2004) and other researchers (Burke et al. 2001; Trudeau et al. 2003; Bouchard 2007, Onywera 2010) suggest that there may be a greater maternal than paternal effect on the development of the child's eating and activity patterns that may also influence body weight. However, Pietilainen et al. (2001) found that while maternal effects on offspring weight were greater in infancy and early childhood, by the age of 16 years, this effect was not significantly different from the paternal effect on offspring weight. This may explain why other studies have found that the weight of each parent has a similar positive effect on the weight of their children (Whitaker et al. 1997; Davey Smith et al. 2007; Oliviera et al. 2007).

When making comparisons between Zulu and Caucasian *cases* and between Zulu and Caucasian *controls*, it is evident that Caucasians were significantly more likely than their Zulu counterparts to perceive their fathers to currently be overweight. Caucasian *cases* were also significantly more likely to perceive their fathers to have been overweight/obese during their childhood than their Zulu counterparts. While it is important to consider the issues surrounding the lack of HIV screening of parents discussed above, these results reflect the results of the South African Demographic and Health Survey (SADHS 2003), namely that Caucasian males have the highest prevalence of overweight and obesity for adult males living in South Africa, while African males have the lowest prevalences.

From the discussion regarding the association between parental weight and offspring BMI, it can be concluded that:

- Perceiving one's mother to be overweight/obese during childhood is a risk for overweight/obesity in Caucasian and Zulu women.

The following trend is worth mentioning and should be considered when developing weight management programmes:

- Fathers of Caucasian subjects are significantly more likely to have a history of overweight/obesity.

5.3 Weight management practices

Attempting weight reduction is a common practice amongst Caucasian women (Serdula et al. 1999; Bish et al. 2005; Weiss et al. 2006; Millstein et al. 2008), with weight loss attempts increasing with increasing BMI (Ikeda et al. 2004; Raynor et al. 2008). In South Africa weight reduction attempts have also been found to be common in overweight/obese and normal weight Caucasian (Cilliers et al. 2006) and African (Senekal et al. 2001) women. Furthermore, Senekal et al. (2003) suggested that the increased frequency of dieting amongst economically active South Africans is associated with overweight and obesity.

Previous weight reduction attempts were found to be a common practice in this study in overweight/obese women, with no significant difference found between the Zulu and Caucasian *cases*. This practice was also common in normal weight women, although Caucasian *controls* were significantly more likely to have dieted previously than Zulu *controls*. Since it was not possible to control for age in this analysis, one needs to consider that the Caucasian *controls* were significantly older than their Zulu counterparts and that, had they been older, more Zulu *controls* may have reported previous weight loss attempts. Nevertheless, previous weight reduction attempts were found to be a significant risk for the development of overweight/obesity for both Caucasian (OR: 30.2) and Zulu (OR: 12) women. This finding is in line with the literature for Caucasian women, (Jeffrey et al. 2002; Kroke et al. 2002; Ikeda et al. 2004; Hart and Warriner 2005; Luo et al. 2007; Vergnaud et al. 2008). The only available evidence for Africans is reported in the above mentioned mixed ethnicity study by Senekal et al. (2003), namely that dieting behaviour was a risk factor for overweight/obesity amongst economically active South Africans. The current study confirms that this risk is apparent for Zulu / African women, which is a novel finding. These results imply that previous weight loss attempts increase the risk for obesity development irrespective of ethnicity, although the reported odds ratios indicate that the magnitude of this risk may be lower for Zulu women.

Regaining weight lost on a diet was also a significant risk for the development of overweight/obesity for Caucasian women (OR: 5.8) but not for Zulu women, although weight regain was evident for Zulu cases. Furthermore, overweight/obese Caucasian *cases* and *controls* with a past history of dieting had attempted a significantly greater variety of dieting strategies than their Zulu counterparts (see detail later in this Chapter). This may reflect repeated unsuccessful attempts to lose weight by the Caucasian *cases*. Since weight cycling is defined as repeated bouts of weight loss and weight regain (McCargar & Crawford 1992), it can be speculated that this group of women have a history of weight cycling. Weight cycling is more common in overweight/obese individuals (Field et al. 2004) and has been found to be associated with obesity development (Kroke et al. 2002; Luo et al. 2007;

Vergnaud et al. 2008). Furthermore, the fact that no difference was found between Caucasian (97.8%) and Zulu (98%) *cases* in terms of having previously attempting to lose weight indicates the possibility that both groups of women are weight cycling. Further supporting evidence for this conclusion includes the fact that both groups of *cases* reported to having attempted a variety of weight reduction strategies and both groups indicated a high prevalence of weight regain after weight loss. Therefore, those overweight/obese Zulu women who volunteer for a weight loss programme at the age of approximately 32 years may be experiencing the same weight management difficulties as Caucasian women. The risk for and consequences of weight cycling emphasise the necessity for support measures to be put in place in all weight management programmes to facilitate maintenance of any weight lost.

The age at first weight loss attempt for overweight/obese Caucasian women is reported to be between 11 years and 16 years, with obese women more likely to attempt their first diet at a younger age than their overweight counterparts (Hill 2002; Ikeda et al. 2004). However, no information on age at first diet is available for Africans. It is thus interesting to note that the overweight/obese Zulu women who voluntarily entered our weight loss programme were significantly older (median(IQR): 25(20-30) years) at the time of their first weight loss attempt than Caucasian women (median(IQR): 17(15-24) years) entering the same weight loss programme. This may be related to the greater tolerance for a larger body size found in African communities and subsequent lower perceived need to lose weight. Furthermore, this later age of first dieting attempt may indicate that the cycle of weight loss attempts starts at a later stage for these women. However, it can be argued that, although dieting attempts in Zulu *cases* start later than in Caucasians, this practice may contribute to the development of overweight/obesity at the age of approximately 32 years. The fact that there was no significant difference in the prevalence of having previously attempted weight reduction between Caucasian and Zulu *cases* supports this notion and reflects the inability of both groups of women to make the necessary lifestyle / behavioural changes to ensure weight maintenance after successful weight loss. Thus emphasis needs to be placed on the adoption of healthy lifestyles in the long-term for both ethnic groups.

Of concern is the fact that whilst 68% of the normal weight Caucasians from this study had attempted weight loss at some stage, only 22% reported ever having a maximum adult BMI>25kg/m^2. Dieting amongst normal weight Caucasian females is reported extensively in the literature (Serdula et al. 1999; Kruger et al. 2004; Bish et al. 2005; Weiss et al. 2006; Millstein et al. 2008), although the reported prevalence of 25% to 30% is much lower than was found in this study. However, these studies investigated dieting practices over the past

year and not whether dieting for weight loss had "previously been attempted". Thus, the higher prevalence of weight reduction attempts reported in this study is to be expected. In support of the current results, Cilliers et al. (2006) found the prevalence of weight loss attempts in the two years prior to their study to be 55.3% in South African female Caucasian university students, even though only 10% of the sample had been overweight or obese. Since the Caucasian sample was older in the current study, one would expect that more subjects would have attempted dieting in this group of older normal weight women.

The finding that Zulu *controls* also reported to have previously dieted (28% dieted; 30% reported a maximum weight BMI >25kg/m^2) to lose weight, supports the notion that African women are increasingly under pressure to conform to western body shape ideals. In research conducted amongst female African students in the North West province of South Africa, Senekal et al. (2001) found that there are signs of assimilation of western body shape ideals (acculturation) in urbanised Africans (O'Dea 1995; Senekal et al. 2001; Renzhao 2004). However, since 28% of the *controls* in this study reported that they actually wanted to gain weight, one could speculate that while the western desire for slimness is being internalised by some Zulu women, cultural beliefs and practices regarding a larger body size are still present.

When comparing the weight loss goals (the amount of weight that they wanted to lose) between Zulu and Caucasian *cases*, it is evident that Caucasian *cases* were significantly more likely to want to lose more than 5kg than their Zulu counterparts, indicating a greater need to reduce their weight. However, Caucasian *cases* also reported significantly higher goal weights (the actual weight that they would like to attain after weight loss) than Zulu *cases*. The latter result may be explained by the fact that the Caucasians were significantly taller than the Zulus and thus, a higher weight goal could be expected.

The use of a significantly greater variety of weight loss strategies was evident for both Caucasian cases and Zulu cases who reported previous dieting attempts than their respective controls. Since dieting attempts and frequency of attempts increases with increasing BMI (Ikeda et al. 2004; Raynor et al. 2008) this is not a surprising result. Furthermore, Caucasian *cases* and *controls* used a significantly greater variety of weight loss strategies than their Zulu counterparts. In interpreting these results it is important to bear in mind that the demographic variables that differed between the groups could not be controlled for in the cross-tabulated data between Caucasian *cases* and Zulu *cases* (age, education and marital status) and between Caucasian *controls* and Zulu *controls* (age, education, and marital status). Since the Zulu women in both instances were significantly younger than the Caucasian women, it is possible that, had they been older, the Zulu women

would have had the time to attempt more weight loss strategies and consequently a significantly different result may not have been reported. Furthermore, the significantly higher level of education attained by the Caucasian *cases* and *controls* when compared to their respective Zulu counterparts may also have had an impact on the variety of weight loss strategies attempted. One could speculate that the Caucasian women may have had greater access to information on dieting strategies from reading materials such as magazines and the internet as well as to weight loss "products", thereby increasing the opportunity to attempt a wider variety of strategies. Nevertheless, the literature indicates that Caucasian women are more likely to attempt weight loss than women from other ethnic groups (Serdula et al. 1999; Weiss et al. 2006; Pillitteri et al. 2008; Millstein et al. 2008). This fact, together with the pressure to conform to body shape norms that differ for Caucasian and Zulu women, as discussed earlier, indicates a possible explanation for the greater variety of dieting strategies reported by the Caucasian women.

A balanced diet was commonly used by both Caucasian and Zulu women included in the study, although Caucasian *cases* and *controls* were significantly more likely to use a balanced weight loss diet than their Zulu counterparts. Caucasian *cases* were also significantly more likely than Zulu *cases* to eat less or nothing between meals. Again, it was not possible to control for the mentioned demographic variables in these comparisons between *cases*. Since the use of healthy weight loss methods has been found to be associated with higher education levels (Kruger et al. 2004; Bish et al. 2005; Tsai et al. 2009), it is possible that the greater use of healthy weight loss methods by Caucasian women in this study can be explained by their significantly higher education levels. In support of this possibility, Annunziato et al. (2007) found that both Caucasians and African Americans used a balanced diet as their most common weight loss strategy after controlling for education. However, South African research indicates that although a balanced diet is used, other weight loss strategies are more common for young African women (Senekal et al. 2001), supporting the differences found between the ethnic groups in our study.

