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Psycho-markers of weight loss; the roles of TFEQ Disinhibition and Restraint in exercise-induced weight management

Running title: Disinhibition, Restraint exercise and weight loss

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Abstract

Eating behaviour traits, namely Disinhibition and Restraint, have the potential to exert an effect on food intake and energy balance. The effectiveness of exercise as a method of weight management could be influenced by these traits. 58 overweight and obese participants completed 12-weeks of supervised exercise. Each participant was prescribed supervised exercise based on an expenditure of 500kcal/session, 5d/week for 12-weeks. Following 12-weeks of exercise there was a significant reduction in mean body weight (-3.26±3.63 kg), fat mass (FM: -3.26±2.64 kg), BMI (-1.16±1.17 kg/m^2) and waist circumference (WC: -5.0±3.23 cm). Regression analyses revealed a higher baseline Disinhibition score was associated with a greater reduction in BMI and WC, while Internal Disinhibition was associated with a larger decrease in weight, % FM and WC. Neither baseline Restraint or Hunger were associated with any of the anthropometric markers at baseline or after 12-weeks. Furthermore, after 12-weeks of exercise, a decrease in Disinhibition and increase in Restraint were associated with a greater reduction in WC, whereas only Restraint was associated with a decrease in weight. Post-hoc analysis of the sub-factors revealed a decrease in External Disinhibition and increase in Flexible Restraint were associated with weight loss. However, an increase in Rigid Restraint was associated with a reduction in % FM and WC. These findings suggest that exercise-induced weight loss is more marked in individuals with a high level of Disinhibition. These data demonstrate the important roles that Disinhibition and Restraint play in the relationship between exercise and energy balance.

Key words: Disinhibition, Restraint, TFEQ, weight loss, eating behaviour, exercise.

Introduction

With rising levels of obesity, the need to improve the effectiveness of weight control interventions is crucial. Exercise and physical activity are key behaviours which are constantly being targeted to improve weight loss opportunities. The identification of predictors of weight loss, including pre-treatment, within treatment and weight loss maintenance could help to improve the outcomes of weight control programmes. In this way weight control treatments could be tailored to meet individual needs, where those less likely to succeed would receive specific or supplementary treatments (Teixeira. Going, Sardinha & Lohman, 2005). The individual variability in the susceptibility to gain weight in an obesigenic environment (Blundell, Stubbs, Golding et al., 2005), and in response to weight loss interventions (e.g. King, Hopkins, Caudwell, Stubbs & Blundell, 2007), has been documented. It is likely that this large individual variability has contributed to the modest success rates of long term weight loss within weight control programs (Teixeira, Going, Houtkooper et al., 2004; Lean, 2000, Jeffery, Drenowski, Epstein et al., 2000). Thus the identification of significant predictors of susceptibility to gain weight and the resistance to lose weight is important in improving the strategies and interventions which promote weight loss and improve health. In addition, the identification of psychological characteristics that help explain the individual variability within weight loss interventions would also be valuable.

The importance of an individual's response to a weight loss intervention, in terms of their eating behaviour, is clear. If an individual compensates for the intended energy deficit of the intervention *per se*, s/he will fail to lose weight at the expected rate. King et al (2007; King, Caudwell, Hopkins, Stubbs, Naslund & Blundell, 2009) demonstrated this by reporting large individual variability in weight loss (-14.7 to + 1.7kg) in response to a 12 week supervised exercise intervention. Individuals who lost less than the theoretically expected amount of body weight tended to compensate for the increase in energy expenditure by increasing their energy intake.

Through understanding an individual's response to an exercise intervention, it would be possible to predict their susceptibility to compensate, thus experience lower weight loss. Given the potency of eating behaviour traits (e.g., Disinhibition and Restraint) to influence body weight via energy intake, there is scope to use these behavioural traits as psycho-markers of compensation. The Three Factor Eating Questionnaire (TFEQ: Stunkard and Messick, 1985) is used to assess eating behaviour traits. The self-report questionnaire is designed to measure three eating behaviour traits: Restraint, Disinhibition and Hunger. Restraint refers to the cognitive control to restrict food intake to achieve a better control of body weight - for example, stopping eating before reaching satiation, avoiding high fat foods and consuming small portions of food. Disinhibition refers to a tendency to eat opportunistically, for example, eating in the presence of others eating, being responsive to the palatability of food and eating in response to negative mood. Hunger relates to an individual's perception of their level of motivation to eat and the extent to which this elicits food intake. The TFEQ has been widely used in weight loss research (Bryant, King & Blundell, 2008) to measure eating behaviour traits and their role in weight control. The factors of Disinhibition and Restraint in particular, have emerged as important eating behaviour traits which influence weight gain, weight loss and weight maintenance.

The role of Disinhibition and Restraint in weight gain has received attention in recent years (e.g. Hays and Roberts, 2008; Dykes, Brunner, Martikainen & Wardle, 2004; Hays, Bathalon, McCrory, Roubenoff et al., 2002), where Disinhibition in particular, has been associated with an increased weight and BMI. Restraint on the other hand has produced mixed findings, whereby an increase in Restraint has been associated with a lower weight (e.g. Bas and Donmez, 2009; Westerterp-Plantenga et al., 1998) or with weight gain (e.g. Hays et al., 2008; Pilner and Saunders, 2008). In addition, the role of these eating behaviour traits in weight loss interventions has also emerged. Their use as predictors of weight loss, as well as their influence on weight change and during the weight maintenance period has been addressed. The studies which have utilised Disinhibition and Restraint as measures of eating behaviour traits have adopted varied methodologies including combinations of dietary intervention, physical activity and behavioural modification. Findings from these studies suggest that baseline Restraint, Disinhibition and Hunger play a modest role in predicting subsequent weight loss (for a review of pre-treatment predictors of weight control see Teixeira et al., 2005). However, more recently, evidence has come to light which suggests the baseline level of Internal Disinhibition (a sub-factor of Disinhibition measuring eating episodes prompted by negative emotion: Niemeier, Phelan, Fava & Wing, 2007) is predictive of weight loss success, where a higher Internal Disinhibition predicted less successful weight loss. In addition, Flexible Restraint (a sub-factor of Restraint measuring a tendency to restrict food intake but allowing occasional intake of 'forbidden foods'; Westenhoefer et al., 1999) has been recently shown to be positively associated with weight loss success (Teixeira et al., 2010).

A more relevant role for the TFEQ traits in weight control is their influence on weight loss during an energy balance intervention. A robust finding is that successful weight loss is associated with a decrease in Disinhibition and Hunger, and an increase in Restraint (e.g.

Pekkarinen, Takala, Mustajoki, 1996; Foster, Wadden, Swain et al., 1998; Westerterp-Plantenga, Kempan, Saris, 1998; Keirnan, King, Stefanick et al., 2001; Chaput, Drapeau, Hetherington et al., 2005). That is, individuals who successfully lose weight respond by increasing their control over eating (Restraint) and reducing their opportunistic eating behaviour (Disinhibition). More specifically, Butryn et al (2009) found that individuals who showed a larger decrease in their level of Internal Disinhibition (e.g. eating in response to negative affect) during the intervention, experienced the greatest weight loss. Whereas evidence suggests that those who see an increased in Flexible Restraint attain a greater weight loss (Elfhag and Rossner, 2005; Teixeira et al., 2010).

Furthermore, there is a body of evidence which suggests eating behaviour traits influence weight regain following weight loss. A recent review demonstrated that a higher level of Disinhibition (measured during and after weight loss intervention), Hunger and binge eating (following weight loss) predicted weight regain, whereas a higher Restraint (measured during and after weight loss intervention) predicted a maintained weight loss (Elfhag and Rossner, 2005). In support of this evidence, Karlsson et al (1994) and McGuire et al., (1999) found that those who manage to maintain weight loss, are characterized by a lower Disinhibition and Hunger score; where an initial high Disinhibition score is predictive of weight regain. In addition, those individuals who have a high level of Flexible Restraint compared to Rigid Restraint (a dichotomous, all or nothing approach to food intake restriction) are more successful at weight loss maintenance (Westenhoefer 2001). Thus it appears that there are differences in the significance of eating characteristics in relation to weight loss and weight regain, where to date, data support a more influential role for eating behaviour traits (Restraint, Disinhibition and Hunger) in predicting weight regain, rather than weight loss.

Most of the evidence that assesses the effects of energy balance interventions on TFEQ scores and their respective roles in weight control arise from cross-sectional, or dietary-restriction studies. The purpose of this study was to explore the predictive power of TFEQ traits in determining the magnitude of exercise-induced weight loss, and to examine any changes in TFEQ factors during the. Previous evidence has suggested an uncoupling between energy expenditure and energy intake (King et al 1994; 1999), whereby an increase in exercise does not necessarily lead to an up-regulation of energy intake. Therefore, this study examines if an exercise-induced increase in energy expenditure over a prolonged period leads to changes in a psychological drive to eat (eating behaviour traits). It was hypothesised that changes in TFEQ Disinhibition, Hunger and Restraint would be better predictors of exercise-induced weight loss compared with baseline Disinhibition, Hunger and Restraint due to physiological changes (e.g. appetite peptides; see Blundell et al., 2008 and Martins et al 2008 for a review) occurring during the exercise intervention which will have a more direct impact upon eating behaviour traits.