Caucasian *controls* were significantly more likely to have used exercise as a weight loss strategy (83%) than their overweight/obese counterparts (66%), with exercise being the most popular choice for *controls*. Caucasian *controls* were also found to be significantly more likely to have used exercise for weight loss than their Zulu counterparts. Bearing in mind that the secondary analysis of categorical variables was not controlled, differences in education levels between the Caucasian and Zulu *controls* may explain this result since the literature points to exercise being used more often as a weight reduction method by women with higher education levels (Serdula et al. 1999; Bish et al. 2005). Nevertheless, a greater

likelihood of use of exercise for weight loss amongst normal weight Caucasian women is also reported in the literature (Serdula et al. 1999; Kruger et al. 2004; Tsai et al. 2009). As it has been shown that physical activity is important in successful weight loss maintenance (Serdula1999; Field et al. 2004), it can be speculated that this may be one reason why these women are normal weight, especially for those *controls* who reported a maximum weight BMI in the overweight/obese category. It can be further speculated that the lower use of exercise seen in the overweight/obese Caucasian women may have contributed to weight regain after weight loss, resulting in higher BMIs.

The use of exercise for weight loss was not significantly different for Zulu *cases* and *controls*. Although international research indicates that the use of exercise is more common as a weight management strategy for African Americans than Caucasians (Bish et al. 2005; Tsai et al. 2009), the possibility exists that the finding in the current study confirms the results of South African studies that show that exercise is used less often as a weight loss strategy by African women (Senekal et al. 2001). Furthermore, exercise as such does not appear to be associated with a reduced BMI in African women (Malhotra et al. 2008).

Weight management programmes that provide group support, such as Weigh-Less and Weight Watchers were used more often by the overweight/obese Caucasian women than their normal weight counterparts (52.4% vs. 17.4%) and were significantly more likely to have been used by Caucasian *cases* than Zulu *cases*. These results may have been influenced by differences in age and education between the Caucasian and Zulu women with the older, better educated Caucasian women being more likely to have attempted to access these programmes. However, these results may also reflect an increase in the level of weight loss support and psychological help required by the Caucasian women as has been shown in other research (Ikeda et al. 2004). Furthermore, the lesser use of these programmes by overweight/obese African women is also supported in the literature (Annunziato et al. 2007). This result was explained by the latter authors as being associated with greater recognition by Caucasian women of the role played by eating behaviours such as disinhibition in limiting successful weight loss (Annunziato et al. 2007). Therefore, since the results of our study are supported by the literature, it is possible that Zulu women are less likely to use weight reduction programmes that offer group support.

For both Zulu and Caucasian groups, *cases* were significantly more likely than *controls* to have used low carbohydrate diets for weight loss. Extreme methods, namely appetite suppressants and passive exercise machines were also used significantly more often by Zulu and Caucasian *cases* than *controls*. The use of unhealthy/extreme methods of weight loss in overweight/obese women is illustrated in the literature (Field et al. 2004; Kruger et al.

2004; Malinauskas et al. 2006). It has been suggested that overweight/obese individuals who are desperate to lose weight are more likely to resort to unhealthy and/or extreme practices when other methods of weight loss fail (Saper et al. 2004).

The one dieting practice reported more often by Zulu *controls* was the unhealthy practice of missing meals for weight loss, with these women being significantly more likely to use this practice than Caucasian *controls*. Although no significant differences were found between the Caucasian and Zulu *cases*, the practice of skipping meals for weight loss was the second most popular method for Zulu *cases*. The use of this strategy may be explained by the significantly lower levels of education reported by the Zulu women, since other unhealthy practices have been found to be used more often by women with lower education levels (Tsai et al. 2009). On the other hand, skipping meals is also associated with increased attempts at weight loss (Field et al. 2004; Malinauskas et al. 2006) and one could thus have expected the Caucasian women to have reported this strategy more often. However, the greater use of meal skipping for weight loss by Zulu women in this study is supported by information on dieting practices reported by African female university students, where the most common practice for weight loss (46% of subjects) was found to be skipping meals or eating less between meals (Senekal et al. 2001). When making this comparison it is important to note however, that the practice of eating less between meals was included in this analysis. One could speculate that, considering the possibility of lower levels of motivation to lose weight amongst Zulus owing to their tolerance for a larger body size, skipping meals may appear easy and require no planning when compared to the commitment needed to make healthy dietary choices for weight loss (Bish et al. 2007).

Conclusions regarding weight management practices and the development of overweight/obesity that are evident from the results of this study are as follows:

- Previous weight reduction attempts are a risk for overweight/obesity in both Zulu and Caucasian women.
- Zulu and Caucasian cases use low carbohydrate diets, appetite suppressants and passive exercise machines more often than their respective controls.
- Overweight/obese Caucasian women use a greater variety of weight loss strategies than their Zulu counterparts.
- Overweight/obese Caucasian women use exercise for weight reduction less often than their normal weight counterparts.
- Programmes that offer group support and psychological help are used more often by

overweight/ obese Caucasians than Zulus.

- Overweight/obese Zulu women are older than Caucasian women at their first weight reduction attempt.
- Overweight/obese Caucasian women want to lose more weight than their Zulu counterparts.
- Regain of lost weight is a risk for overweight/obesity in Caucasian women but not in Zulu women.

The following trends are worth mentioning and should be considered when developing weight management programmes:

- Based on the size of the odds ratios, previous weight reduction attempts appear to increase the risk for obesity development to a greater extent for Caucasian women than Zulu women.
- Overweight/obese Zulu women appear to be having similar weight management difficulties as Caucasian women.
- Normal weight Caucasian women are significantly more likely to have attempted weight reduction than their Zulu counterparts.
- Normal weight Zulu women are significantly more likely to skip meals in an attempt to lose weight than their Caucasian counterparts.
- Indicators are present of both acculturation to Western body shape norms (dieting by normal weight Zulu women) and the acceptance of a larger body size (normal weight women wanting to gain weight) in normal weight Zulu women

5.4 Weight perception and satisfaction

As mentioned previously, in African communities a larger body size may indicate increased social status or greater financial resources, which may contribute to social desirability (Kruger et al. 2005). In South Africa the preference for a larger body size has been further entrenched since being thin can equate to being HIV positive (Puoane et al. 2002). Studies from other middle-income countries also indicate that being obese is not always associated with psychological distress and may be considered desirable (Tur et al. 2005; Lahmam et al. 2007; Fernald 2009). However, there is some evidence to suggest that as countries become more modernised/westernised, the preference for a smaller body size increases resulting in greater levels of body size and shape dissatisfaction. This may partly be explained by

increasing exposure to westernised media and advertising (Becker et al. 2002; Becker et al. 2005). Dissatisfaction with body weight and shape has been shown to be a strong motivator for attempting weight loss (Senekal et al. 2001; Ikeda et al. 2004; Bish et al. 2005; Malinauskas et al. 2006; Raynor et al. 2008; Godfrey 2008), with inaccurate perception of body weight being found to be associated with dieting behaviour in overweight/obese and normal weight women (Biener & Heaton 1995; Malinauskas et al. 2006).

In our study, the perception of Caucasian *cases* current weight was accurate, with only 2.3% of these women perceiving themselves to be normal weight. Although not significant, Zulu *cases* were more likely to perceive their current weight as being normal (8%) than Caucasian cases. In other local research, overweight/obese African women were found to be even more likely to perceive their weight as being normal, with approximately 50% of overweight/obese women doing so (Senekal et al. 2001). Apart from the greater tolerance for a larger body size for Africans referred to above, incorrect perception of body weight may also be related to the individual's education, with lower education levels being associated with greater differences between perceived and actual BMI (Paeratakul et al. 2002; Puoane 2005). In this study, subjects had a minimum of a school leaver's certificate, with the majority of Zulu *cases* having post-matric qualifications. This level of education may have resulted in greater accuracy of perceived weight for the Zulu *cases* when compared to the literature. Furthermore, the *cases* were recruited for the parent study in order to enter a weight loss programme. Thus, these women were likely to have already acknowledged that they were overweight and needed to lose some weight. However, the fact that 8% of overweight/obese women attending a weight loss programme think their weight is normal is a concern, as this may reflect on low motivation to actually implement the necessary weight loss strategies in order to lose weight and maintain a lower weight.

When considering the normal weight *controls*, the propensity for normal weight Caucasian females to perceive themselves to be overweight that is reported in South African literature (Cilliers et al. 2006) is evident in this study. However, this trend is not as prominent as is reported by Cilliers et al. (2006) (26% reported by Cilliers et al. vs. 13.7% reported in our study). This phenomenon of inaccurate perceived weight in normal weight Caucasian women is also described in international research (Biener and Heaton 1995; Paeratakul et al. 2002; Malinauskas et al. 2006; Linder et al. 2010). It is interesting to note that we found the same trend for the Zulu *controls*, with 10% of these subjects perceiving themselves to be overweight. It needs to be mentioned that the study by Cilliers et al. (2006) focused on adolescents and young adults (university students) whereas our sample was older. Increased realism regarding body weight status with age is described in the international literature, which may explain the lower prevalence of inaccurate body shape perception in

our adult sample (Biener & Heaton 1995; Malinauskas et al. 2006). However this remains a concern as inaccurate perception of weight may lead to unnecessary dieting and eating disorders in normal weight women.

As can be expected, levels of dissatisfaction with body weight were found to be high for both Caucasian (98.9%) and Zulu *cases* (97%). Dissatisfaction with weight was associated with significant risk for the development of overweight/obesity in both groups of women (Caucasian OR: 74.88; Zulu OR: 27.45). Dissatisfaction with specific parts of the body was also a significant risk for obesity development in both ethnic groups for all body parts (arms, stomach, middle, hips, buttocks, thighs and calves: see Chapter 4 for ORs). The significantly higher levels of dissatisfaction found for both Caucasian *cases* and Caucasian *controls* when compared to their Zulu counterparts was also expected. For Caucasian and Zulu *cases*, greater dissatisfaction was found among Caucasians for their stomachs, middles, hips, buttocks, thighs and calves. For Caucasian and Zulu *controls*, Caucasians were found to be significantly more dissatisfied with their body weight, their middles and thighs.