Method

Participants

Fifty-eight overweight and obese participants (men = 19, women = 39) completed an exercise programme of high intensity exercise sessions, five times per week for 12 weeks (baseline mean BMI = 31.83±4.46 kg/m^2, age = 35.57±9.78y, VO_2max = 29.09±5.68 ml/kg/min). Recruitment was advertised via posters, recruitment emails and adverts in the local press. The study was advertised as an investigation into the influence of exercise on health. Participants were sedentary at baseline, non-smokers and not taking any medication that would affect appetite or physical activity levels. Due to the prescription of a substantial exercise programme, participants were required to obtain medical permission from their General Practitioner in order to commence the study.

Design and Procedure

The study protocol was approved by the Ethics Committee of the Institute of Psychological Sciences, University of Leeds. All participants provided written, informed consent before starting the study.

During a 3 month study participants exercised under supervision, for 5d/week, at an intensity of 70% VO_{2max} for 12 weeks. Each exercise session was designed to expend 500 kcal. Every four weeks, a probe day was carried out where participants were required to complete a VO_{2max} test, body composition and the Three Factor Eating Questionnaire (TFEQ: Stunkard and Messick, 1985). This was part of a larger study, therefore other variables were assessed during the probed days, but not reported here (see King et al., 2009).

Exercise Protocol

The submaximal VO_2 tests were performed using a bicycle ergometer and the Vmax29 indirect calorimeter (Sensormedics, USA). Heart rate (POLAR heart rate monitors; S610, Finland) and expired air were measured every four minutes during an incremental cycling test which was terminated when the participants' age-predicted maximum heart rate was achieved. These data were used to prescribe the duration and intensity required for each individual to attain the 500 kcal per session. The exercise sessions were ramped in order to attain the prescribed energy expenditure to accommodate changes in aerobic fitness. Body composition and body weight were measured every 4 weeks using the bioimpedance technique (BC-300 Body Composition Analysis System. Spacelabs). Waist circumference was also measured every 4 weeks.

At the outset and during the study, participants received no dietary advice or instruction on their diet or eating patterns. The main aim of the study was to determine any influence exercise had on eating behaviour or energy intake in an overweight and obese sample.

Energy Intake

Energy intake was measured during probe days every 4 weeks. Participants were instructed to eat *ad libitum*, until comfortably full. Energy intake was calculated by weighing food before and after consumption (to the nearest 0.1g). To calculate test meal energy intake energy equivalences for protein, fat and carbohydrate were 4, 9 and 3.75kcal/g respectively. Breakfast was a choice of cereal, toast, butter and jam (strawberry or raspberry), and tea or coffee. Lunch was cheese, salad sandwiches, ready salted crisps and fruit malt loaf and dinner consisted of lasagne, peas and raspberry yoghurt.

The Three Factor Eating Questionnaire (TFEQ)

The TFEQ (Stunkard & Messick, 1985) is a 51-item questionnaire measuring Restraint (Cronbach's α 0.83), Disinhibition (Cronbach's α 0.76) and Hunger (Cronbach's α 0.82). This questionnaire is composed of two parts; the first 36-items use a dichotomous (true/false) response format, while the latter 15-items use a four point Likert scale response format. In addition to the original factors, sub-factors of Disinhibition and Restraint were measured. The sub-factors of Internal (Cronbach's α 0.76) and External Disinhibition (Cronbach's α 0.40) were calculated using both the dichotomous and Likert scale response items (Niemeier et al., 2007). Internal Disinhibition is related to eating episodes which are prompted by negative affect (e.g. feeling anxious or low), while External Disinhibition refers to the influence external cues (such as the presence of others eating) have on initiating eating episodes. In addition, the sub-factors of Restraint: Flexible and Rigid Restraint were measured (Westenhoefer, Stunkard & Pudel, 1999). Both of these sub-factors measure efforts at restricting food intake, whereby Rigid Restraint (Cronbach's α 0.75) refers to an all or nothing approach to dieting, whereas Flexible Restraint (Cronbach's α 0.50) refers to a much more regulated approach to dieting, where 'forbidden' foods can be eaten in limited amounts without feelings of guilt. The TFEQ was completed by participants under controlled and standardised conditions at each of the 4 time points. That is, at the same time of day and fasted (participants were asked to abstain from consuming food from 22.00 the previous night and were asked to only consume water).