It is thus evident that dissatisfaction was most prominent in overweight/obese Caucasian women and least prominent in normal weight Zulu women. These results are in line with the literature, with pressure to conform to western body weight/shape ideals likely to have affected dissatisfaction levels in both groups of Caucasian women (Serdula et al. 1999; Godfrey 2008; Wharton et al. 2008). Since the overweight/obese Zulu women voluntarily joined a weight reduction programme, it could have been anticipated that they would have levels of dissatisfaction similar to Caucasian women who also joined our weight reduction programme (Ikeda et al. 2004; Bish et al. 2005; Malinauskas et al. 2006; Raynor et al. 2008; Godfrey 2008). The lower levels of body part dissatisfaction in Zulu *cases* when compared to Caucasian *cases* (for all body parts except arms) is likely to be related to the greater societal tolerance of a larger body size for this group (Renzaho 2004; Puoane et al. 2005; Kruger et al. 2005; Puoane et al. 2010). However, the fact that most Zulu *cases* reported to having been dissatisfied with their body weight suggests that they may also be internalising western body weight/shape norms to some extent. This may be further supported by the fact that they joined our weight loss programme.

An important finding is that 37% of Zulu *controls* were dissatisfied with their weight. In interpreting this data it is important to bear in mind that 28% of the Zulu *controls* indicated that they wanted to gain weight (none of whom indicated that they were dissatisfied with their weight). These results may support the possibility that Zulu women are beginning to assimilate western body weight/shape ideals, although pressure to conform to traditional body weight norms is also present in this group.

It is interesting to note that fear of weight gain is a significant risk factor for the development of overweight/obesity in both ethnic groups (Caucasian OR: 9.9; Zulu OR: 19.8). One would expect that this fear would serve as a motivator for attempting weight loss, as was reported by Malinauskas et al. (2006). The fact that the subjects were still overweight despite previous attempts to lose weight may indicate that fear of weight gain may have resulted in repeated unsuccessful weight loss attempts in both ethnic groups. This may have contributed to further weight gain and the perceived need to join the weight reduction programme linked to the parent study of this research. The lack of significant differences for fear of weight gain between Caucasian *controls* (83%) and Zulu *controls* (77%), the prevalence of previous dieting as well as dissatisfaction with body weight and shape in both groups of normal weight women, may also reflect the ongoing development of a similar mindset regarding body weight ideals in normal weight Zulu and Caucasian women. This indicates that acculturation may be taking place in normal weight Zulu women.

From the discussion regarding the association between weight perception and satisfaction, the following can be concluded:

- Overweight/obese Caucasian and Zulu women who enter a conservative weight loss programme have accurate perceptions of their body weight.
- Fear of weight gain is a risk for overweight/obesity in Caucasian and Zulu women.
- Dissatisfaction with body weight is a risk for overweight/obesity in Caucasian and Zulu women.
- Dissatisfaction with certain individual body parts is a risk for overweight/obesity in Caucasian and Zulu women.

The following trends are worth mentioning and should be considered when developing weight management programmes:

- Based on the size of the odds ratios, fear of weight gain appears to increase the risk for obesity development to a greater extent for Zulu women.
- Overweight/obese and normal weight Caucasian women are more dissatisfied with the shape of their individual body parts than their Zulu counterparts.
- Normal weight Caucasian women are more dissatisfied with their body weight than their Zulu counterparts
- Indicators of acculturation to western body shape norms are present for Zulu women (inaccurate perception of body weight in normal weight women; fear of weight gain and body weight and shape dissatisfaction in normal and overweight/obese women).

5.5 Eating behaviour

The regulation of energy intake is not only controlled by biological functions such as hunger and satiety, but also by a number of complex behavioural traits (Riou et al. 2011). Cognitive restraint, disinhibition and perceived hunger have been found to be associated with energy intake and there is some evidence to suggest that each of these eating behaviours has a role to play in the development of obesity (Westenhoefer et al. 1999; Bond et al. 2001) .

High cognitive restraint is associated with lower intakes of dietary fat (Tepper et al. 1996) and energy (Tepper et al. 1996; Westenhoefer et al. 1999; Provencher et al. 2003) and with weight loss attempts in adults (Tepper & Ullrich, 2002; Field et al. 2004; Konttinen et al. 2009; Savage et al. 2009; de Sousa et al. 2010). Therefore the presence of cognitive restraint could be expected to protect against the development of overweight/obesity.

In this study, cognitive restraint was not associated with weight status in either Caucasian and Zulu women (dichotomised data). However, mean restraint scores were found to be significantly higher for Zulu *cases* (85% previously dieted) than *controls* (28% previously dieted), indicating that Zulu *cases* may be more likely to be habitually controlling their food intake than their normal weight counterparts. Similarities between the Caucasian *cases* and *controls* with regards to cognitive restraint were not surprising since 68% of normal weight women had a history of previous weight reduction attempts (vs. 98% of cases). Similarities in cognitive restraint between Zulu and Caucasian *cases* can be explained by the fact that they were all about to start a weight loss programme and one could thus also expect their levels of cognitive restraint to be similarly high at this point. Furthermore, both groups of women had reported to having previously attempted weight loss. The presence of cognitive restraint in 31% of the Zulu *controls* can possibly also be explained by the fact that 28% of these women had previously attempted weight loss. The results for Caucasian women reflect the literature, with high levels of cognitive restraint being found in both normal weight and overweight/obese women (Provencher et al. 2003; Drapeau et al. 2003; de Lauzon-Guillain et al. 2006). However, there is no information reported in the literature for African women and the results from this study for the Zulu women are thus novel. Therefore, although present in both ethnic groups, with no significant differences found between Zulu and Caucasian *cases* or between Zulu and Caucasian *controls*, our results indicate that cognitive restraint does not seem to be a risk factor or a protective factor for the further development of obesity for already overweight/obese women. One should consider that, while this may be a true reflection of cognitive restraint for this group of women, Cronbach's alpha for the

restraint scale of the TFEQ was moderately low for the true/false section (refer to Chapters 3 and 6) and this result may thus not be reliable.

A higher score on the cognitive restraint sub-scale, *flexible control (TFEQ-FCR7)* has been reported to be associated with a lower BMI, lower energy intakes and weight reduction success (Westenhoefer et al. 1999; Provencher et al. 2003). A high score on this subscale emerged as a significant risk factor for overweight/obesity for Zulu women (OR: 2.5), contrary to the results that could have been expected. As there is no clear explanation for these results, further confirmation is necessary. In addition, more Caucasian *controls* than *cases* demonstrated higher levels of *flexible control*, which is more in line with the literature (Westenhoefer et al. 1999; Provencher et al. 2003) and a larger sample size may have produced a significant result for Caucasian women. When interpreting these results it should be borne in mind that the small number of questions in the subscales of the restraint scale resulted in Cronbach's alpha not being computed for any of the subscales and thus their internal reliability cannot be commented upon. The results for all of the restraint subscales thus need to be interpreted with caution. Nevertheless, further research may be warranted to explore this association in Zulu women.

When considering the cognitive restraint subscale *attitude to self-regulation (TFEQ-R2),* Caucasian *cases* had significantly higher mean scores than *controls*, although the dichotomised data did not show significant odds ratios. As the method of dichotomising the data for this analysis was designed specifically for this study, further confirmation of the cut-off methods applied and consequently of this result is necessary. There is little reported data in the literature regarding the association between BMI and *attitude to self-regulation* owing to a lack of differentiation between the cognitive restraint subscales TFEQ-R1, TFEQ-R2 and TFEQ-R3 (Provencher et al. 2003; Hayes & Roberts 2008). While other research indicates that *rigid control* is associated with a higher BMI and weight gain in Caucasian women (Westenhoefer et al. 1999; Provencher et al. 2003), no such association was evident for either ethnic group in our study.

The literature indicates a strong positive association between high levels of dietary disinhibition in Caucasians and a high BMI (Westenhoefer et al. 1999; Tepper & Ullrich 2002; Provencher et al. 2003; Field et al. 2004; Dykes et al. 2004; Bryant et al. 2008; Savage et al. 2009; Paradis et al. 2009; Gallant et al. 2010), weight gain (Hayes & Roberts 2008; Savage et al. 2009) and reduced weight loss success (Westenhoefer et al. 1999). Little information is available regarding disinhibition in African women.

In this study increased disinhibition and the behaviour-specific subscales of disinhibition were associated with a significant risk for overweight/obesity development (disinhibition:

Caucasian OR: 19.85, Zulu OR: 5.5; *habitual susceptibility to disinhibition*: Caucasian OR: 43.64, Zulu OR: 5.3; *emotional susceptibility to disinhibition*: Caucasian OR: 14.46, Zulu OR: 4.2; *situational susceptibility to disinhibition*: Caucasian OR: 8.32, Zulu OR: 4.4). Since the odds ratios for all of these indicators are higher for Caucasians, one could speculate that this risk is greater in Caucasians and may be associated with a longer dieting history as reflected by the significantly younger age at which they attempt their first diet, greater variety of dieting strategies attempted and increased likelihood of weight regain occurring following weight loss. The fact that the Zulu women also reported high levels of previous dieting attempts and that no significant differences were found when comparing disinhibition between Caucasian and Zulu *cases* and between Caucasian and Zulu *controls,* indicates that disinhibition may be emerging as a significant risk factor for the development of overweight/obesity in Zulu women. Cronbach's alpha for the disinhibition scale of the TFEQ was found to be good and so these results are likely to be reliable (see Chapters 3 and 6). However, the results for the disinhibition subscales need to be interpreted with caution as Cronbach's alpha could not be determined owing to the small number of items in each subscale. Nevertheless, one might speculate that, since the whole scale was found to be reliable, the subscale results may also be reliable.

The results for *situational susceptibility to disinhibition* in our research is not totally in line with the work by Hayes and Roberts (2008), who found an association between a high BMI and *habitual* and *emotional susceptibility to disinhibition* but no association with *situational susceptibility to disinhibition*. In our study we did find an association between *situational disinhibition* and overweight/obesity, as well as between *habitual and emotional susceptibility to disinhibition* in both ethnic groups, although the strength of the odds ratios for *habitual and emotional susceptibility to disinihibition* was greater. Thus disinhibition, especially *habitual susceptibility to disinhibition*, is a risk factor for the development of overweight/obesity in this study sample, although this risk may be greater for Caucasians, bearing in mind the lack of internal reliability testing for *habitual susceptibility to disinhibition*.

The association between perceived hunger and overweight/obesity has not been clearly demonstrated in the literature. While some studies have found positive associations, with high levels of perceived hunger being associated with higher BMIs in Caucasians (Provencher et al. 2003; Dykes et al. 2004), others have found an association between perceived hunger and disinhibition but not perceived hunger and overweight/obesity (Hayes & Roberts 2008; Gallant et al. 2010; Riou et al. 2011). Furthermore, no data for African women has been reported in the literature.

In this study perceived hunger was found to be a significant risk factor for overweight/obesity in both ethnic groups (Caucasian OR: 3.2, Zulu OR: 2.1) with no significant differences found between Zulu and Caucasian *cases* or between Zulu and Caucasian *controls*. In the Zulu sample, both *internal locus for control of perceived hunger* (OR 3.57) and *external locus for control of perceived hunger* (OR 4.56) were also found to be significant risks for the development of overweight/obesity

It is possible that Zulu women are more susceptible to internally mediated feelings of hunger but also perceive themselves to be hungry and eat when they are in the presence of other people who are eating, resulting in higher energy intakes and weight gain. It is important to mention that food is used as a sign of acceptance and friendship in African cultures in South Africa and it is considered rude to refuse food when offered (Puoane et al. 2006). One could thus speculate that social occasions when food is freely available contributes to *situational susceptibility to disinhibition* in Zulu women and consequently, excessive eating and the development of overweight/obesity. For Zulu women who are attempting weight loss, these social situations may thus be particularly challenging. However, when interpreting the results for perceived hunger, it is important to consider that Cronbach's alpha was exceptionally poor for the likert scale of the perceived hunger scale although very good for the true/false section. Therefore, the results for perceived hunger should be interpreted with caution. Furthermore, as mentioned for the other TFEQ subscales, the perceived hunger subscales were not tested for reliability and so this data should be interpreted with caution (see Chapters 3 and 6).

In summary, no associations were found between cognitive restraint and the risk for overweight/obesity, although the subscale, *flexible control of cognitive restraint* was associated with obesity in Zulu women. The expected associations for disinhibition (increased disinhibition being associated with increased BMI) were found for both Caucasian and Zulu women as well as for all of the subscales, with odds ratios being higher for Caucasians. Furthermore, the expected associations for perceived hunger were also found for both groups of women (high perceived hunger being associated with an increased BMI), with the odds ratios being higher for Zulus.

Bearing in mind the limitations of the reliability of the TFEQ in this study, the following can be concluded:

- Cognitive restraint is not a risk for overweight/obesity in Caucasian and Zulu women.

- Disinhibition is a risk for overweight/obesity in both Zulu and Caucasian women.
- Perceived hunger is a risk for overweight/obesity in both Zulu and Caucasian women.

The following trends are worth mentioning and should be considered when developing weight management programmes:

- Based on the size of the odds ratios, disinhibition may be a greater risk for the development of overweight/obesity in Caucasian women when compared to Zulu women.
- Based on the size of the odds ratios, perceived hunger may be a greater risk for the development of overweight/obesity in Zulu women when compared to Caucasian women.

5.6 Taste sensitivity

The role of the PROP phenotype in determining BMI is highly controversial and has resulted in ongoing debate in the literature (Drewnowski et al. 2007; Tepper, 2008; Lumeng et al. 2008). PROP non-tasters have been shown to have a greater preference for high fat and sweet foods than super-tasters (Chang et al. 2006; Yeomans et al. 2007; Hayes & Duffy 2008; Hedge & Sharma 2008; Villarino et al. 2009). It has thus been postulated that PROP non-tasters may consume diets higher in energy than PROP super-tasters, increasing their risk for weight gain (Goldstein et al. 2005). In support of this possibility, PROP super-tasters have also been found to consume less energy than non-tasters (Drewnowski et al. 2007; Goldstein et al. 2007). As dietary restraint and disinhibition are thought to mask the association between PROP phenotype and BMI, it has been recommended that these eating behaviours should be adjusted for when examining this association (Tepper & Ullrich 2002).

When comparing the PROP phenotype distribution for Caucasian and Zulu women in this study with other Caucasian studies (Tepper, 1998; Goldstein et al. 2005; Hayes & Duffy 2007; Tepper et al. 2008), a high proportion of PROP supertasters (Caucasian: 42%, Zulu:45% vs.25% in the literature) and low proportion of PROP non-tasters (Caucasian: 20%, Zulu: 14% vs. 30% in the literature) were found. This reflects the global variance between ethnic groups as suggested by a number of researchers (Guo & Reed 2001; Chang et al. 2006; Lumeng et al. 2008; Hedge & Sharma 2008; Villarino et al. 2009). It needs to be noted that a high proportion of PROP super-tasters has also been found in African American individuals (Guo & Reed, 2001; Lumeng et al. 2008).

This study found no significant association between PROP *medium and non-tasters* and overweight/obesity for Caucasian women in the unadjusted and adjusted data. Furthermore, the association between PROP *non-tasters* and overweight/obesity was also not significant. This result is in line with many other studies that were also not able to show any associations between PROP non-tasters and BMI (Yeomans et al. 2007; Drewnowski et al. 2007; Hayes & Duffy 2007; Villarino et al. 2009; Bajec et al. 2010). However, the current study used a small sample and the results need to be confirmed, especially since associations have been found between PROP non-tasters and an increased BMI in other small studies (Tepper and Ullrich 2002; Goldstein et al. 2005; Tepper et al. 2008). It is important to consider, as mentioned earlier, that while Cronbach's alpha was found to be reliable for disinhibition, it was poor for cognitive restraint in the Caucasian sample (refer to Chapter 3 and Chapter 6) and one could question the appropriateness of adjusting for cognitive restraint using the TFEQ in this analysis.

For the Zulu women, a significant association between PROP *medium and non-tasters* and overweight/obesity risk was found before adjusting for cognitive restraint and disinhibition (OR 2.13). However, after controlling for cognitive restraint and disinhibition, this association was no longer significant. Cronbach's alpha for the true/false section of the cognitive restraint scale of the TFEQ was 0.42 for the Zulu sample, indicating that internal reliability of this section of the questionnaire is only moderate. Therefore, adjusting for cognitive restraint using the TFEQ in this analysis may be inappropriate. Cronbach's alpha indicated good internal reliability for the disinhibition scale of the TFEQ in the Zulu sample (refer to Chapter 3 and Chapter 6), indicating that it may be appropriate to control for disinhibition in this analysis using the TFEQ. It could also be argued that, although restraint and disinhibition are present in the Zulu sample, their role as risk factors for overweight/obesity development is lower than for the Caucasian women, as mentioned earlier in this discussion. These eating behaviours may therefore have less of an effect on the association between PROP phenotype and BMI. Since the recommendation by Tepper and Ullrich (2002) to control for eating behaviours was based on Caucasian research, it may not be appropriate to do so for Zulu women. In support of this possibility, Hedge and Sharma (2008) were also able to show a strong positive association between PROP non-tasters and obesity development in Indian children without controlling for restraint and disinhibition.

However, other studies have reported no association between PROP non-tasters and overweight/obesity (Yeomans et al. 2007; Drewnowski et al. 2007; Hayes & Duffy 2007; Villarino et al. 2009; Bajec et al. 2010). It is also important to note that the studies that have shown an association between PROP phenotype and overweight/obesity were conducted amongst fairly homogenous groups of individuals (Tepper & Ullrich, 2002; Goldstein et al.

2005; Tepper et al. 2008; Hedge & Sharma 2008). In this study, the Zulu women may be genetically more homogenous than the Caucasian women and this may have been the reason for the result found for Zulus. Nevertheless further research may be warranted to explore the role of PROP phenotype in the development of overweight/obesity in Zulu women.

From the discussion regarding the association between taste sensitivity and overweight/obesity, the following can be concluded:

- PROP medium and non-taster status is not a risk for overweight/obesity in Caucasian women, even after controlling for eating behaviours.
- PROP medium and non-taster status is a risk for overweight/obesity in Zulu women, if not controlled for cognitive restraint and disinhibition.

CHAPTER 6

CRITIQUE ON METHODOLOGY

AND

RECOMMENDATIONS

In order to formulate recommendations on the basis of this research, a critique of the research design and methods is presented. This is followed by comments on the current situation in South Africa regarding the status of obesity prevention and management strategies from a public health perspective. Finally, recommendations are presented to guide the consideration of the findings of this research in the development of strategies to prevent and manage obesity in South Africa, bearing in mind the multi-cultural nature of our society.

6.1 Critique on the research design and data collection techniques

The case-control study design is a retrospective longitudinal study design that compares individuals with the disease in question (cases: overweight/obese women in this study) to individuals without the disease in question (controls: normal weight women in this study) (Bonita et al. 2006). Case-control studies can be an efficient way of identifying associations between exposures and outcomes, are relatively inexpensive, quick and easy to conduct and useful for highlighting associations that may warrant further research (Lewallen & Courtright 1998; Bonita et al. 2006). However they do not demonstrate causation (Lewallen & Courtright 1998). One of the difficulties with conducting case-control studies is ensuring that the results are reliable and valid and not confounded by other factors that may play a role in the development of the disease in question, especially when there may be multiple causes of the disease. In the case of obesity, causation is recognised as being multifactorial, reflecting complex interdependent interactions of multiple genes, environmental and lifestyle/behavioural factors (Newell et al. 2007; Bouchard 2008; Huang et al. 2009). Thus, controlling for all confounding factors in obesity research is very challenging. For these reasons, socio-demographic factors that differed significantly were controlled for in this research.

Since purposeful sampling techniques were used to recruit cases and controls for this study, it should be borne in mind that the results of this study cannot be generalised to the South African population. Furthermore, the cases in this study were women who joined a healthy weight loss programme and one could assume that these women were dissatisfied with their body weight and shape and were motivated to address this by joining our programme. These women are unlikely to be representative of all overweight/obese Caucasian and Zulu women living in South Africa as it is unlikely that all of these women are similarly motivated to lose weight and to use healthy methods. This fact may have contributed to the many similarities found for overweight/obesity risk factors in Zulu and Caucasian women, thus attenuating differences that may have been found had our sample selection criteria been different.

The case control study design is weakened if data collection is inadequate or unreliable (Lewallen & Courtright 1998). Recall bias, an important challenge in case-control studies

(Bonita et al. 2006) may also have influenced the results of this study since individuals had to remember information from as far back as childhood. While recall bias may influence all of the self-reported variables in this study, self-reported weight measurements and perceived weight status may have been especially affected. Many studies have used self reported weights in their design (Power et al. 1997; Pietiläinen et al. 2001; Laitinen et al. 2001; Savva et al. 2002; Giampietro et al. 2002; Trudeau et al. 2003; Danielzik et al. 2004; Gale et al. 2007; Lawlor et al. 2007; Davey Smith et al. 2007; Davis et al. 2008; Carvalho Francesco-Antonio Menezes et al. 2009). While self-reported heights and weights have been shown to provide acceptable correlations with actual height and weight in Caucasian subjects (Reed & Price 1998; Hill & Roberts 1998; Bolton-Smith et al. 2000; Kuczmarski et al. 2001), accuracy of self-reported weight data has not been assessed for Zulu subjects or for Caucasian South Africans. In addition, estimates of the prevalence of obesity based on self-reported weight data may be affected by bias towards a lower BMI, especially for the Caucasian women, owing to underreporting influenced by the social desirability to be slim (Jeffrey 1996; Black et al. 1998).

Similarly, the use of perceived weight status as a proxy for actual weight status during childhood, adolescence and young adulthood may have skewed the results since acceptable correlations have also only been established for Caucasian women (Munoz et al. 1996, Koprowski et al. 2001, Must et al. 2002), especially those who are overweight/obese (Paeratakul et al. 2002; Linder et al. 2010). African women living in South Africa are known to prefer a larger body size (Puoane et al. 2005) and may perceive themselves to be normal weight when they are overweight (Senekal et al. 2001; Mchiza et al. 2005). Thus the weight perceptions recorded by the Zulus may have been influenced by a different frame of reference than those recorded by the Caucasians, rendering comparisons between the groups difficult to interpret. Furthermore, differences found in the data between perceived and actual current weight status in both ethnic groups indicate that there may well be inaccuracies in the rest of the self-reported perceived weight data.

Data collection was challenging and resulted in some missing weight history data, especially for the Zulu cases despite the fact that the same Zulu speaking fieldworkers were used for both Zulu cases and controls. Missing data may introduce a selection bias into the study (Laitinen et al. 2004). Since missing data was more prevalent for the Zulu cases than any of the other groups, this may have influenced risk outcomes for these variables in the Zulu case control study as well as in the secondary analysis of comparison of Zulu and Caucasian cases. A further challenge in this regard involved the need to estimate BMIs from

dress sizes for maximum, minimum and stable weight for approximately half of the Zulu cases, which may have introduced a reporting error.

The appropriateness of the use of the Three Factor Eating Questionnaire (TFEQ) in this study also warrants discussion, bearing in mind that it was developed using subjects from westernised countries. Internal reliability analysis outcomes of the TFEQ for our study sample was good for the total questionnaire and for the disinhibition scale for Caucasians (Cronbach's alpha: true/false section, 0.63; likert scale section, 0.77) and Zulus (Cronbach's alpha: true/false section, 0.69; likert scale section, 0.66). However, while reliability analysis outcomes of the likert scale section of the cognitive restraint scale was good for both groups (Caucasians: 0.7; Zulus: 0.76), the true/false section was poor for both (Caucasians: 0.27; Zulus: 0.42). Similarly, reliability analysis outcomes of the true/false section of the perceived hunger scale was very good for both groups (Caucasians: 0.77; Zulus 0.8), but for the likert scale section, it was extremely poor for both (Caucasians: 0.01; Zulus: 0.05). Since a reliability co-efficient of >0.6 is often considered to have met internal consistency requirements (Thiessen 1993), the use of the TFEQ in this study is appropriate for measuring disinhibition. However, results of the cognitive restraint and hunger scales should be interpreted with caution since one section of each scale shows poor internal reliability. Furthermore, because the Cronbach's alpha could not be computed for the TFEQ sub-scales owing to the small number of questions in each, the internal reliability of these sub-scales cannot be commented upon and these results should thus also be interpreted with caution. In addition, the method of dichotomising the data was designed specifically for this study and further confirmation of the cut-off methods applied is necessary.

Despite the limitations regarding the generalisability of the outcomes of this study to all South African Zulu and Caucasian women, the insights generated are unique and with cautious interpretation, contribute to a body of knowledge on risk factors for obesity development that is currently very limited. The information generated may pave the way for a better understanding of some of the factors that need to be considered in the development of strategies to address overweight/obesity in South Africa.

6.2 Recommendations for the development of weight management strategies for South African Caucasian and Zulu females

It is clear that overweight/obesity is a growing problem in South Africa (SADHS 2003; Steyn et al. 2005; Armstrong et al. 2006; Reddy et al. 2010) and that strategies urgently need to be implemented to prevent and treat this condition as it has a devastating effect on the development of chronic diseases of lifestyle (Kumanyika et al. 2002; Sawaya et al. 2003; Havel 2004; Steyn et al. 2005). To date, Public Health policies in South Africa have focussed

mainly on the management of HIV/AIDS and TB while the management of chronic diseases of lifestyle, including obesity, has not received adequate attention (Steyn et al. 2006; WC Chronic Disease Management Policy 2009).

Within the South African context, public health strategies to manage overweight/obesity fall within the *Integrated Nutrition Programme (INP)* of the Department of Health (DOH) (Labadarios et al. 2005). At national level, obesity prevention and management is thus currently addressed in the INP's "National Guideline on Primary Prevention of Chronic Diseases of Lifestyle" (DOH 2005), although no strategic national plan appears to be in place. According to Labadarios et al. (2005), implementation of obesity management guidelines seems to be hampered by a lack of human resource capacity.

Current obesity management guidelines prescribed by the Department of Health are based on the conservative approach of modifying dietary and lifestyle factors in order to reduce energy intake and increase energy expenditure (DOH 2003; DOH 2005; Western Cape INP 2007). No consideration of ethnic/cultural attitudes and practices regarding issues surrounding body weight perceptions and preferences appear to have been included in any of the guidelines currently available. The results of this research may thus provide an important ethnic/cultural perspective to the development of the urgently needed interventions to prevent and manage overweight/obesity in South African Caucasian and Zulu women (Table 6.1).

Table 6.1: Summary of core conclusions and noteworthy trends as well as recommendations for the development of weight management strategies for South African Caucasian and Zulu females

Core conclusions	Noteworthy Trends	*Recommendations*
Perceived overweight/obesity during childhood as well as adolescence are risks for overweight/obesity in Caucasian and Zulu women. Perceived overweight/obesity in young adulthood is a risk for overweight/obesity in Caucasian and Zulu women. Perceiving oneself to have weighed more than one's peers in adolescence is a risk for overweight/obesity in Caucasian and Zulu women. Weight tracking from childhood and adolescence into adulthood is evident in overweight/obese Caucasian and Zulu women. Perceiving one's mother to be overweight/obese during childhood is a risk for overweight/obesity in Caucasian and Zulu women.	Based on the size of the odds ratios, weight tracking of overweight/obesity from childhood and adolescence through into adulthood appears to be greater for Zulu women. Based on the size of the odds ratios for perceived overweight/obesity in young adulthood, the greatest risk for overweight/obesity for Caucasian women appears to be weight gain in adulthood. Caucasian fathers appear to be at a high risk for overweight/obesity.	*A focus on the concepts of healthy weight and healthy lifestyle choices (diet, physical activity and eating behaviours) should be included in health education programmes/curriculums for all children/adolescents of both Caucasian and Zulu ethnicity, but especially for Zulu girls. Since health related practices of children are influenced by the significant adults in their environments (parents, caregivers, teachers), these adults should also be targeted for obesity related health education.* *Health education programmes that include a strong focus on the concepts of healthy weight and healthy lifestyle choices (diet, physical activity and eating behaviours) for healthy weight management should be developed and implemented. These programmes should target young adult Zulu and Caucasian women, but especially young adult Caucasian women.* *In developing such programmes/curriculums, ethnic/cultural differences in preferences and perceptions regarding body weight and shape should be considered. These include both the acceptance of a larger body size by Zulu women and the drive to achieve the western body weight/shape ideal of slimness by both Caucasian women and to some extent normal weight Zulu women.*

Core conclusions	Noteworthy Trends	*Recommendations*
Previous weight reduction attempts are a risk for overweight/obesity in both Zulu and Caucasian women. Regain of lost weight is a risk for overweight/ obesity in Caucasian women. Overweight/obese Zulu women are older than Caucasian women at their first weight reduction attempt.	Based on the size of the odds ratios, previous weight reduction attempts appear to increase the risk for obesity development to a greater extent for Caucasian women. Overweight/obese Zulu women who join a conservative weight loss programme appear to be experiencing similar weight management difficulties as Caucasian women (weight loss attempts, weight regain following weight loss). Normal weight Caucasian and Zulu women experience periods of being overweight	*It is essential to include a weight loss maintenance component in any weight reduction programme to prevent weight regain and possibly weight cycling for both Caucasian and Zulu women, but especially for Caucasian women.* *As the older age at first weight reduction attempt may reflect acceptance of a larger body size in Zulu women, health education programmes targeted at Zulu females should focus on increasing awareness of the concept of a healthy weight from a young age as well as the need for weight reduction when overweight/obese.* *In developing such strategies to be included in health education/weight loss programmes, ethnic/cultural differences in preferences and perceptions regarding body weight and shape should be considered. These include both the acceptance of a larger body size by Zulu women and the drive to achieve the western body weight/shape ideal of slimness by both Caucasian women and to an extent normal weight Zulu women.*

Core conclusions	Noteworthy Trends	*Recommendations*
Overweight/obese Caucasian women use a greater variety of weight loss strategies than their Zulu counterparts. Programmes that offer group support and psychological help are used more often by overweight/ obese Caucasians than Zulus. Overweight/obese Zulu and Caucasian women use low carbohydrate diets, appetite suppressants and passive exercise machines more often than their normal weight counterparts. Overweight/obese Caucasian women are less likely to use exercise for weight reduction than their normal weight counterparts.	Overweight/obese Zulu women appear to be having similar weight management difficulties as overweight/obese Caucasian women (a number of weight loss methods attempted). A balanced diet and/or physical activity were commonly used by overweight/obese Zulu and Caucasian women and normal weight Caucasian women for weight loss purposes. Skipping meals is a popular weight loss method for overweight/obese Zulu women. Skipping meals is used more often as a weight loss method by normal weight Zulu women than their Caucasian counterparts.	*Although commonly used, healthy weight loss strategies (increased physical activity, a healthy diet, behaviour change) should be strongly promoted in all weight loss education/interventions targeting Caucasian and Zulu females.* *Health education/weight loss intervention strategies targeting Caucasian and Zulu females should include a strong focus on the characteristics (criteria for identification) and dangers of unhealthy/extreme weight loss methods.* *The importance of eating regular meals when attempting weight loss should be specifically emphasised in weight loss education/intervention programmes targeting Zulu women.* *In developing such strategies to be included in health education/weight loss programmes, ethnic/cultural differences in preferences and perceptions regarding body weight and shape should be considered. These include both the acceptance of a larger body size by Zulu women and the drive to achieve the western body weight/shape ideal of slimness by both Caucasian women and to an extent normal weight Zulu women.*

Core conclusions	Noteworthy Trends	*Recommendations*
Overweight/obese Caucasian and Zulu women who enter a conservative weight loss programme have accurate perceptions of their body weight. Fear of weight gain is a risk for overweight/obesity in Caucasian and Zulu women. Dissatisfaction with body weight is a risk for overweight/obesity in Caucasian and Zulu women. Dissatisfaction with individual body parts is a risk for overweight/obesity in Caucasian and Zulu women.	Based on the size of the odds ratios, fear of weight gain appears to increase the risk for obesity development to a greater extent for Zulu women. Overweight/obese and normal weight Caucasian women are more dissatisfied with the shape of their individual body parts than their Zulu counterparts. Indicators of acculturation to Western body shape norms are present for overweight/obese Zulu women (fear of weight gain and body weight and shape dissatisfaction). For normal weight Zulu women, indicators of acculturation to Western body weight/shape norms (dieting by normal weight Zulu women, inaccurate perception of body weight, fear of weight gain and body weight and shape dissatisfaction) are present on the one hand. On the other hand, indicators of acceptance of a larger body size by normal weight Zulu women are also present (normal weight women wanting to gain weight).	*Since body weight/shape dissatisfaction and fear of weight gain are more likely to result in weight gain rather than weight loss/maintenance, a focus on healthy weight loss strategies and strategies to ensure optimal weight loss maintenance (mentioned earlier) is essential to prevent recurring unsuccessful weight loss attempts, fear of weight gain and dissatisfaction with body weight and shape.* *In developing health education/weight loss intervention strategies for Caucasian and Zulu women, the possibility that normal weight Caucasian and to some extent Zulu women are at risk of developing eating disorders needs to be considered.*

Core conclusions	Noteworthy Trends	*Recommendations*
Disinhibition is a risk for overweight/obesity in both Zulu and Caucasian women. Perceived hunger is a risk for overweight/obesity in both Zulu and Caucasian women. Cognitive restraint is not a risk for overweight/obesity in both Zulu and Caucasian women.	No significant differences were found between overweight/obese and between normal weight Zulu and Caucasian women for cognitive restraint, disinhibition and perceived hunger. Based on the size of the odds ratios, disinhibition may be a greater risk for the development of overweight/obesity in Caucasian women when compared to Zulu women. Based on the size of the odds ratios, perceived hunger may be a greater risk for the development of overweight/obesity in Zulu women when compared to Caucasian women.	*Behaviour change strategies should be included in any weight management programmes targeted at Caucasian and Zulu females and should focus on:* 1. *Addressing disinhibition for both Zulu and Caucasian women but especially for Caucasian women.* 2. *Addressing perceived hunger for both Zulu and Caucasian women but especially for Zulu women. For Zulu women, these strategies should specifically provide guidance on how to cope with eating at social occasions.*
PROP medium and non-taster status is not a risk for overweight/ obesity in Caucasian women, even after controlling for eating behaviours. PROP medium and non-taster status is a risk for overweight/ obesity in Zulu women, if not controlled for cognitive restraint and disinhibition.		*The association between PROP phenotype and BMI in the Zulu population warrants further research to determine its usefulness as a screening tool for the identification of Zulu women at risk for weight gain.*

The core themes that emerge from these recommendations that should be considered when developing health education/weight loss intervention strategies for Zulu and Caucasian women living in South Africa are as follows:

- Risks for the development of overweight/obesity appear to be similar for Zulu and Caucasian women who had voluntarily joined a weight loss programme.
- The presence of cultural norms for the acceptance of a larger body size is evident for normal weight and overweight/obese Zulu women.
- The presence of acculturation of Zulu women to the slim western body weight/shape norm is also evident, increasing the risk for the development of eating disorders in normal weight Zulu women as has been recorded for Caucasian women.
- Previous dieting as implemented by Caucasian and Zulu women does not seem to result in sustained weight loss and is a risk for the development of overweight/obesity.
- Healthy weight loss strategies (balanced diet and physical activity) are used by Caucasian and Zulu women, but the lack of success and prevalence of unhealthy/extreme strategies is of concern and needs attention.
- Dissatisfaction with body weight, with the shape of individual body parts and fear of weight gain do not protect against the development of overweight/obesity, but are rather risks for overweight/obesity development in Zulu and Caucasian women.
- Disinhibition and perceived hunger are risks for overweight/obesity in Zulu and Caucasian women and need to be addressed.
- At this stage there is not sufficient evidence to consider taste sensitivity as a risk for overweight/obesity for Zulu and Caucasian women.

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ADDENDUM A

Screening questionnaires

SCREENING QUESTIONNAIRE: CONTROLS

DATE:_____

NAME AND SURNAME_____

DATE OF BIRTH_____AGE (years) _____

WEIGHT_____(kg) HEIGHT_____(m) BMI_____(kg/m²)

Highest academic qualification achieved:_____

What is your current profession:_____

Please answer yes or no to the following questions:

		YES	NO
1	Are you currently pregnant?		
2	Are you currently breastfeeding?		
3	Have you ever been diagnosed with an eating disorder such as anorexia or bulimia?		
4	Have you ever been diagnosed with depression?		
5	Do you suffer from Graves disease?		
6	Have you used weight reduction aids regularly over the past two years? If Yes, specify: Name(s) of aid_____ How often used_____		
7	Have you lost any weight in the last 3 months? If yes, how much _____ **OR:** Have your clothes got looser / have you reduced a dress size in the last three months?		
8	If you have answered yes to question **7** above, do you think you have lost weight because: • You have been ill: • You have been trying to lose weight: • You have been on new medication which has made you lose weight: • You are not sure: • Other: Please specify: _____		
9	Are you currently suffering from any of the following symptoms: blocked or runny nose, cold, flu, sinusitis, trouble hearing, ear infection or coughing?		
10	Are you suffering from any chronic diseases? (eg. diabetes, kidney disease, liver disease, cancer, other) If yes, specify:_____		

11 Have you suffered from any of the following in the last three months:

	NO	YES	IF YOU ANSWERED YES			
			How often in the last three months (eg. One time only, once a week, daily etc)	**Please name any medication you took to treat the condition**	**Were you hospitalized ?**	
					Yes	**No**
A painful rash / blisters on skin						
Regular bouts of diarrhoea / vomiting						
Sore mouth or tongue						
Thrush : white spots on tongue or inside cheeks.						
Recurrent bladder infections						
Pneumonia						
Painful cough						
					YES	**NO**
12	Have you been hospitalized or received medication for any other illness not listed above?					
13	If you answered yes to question 15 above, please state what you were hospitalized for and what medications you took: Illness_____ Medications_____					

14. Please complete the following table which is related to physical activity:

Do you take part in any of the following:	**No**	**Yes**	**IF YOU ANSWERED YES**	
			Number of times you do this exercise per week	**Length of time during each exercise session**
Gym				
Going for a walk				
Fast walking				
Jogging / running				
Tennis				
Squash				
Swimming				
Other (specify)				

Contact Details

Telephone (H)_____ (W): _____

(Cellular) _____ e mail:_____

Screening Questionnaire

Caucasian Cases

Eligible for study

Today's date | | | / | | | / | 2 | 0 | 0 | |
d d m m y y y y

Name ..... Surname: _____

Date of birth | | | / | | | / | 1 | 9 | | | Age: | | | years
d d m m y y y y

Weight | | , | | kg Height | | , | | | m BMI | | , | | |

Highest academic qualification achieved .....

What is your profession currently _____

Please answer yes or no to the following questions

Are you currently pregnant 1. Yes ☐ 2. No ☐ 3. Not applicable ☐

Are you currently breast feeding 1. Yes ☐ 2. No ☐ 3. Not applicable ☐

Have you ever been diagnosed with Anorexia 1. Yes ☐ 2. No ☐

Have you ever been diagnosed with Bulimia 1. Yes ☐ 2. No ☐

Have you ever been diagnosed with a Psychiatric illness 1. Yes ☐ 2. No ☐

If yes, specify:

Do you have a history of drug or alcohol abuse 1. Yes ☐ 2. No ☐

Do you suffer from Graves disease 1. Yes ☐ 2. No ☐

Do you use weight reduction aids on a regular basis 1. Yes ☐ 2. No ☐

If yes, specify: Name(s) of aids:

How often using it:

Contact details of potential subject

Telephone (home) ( ) Cell phone

Telephone (work) ( ) E-mail

In which town/ city/ suburb do you live? Stellenbosch ☐ Somerset-West ☐ Strand/ G'bay ☐ Paarl ☐

Other, specify ☐

In which town/ city/ suburb do you work? Stellenbosch ☐ Somerset-West ☐ Strand/ G'bay ☐ Paarl ☐

Other, specify ☐

SCREENING QUESTIONNAIRE	**Zulu Cases**

Today's date…… Name and surname…… ……. Date of birth…… Age (years)…… Weight (kg) (1)…… (2)…… Blood pressure (sitting and left arm)……		Height (m)……. (0nly do 3 measurements later if subject qualifies for study)	BMI……	**Eligible for study**
Highest academic qualification achieved…… What is your current profession ……				
Please answer yes or no to the following questions: 1. Are you currently pregnant? 2. Are you currently breast feeding? 3. Have you ever been diagnosed with an eating disorder such as anorexia or bulimia? 4. Have you ever been diagnosed with a psychiatric illness? If yes, please specify:……	**Yes**	**No**	**Not applicable**	**Eligible for study**

5. Do you have a history of drug or alcohol abuse? 6. Do you have problems with your thyroid gland, e.g. Grave's disease? 7. Are you diabetic? 8. Have you used weight reduction aids regularly over the past two years? If yes, please specify: Name(s) of aid:…… How often used:……..				

9. Have you gained any weight/increased a dress size in the last 3 months? If yes, how much……..

10. If you answered yes to question 9, do you think you have gained weight because:

10.1 You have been on medication that has made you gain weight……..

10.2 You are not sure……..

10.3 Other: please specify……

11. Have you lost any weight/ decreased a dress size in the last 3 months? If yes, how much……..

12. If you answered yes to question 11 above, do you think you lost weight because:

12.1 You have been ill……

12.2 You have been trying to lose weight……

12.3 You have been on medication that made you lose weight……..

12.4 You are not sure……..

12.5 Other, please specify……

13. Are you currently suffering from any chronic disease (apart from diabetes)? If yes, please specify……..

14. Have you suffered from any of the following in the last three months? If yes, please name any medication that you took to treat the condition and whether you were hospitalized for it.

14.1 Painful rash/ blisters on the skin……

14.2 Regular bouts of vomiting and/or diarrhoea……..

14.3 Sore mouth or tongue……..

14.4 Thrush: white spots on the tongue and/or inside the mouth……..

14.5 Regular bladder infections……

14.6 Bronchitis and/or pneumonia……..

14.7 Painful cough……..

15. Have you been hospitalized or received medication for any other illness not listed above? If yes, please state the illness and the medication you took……..

16. Has your body shape changed the past three month's e.g. bigger bust, smaller buttocks, thinner legs or weight gain around the tummy? If yes, please specify……

Contact details of potential subject:

Telephone (home)……..

Telephone (work)……

Cell phone……

E-mail……..

Suburb where you live……

Suburb where you work……

Entry into study: Baseline measurements Waist (cm) (1)…….. (2)…….. (3)…… (median/mean)	Hip (cm) (1)…… (2)…… (3)…… (median/mean)	Height (m) (3 decimal points) (1)…….. (2)…….. (3)…….. (med./mean)	
Exit out of study: Measurements at 4 months: Waist (cm) (1)…….. (2)…….. (3)…… (median/mean)	Hip (cm) (1)…… (2)…… (3)…… (median/mean)	Blood pressure ……..	
Follow-up: Measurements at 6 months: Waist (cm) (1)…….. (2)…….. (3)…… (median/mean)	Hip (cm) (1)…… (2)…… (3)…… (median/mean)	Blood pressure ……..	

ADDENDUM B

Informed Consent

PARTICIPANT INFORMATION AND INFORMED CONSENT FORM

TITLE OF RESEARCH PROJECT

The association between weight status (BMI) and weight management practices, personal and parental weight history, taste sensitivity and eating behaviour in Zulu women: A case control study.

REFERENCE NUMBER: **207 / 2008**

PRINCIPAL INVESTIGATOR: Fiona Herrmann RD

ADDRESS: Division of Human Nutrition
Department of Human Biology
Faculty of Health Sciences
University of Cape Town
Observatory

CONTACT NUMBER: 084 299 8898

We would like to invite you to participate in this research study. Please take some time to read through the included information, which will explain the details of the project.

What is the study about?

This study aims to determine whether there is a link between body weight, weight control practices and personal and parental weight history. We also aim to determine whether there is an association between taste sensitivity, eating behaviour and body weight. To answer these questions, we plan to compare obese women with normal weight women (controls).

This research study has been approved by the ethics **Committee for Human Research at the University of Cape Town** and it will be conducted according to international and locally accepted ethical guidelines for research, namely the Declaration of Helsinki (2000), South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

This is a sub-study of a larger study which is investigating the association between weight reduction success and genotype. Since you may fit the criteria for the control group for this study, you are invited to participate.

What will be expected of you?

- You will be asked to complete a screening questionnaire to determine whether you fit the criteria to take part (in person or telephonically)
- You will be weighed in light clothing and your height taken with a vertical height measure by trained personnel
- You will be requested to provide information about your weight history, your family's weight history, your weight management practices and eating behaviour, (approx 15-30 minutes)
- You will be required to place a piece of blotting paper (3cm diameter) on your tongue. It is saturated with a harmless chemical compound that can have a bitter taste for some people. This will be used to test your taste sensitivity.

Are there any risks involved?

There are no risks involved in participating in this study. You may, however, feel some discomfort when tasting the piece of paper which is saturated with a chemical compound as it may taste bitter to some people.

How will you benefit?

You will have an accurate BMI assessment done, discover your taster status and learn about its association with body weight. You will also be involved in research which will help to determine long term strategies to assist in obesity management in South Africa. Participants will not be paid to take part in this study.

Where will this information be collected?

In and around Durban and Pietermaritzberg

Will your confidentiality be protected?

Your privacy will be protected at all times. Your identity will be kept confidential and no information will be associated with your name. The research staff will only use a coded number when dealing with the information you provide to us, access will be limited to authorized scientists and any scientific publications, lectures or reports resulting from the study will not identify you by name.

Please ask a member of the research team if there is any part of this project that you don't fully understand. It is very important that you understand clearly what this research entails and how you could be involved. Your participation is **entirely voluntary** and you are free to decline to participate. If you decline, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study even if you have initially agreed to take part

Declaration by the participant

By signing below, I …….agree to take part in a research study entitled, "*The association between weight status (BMI) and weight management practices, personal and parental weight history, taste sensitivity and eating behaviour in Zulu women: A case control study".*

I declare that:

- I have read (or had read to me) this information and consent form and it is written in a language with which I am fluent and comfortable. I have had a chance to ask questions and all my questions have been adequately answered.
- I understand taking part in this study is voluntary and I have not been pressurized into taking part.
- I may choose to withdraw from this study at any time and will not be penalized or prejudiced in any way.

Signed at (*place)*……..on (*date*)……2008

……. ……..

Signature of participant Signature of witness

Declaration by investigator

I (*name*) …….declare that:

- I explained the information in this document to …….
- I encouraged her to ask questions and took adequate time to answer them.
- I am satisfied that she understands all aspects of the research as discussed above.
- I did /did not use a translator. (*If a translator is used then the translator must sign the declaration below.)*

Signed at (*place)*……..on (*date)……2008*

……. ……

Signature of investigator Signature of witness

ADDENDUM C

Research Questionnaire

Sociodemographic & weight questionnaire

Date | | | / | | | / | 2 | 0 | 0 | 7 |
d d m m y y y y

Code | | | | |

Name & Surname _____

1. Gender
   1. Male ☐
   2. Female ☐

2. Marital status
   1. Unmarried ☐
   2. Married ☐
   3. Divorced ☐
   4. Separated ☐
   5. Widowed ☐
   6. Living together ☐

3. Home language
   1. Afrikaans ☐
   2. English ☐
   3. Zulu ☐
   4. Other, specify : ☐

   ……

4. Highest level of education completed
   1. Matric ☐
   2. College certificate/ diploma ☐
   3. Technikon diploma/ degree ☐
   4. University degree ☐
   5. Other, specify : ☐

   ……

5. Do you live
   1. alone ☐
   2. with friends ☐
   3. with your husband/ wife/ partner ☐
   4. with your husband/ wife/ partner and children ☐
   5. With your parents ☐
   6. Other, please specify: ☐

   ……

6. In which of the following areas do you stay?
   1. Stellenbosch/ Somerset-West/ Strand/ Gordonsbay ☐
   2. Northern suburbs: Durbanville, Brackenvelle, Bellville etc. ☐
   3. Southern suburbs: ?? ☐
   4. Cape Town: city centre ☐
   5. Other, please specify: ☐

   ……

7. Do you smoke cigarettes
   1. Yes ☐
   2. No ☐

   If YES, please continue with question 9
   If NO, please continue with question 10

8. If yes, how many cigarettes do you smoke …… per day/ week/ month

9. Do you suffer from any of the following conditions?

	Yes	No
9.1. Heart disease	☐	☐
9.2. Diabetes Mellitus	☐	☐
9.3. High blood pressure	☐	☐
9.4. High blood cholesterol	☐	☐
9.5. Arthritis	☐	☐
9.6. Any other, please name	☐	☐

……

10. Write down the medications, supplements, vitamins, minerals that you use currently.

……...

……...

11. Are you currently seeing a psychologist for any problems?
1. Yes ☐
2. No ☐

12. What is the maximum weight that you have ever weighed (excluding during pregnancy)? ……kg

13. How long did you stay at this maximum weight?
1. <1 month ☐
2. 1-6 months ☐
3. >6 months ☐

14. How old were you when you were at this maximum weight? ……years

15. After the age of 20 years what was the minimum weight that you ever weighed? ……kg

16. How long did you maintain this minimum weight?
1. <1 month ☐
2. 1-6 months ☐
3. >6 months ☐

17. After the age of 20 years what was the weight that you were able to retain for the longest period of time ……kg

18. How long was this period?
1. <6 months ☐
2. 6-12 months ☐
3. 1-2 years ☐
4. 2-5 years ☐
5. >5 years ☐
6. Never maintained a stable weight ☐

19. Would you describe your weight during most of your childhood years (ages 2 to 10) as:
1. Underweight ☐
2. Normal weight ☐
3. Overweight ☐
4. Obese ☐

20. Would you describe your weight during most of your adolescent years (ages 11 to 19) as:
1. Underweight ☐
2. Normal weight ☐
3. Overweight ☐
4. Obese ☐

21. When you were between the ages of 20 to 25 years would you describe your weight as:
1. Underweight ☐

	2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Not applicable ☐	
22. When you were between the ages of 25 to 30 years would you describe your weight as:	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Not applicable ☐	
23. When you were between the ages of 30 to 35 years would you describe your weight as:	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Not applicable ☐	
24. When you were an adolescent, in comparison with your friends did you always weigh	1. More than them ☐ 2. The same as them ☐ 3. Less than them ☐ 4. Don't know ☐	
25. Would you classify these friends as	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐	
26. Would you consider your mother for most of your adolescent years to be:	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Did not know her ☐	
27. Would you consider your father for most of your adolescent years to be:	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Did not know him ☐	
28. How would you describe the weight of your living biological parents at present 28.1 Your father presently is	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Did not know him ☐	
28.2 Your mother presently is	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Did not know him ☐	
29. Do you have any living biological brothers or sisters (siblings) presently? If YES, please continue with question 30 If NO, please continue with question 32	1. Yes ☐ 2. No ☐	
30. How many living biological brothers or sisters do you have presently? ……		

31. How would you describe the weight of your living biological brothers or sisters at present (indicate their gender)

31.1	Sibling1: Your (sister ☐ OR brother ☐) presently is	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Not applicable ☐
31.2	Sibling 2: Your (sister ☐ OR brother ☐) presently is	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Not applicable ☐
31.3	Sibling 3: Your (sister ☐ OR brother ☐) presently is	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Not applicable ☐
31.4	Sibling 4: Your (sister ☐ OR brother ☐) presently is	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Not applicable ☐
31.5	Sibling 5: Your (sister ☐ OR brother ☐) presently is	1. Underweight ☐ 2. Normal weight ☐ 3. Overweight ☐ 4. Obese ☐ 5. Not applicable ☐

32. How many biological children do you have? ……..children

33. Would you describe your current weight as:
1. Underweight ☐
2. Normal weight ☐
3. Overweight ☐
4. Obese ☐

34. How satisfied are you with your current weight
1. Very much dissatisfied ☐
2. Somewhat dissatisfied ☐
3. Completely satisfied ☐

35. How afraid are you of becoming fat OR gaining weight
1. Very much afraid ☐
2. Somewhat afraid ☐
3. Not afraid at all ☐

36. Has anyone ever made a negative comment about your weight?
1. Yes ☐
2. No ☐

37. What do you think about your height
1. definitely too short ☐
2. maybe too short ☐
3. about the right height ☐
4. maybe too tall ☐
5. definitely too tall ☐

38. How often do you weigh yourself
1. at least once a day ☐
2. 1-2 times a week ☐

		3. 3-6 times a week	☐
		4. 1-3 times a month	☐
		5. a few times per year	☐
		6. rarely, if ever	☐
39.	Which of the following describes you the best at this moment?	1. I am completely satisfied with my present weight	☐
		2. I would like to gain some weight	☐
		3. I would like to lose 1-5 kg	☐
		4. I would like to lose 6-10 kg	☐
		5. I would like to lose 11-15 kg	☐
		6. I would like to lose 16-20 kg	☐
		7. I would like to lose >20 kg	☐
40.	Are you critical about overweight people	1. always	☐
		2. often	☐
		3. sometimes	☐
		4. rarely/ never	☐

			Yes	No
41.	Which of the following do you think initiated/ contributed to your weight gain and becoming overweight	41.1. The year after leaving school	☐	☐
		41.2. After a pregnancy	☐	☐
		41.3. After getting married	☐	☐
		41.4. After a tragedy e.g. death, divorce, job	☐	☐
		41.5. Always weigh too much	☐	☐
		41.6. Never had a problem with my weight	☐	☐
		41.7. Other, specify	☐	☐
		.....		

			Yes	No
42.	Are you dissatisfied with the sizes and/or shapes of the following body parts?	42.1. Arms	☐	☐
		42.2. Stomach	☐	☐
		42.3. Middle	☐	☐
		42.4. Hips	☐	☐
		42.5. Buttocks	☐	☐
		42.6. Thighs	☐	☐
		42.7. Calves	☐	☐

43.	Have you tried to lose weight previously	1. Yes	☐
		2. No	☐
44.	How old were you when you went on your first weight loss diet?	1. .....years	2. Did not diet previously ☐
45.	What is the maximum length of time that you have been on a reducing diet continuously:	1. <2 weeks	☐
		2. 2-4 weeks	☐
		3. 1 month	☐
		4. 2-6 months	☐
		5. >6 months	☐
		6. never diet before	☐
46.	What is the most weight you have ever lost on a diet?	1. .....kg	2. Did not diet previously ☐
47.	For your **MOST** successful weight loss diet did you	1. keep the weight off for at least 1 year	☐
		2. gain some of it before a year passed	☐

		3. gain all of it before a year passed	☐	
		4. I have never lose weight on a diet	☐	
		5. Not applicable	☐	
			Yes	**No**
48.	Indicate which of the following methods you used to lose weight in the past, even if you used it only once or very briefly.	48.1. Balanced slimming diet	☐	☐
		48.2. Moderate calorie restriction	☐	☐
		48.3. Increase in physical activity	☐	☐
		48.4. Skip one or more meals	☐	☐
		48.5. Eat less or nothing between meals	☐	☐
		48.6. Fasting/ starvation (one or more days)	☐	☐
		48.7. Weigh-less	☐	☐
		48.8. Weight watchers	☐	☐
		48.9. Low carbohydrate and high protein diet e.g Dr Atkin's, The Zone diet, Sugar busters, The Pharmacy diet etc.	☐	☐
		48.10. Fast diets e.g. lose >2kg in 3 days.	☐	☐
		48.11. Diuretics	☐	☐
		48.12. Appetite suppressants	☐	☐
		48.13. Laxatives	☐	☐
		48.14. Vomiting	☐	☐
		48.15. Diet formulas, milkshakes, powders e.g. Herbalife	☐	☐
		48.16. Herb mixtures	☐	☐
		48.17. Machines/apparatus which brake down fat.	☐	☐
		48.18. Injections which help brake down fat.	☐	☐
		48.19. Surgery	☐	☐
		48.20. Other (Specify):	☐	☐
		……		
49.	With which **ONE** of the above methods were you most successful?	……..		
50.	What is your present goal weight?	……. kg		

ADDENDUM D

Three Factor Eating Questionnaire

Three-Factor Eating Questionnaire

Instructions

- Please answer **ALL** the questions by making a cross (X) in the block ☐ next to your choice for each question.
- Make only one cross (X) per question.

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	True ☐ False ☐
2.	I usually eat too much at social occasions, like parties and picnics.	True ☐ False ☐
3.	I am usually so hungry that I eat more than three times a day.	True ☐ False ☐
4.	When I have eaten my quota of kilojoules, I am usually good about not eating any more.	True ☐ False ☐
5.	Dieting is so hard for me because I just get too hungry.	True ☐ False ☐
6.	I deliberately take small helpings as a means of controlling my weight.	True ☐ False ☐
7.	Sometimes things just taste so good that I keep on eating even when I am no longer hungry.	True ☐ False ☐
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.	True ☐ False ☐
9.	When I feel anxious, I find myself eating.	True ☐ False ☐
10.	Life is too short to worry about dieting.	True ☐ False ☐
11.	Since my weight goes up and down, I have gone on reducing diets more than once.	True ☐ False ☐
12.	I often feel so hungry that I just have to eat something.	True ☐ False ☐
13.	When I am with someone who is overeating, I usually overeat too.	True ☐ False ☐
14.	I have a pretty good idea of the number of kilojoules in common food.	True ☐ False ☐
15.	Sometimes when I start eating, I just can't seem to stop.	True ☐ False ☐
16.	It is not difficult for me to leave something on my plate.	True ☐ False ☐
17.	At certain times of the day, I get hungry because I have gotten used to eating then.	True ☐ False ☐

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	True ☐ False ☐
19.	Being with someone who is eating often makes me hungry enough to eat also.	True ☐ False ☐
20.	When I feel blue, I often overeat.	True ☐ False ☐
21.	I enjoy eating too much to spoil it by counting kilojoules or watching my weight	True ☐ False ☐
22.	When I see a real delicacy, I often get so hungry that I have to eat right away.	True ☐ False ☐
23.	I often stop eating when I am not really full as a conscious means of limiting the amount that I eat.	True ☐ False ☐
24.	I get so hungry that my stomach often seems like a bottomless pit.	True ☐ False ☐
25.	My weight has hardly changed at all in the last ten years.	True ☐ False ☐
26.	I am always hungry so it is hard for me to stop eating before I finish the food on my plate.	True ☐ False ☐
27.	When I feel lonely, I console myself by eating.	True ☐ False ☐
28.	I consciously hold back at meals in order not to gain weight.	True ☐ False ☐
29.	I sometimes get very hungry late in the evening or at night	True ☐ False ☐
30.	I eat anything I want, any time I want.	True ☐ False ☐
31.	Without even thinking about it, I take a long time to eat.	True ☐ False ☐
32.	I count calories as a conscious means of controlling my weight.	True ☐ False ☐
33.	I do not eat some foods because they make me fat.	True ☐ False ☐
34.	I am always hungry enough to eat at any time.	True ☐ False ☐
35.	I pay a great deal of attention to changes in my figure.	True ☐ False ☐
36.	While on a diet, if I eat a food that is not allowed, I often then splurge and eat other high caloric foods.	True ☐ False ☐
37.	How often are you dieting in a conscious effort to control your weight? Rarely ☐, Sometimes ☐, Usually ☐, Always ☐	

Three-Factor Eating Questionnaire

Instructions

- Please answer **ALL** the questions by making a cross (X) in the block ☐ next to your choice for each question.
- Make only one cross (X) per question.

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	True ☐ False ☐
2.	I usually eat too much at social occasions, like parties and picnics.	True ☐ False ☐
3.	I am usually so hungry that I eat more than three times a day.	True ☐ False ☐
4.	When I have eaten my quota of kilojoules, I am usually good about not eating any more.	True ☐ False ☐
5.	Dieting is so hard for me because I just get too hungry.	True ☐ False ☐
6.	I deliberately take small helpings as a means of controlling my weight.	True ☐ False ☐
7.	Sometimes things just taste so good that I keep on eating even when I am no longer hungry.	True ☐ False ☐
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.	True ☐ False ☐
9.	When I feel anxious, I find myself eating.	True ☐ False ☐
10.	Life is too short to worry about dieting.	True ☐ False ☐
11.	Since my weight goes up and down, I have gone on reducing diets more than once.	True ☐ False ☐
12.	I often feel so hungry that I just have to eat something.	True ☐ False ☐
13.	When I am with someone who is overeating, I usually overeat too.	True ☐ False ☐
14.	I have a pretty good idea of the number of kilojoules in common food.	True ☐ False ☐
15.	Sometimes when I start eating, I just can't seem to stop.	True ☐ False ☐
16.	It is not difficult for me to leave something on my plate.	True ☐ False ☐
17.	At certain times of the day, I get hungry because I have gotten used to eating then.	True ☐ False ☐

ADDENDUM E

Labeled Magnitude Scale

TASTE SENSITIVITY

CODE ☐☐☐

NAME & SURNAME: _____