Statistical analyses

To determine whether Restraint, Disinhibition and Hunger were associated with success in weight loss at baseline and during the intervention, a series of stepwise multiple regression analyses were performed on residualized outcome variables (e.g. change in weight regressed against baseline weight) to adjust for baseline values. The outcome variables were baseline weight, change in weight, baseline %FM and change in %FM and baseline waist circumference (WC) and change in WC. Although there is some overlap between these outcome variables, it was deemed necessary to perform a regression analysis including them all due to the health risk factors associated with each measure (e.g. %FM is a measure of general body fat whereas WC is a proxy of visceral fat). Weight was included to signify overall success in the weight reduction intervention). BMI was controlled for in the analyses. Sub-factors of Restraint and Disinhibition were also examined as predictors: Rigid and Flexile Restraint (Westenhoefer, Stunkard and Pudel, 1999) and Internal and External Disinhibition (Niemeier et al., 2007). Regression analyses were performed using baseline and residualized TFEQ predictor variables. In each regression model, baseline BMI was entered at step 1, followed in step 2 by either Restraint, Disinhibition, Hunger and energy intake together, or the subfactors (Rigid and Flexible Restraint, Internal and External Disinhibition and energy intake) together to predict the outcome. As the regression model was stepwise the non-significant predictors were removed from the model, thus only the retained, significant predictors are presented in the Tables 2, 3 and 4.

There was large variability in exercise-induced weight and fat mass loss (+1.70kg to -14.70kg). Based on a previous method of identifying compensation for the exercise-induced increase in energy expenditure (i.e., to classify responders and non-responders, the sample was divided into two groups (King et al, 2009, King et al, 2007). Using the measured exercise-induced energy expenditure and changes in body composition it was possible to divide the participants into responders (R) and non-responders (NR) based on their actual weight change compared to that predicted from the measured changes in body composition. Therefore, the terms responders and non-responders are based on individuals' actual body composition changes relative to their predicted changes. For each participant, predicted energy imbalance was estimated by comparing the cumulative total of energy expended (from the monitored exercise sessions) with the changes in fat mass and fat free mass. Calculations were based on the assumed energy costs of 9540kcal/kg and 1100kcal/kg of fat mass and fat free mass respectively (Elia, 1992). This method of classification identified 32 responders and 26 non-responders. The ratio of males:females in each group was similar. To examine the difference between the responders and non-responders with respect to their weight loss and change in eating behaviour 2x4 mixed measures ANOVAs were conducted on changes in body weight, body composition, energy intake and TFEQ factors.

Results

Anthropometry

Pooled data

Table 1 presents anthropometric data. After 12 weeks of exercise there was a significant reduction in mean body weight ($F_{(3, 165)}$ = 42.24, $p<0.001$), FM ($F_{(3, 150)}$ = 38.14, $p<0.001$) and %FM ($F_{(3, 150)}$ = 26.75, $p<0.001$) whereas there was a small, but statistically non-significant increase in lean mass (LM) of 0.56kg ($F_{(3, 156)}$ = 1.18, n.s.). There was also a significant reduction in waist circumference ($F_{(3, 162)}$ = 69.79, $p<0.001$). No significant change in energy intake was observed over time.

Table 1 about here

Changes in TFEQ scores

There was a statistically significant reduction in Disinhibition (-17%) and increase in Restraint (20%) after 12 weeks of exercise ($F_{(3, 144)} = 8.68$, $p<0.001$ and $F_{(3, 144)} = 8.54$, $p<0.001$). However, there was no significant change in Hunger scores ($F_{(3, 144)} = .19$, n.s.) (see figure 1). There was a significant decrease in Internal (-15%) and External Disinhibition (-20%) ($F_{(3, 141)} = 5.54$, $p = 0.001$ and $F_{(3, 141)} = 4.50$, $p<0.01$; respectively). Whereas Rigid (33%) and Flexible Restraint (20%) significantly increased ($F_{(3, 141)} = 5.44$, $p<0.001$ and $F_{(3, 141)} = 5.81$, $p = 0.001$; respectively) (see figure 2).

Figures 1 and 2 about here

Baseline TFEQ scores as predictors of weight loss

Significant correlations were observed between baseline Disinhibition and weight loss (r = -.29, df = 56, p<0.029), and change in waist circumference (r = -.34, df = 56, p=0.01). Internal Disinhibition correlated significantly with change in weight, % FM and waist circumference (r = -.34, df = 56, p=0.009; r = -.30, df = 56, p= 0.029 and r = -.26, df = 56, p=0.049 respectively). External Disinhibition was negatively associated with change in waist circumference (r = -.26, df = 56, p=0.049). This demonstrates that the higher the initial level of Disinhibition, the greater the change in weight loss parameters. In addition, baseline Hunger was significantly associated with change in % FM (r = -.28, df = 56, p=0.042), showing that the higher the initial level of Hunger, the greater the decrease in % FM. Neither baseline Restraint nor its sub-factors, were significantly associated with change in any weight loss parameters.

A stepwise regression was carried out to determine whether baseline TFEQ traits (Restraint, Disinhibition and Hunger) contributed to the variability in weight loss and change in body composition. Baseline Disinhibition was found to account for independent variance in weight loss and change in waist circumference (see table 2). When the baseline sub-factors of Restraint and Disinhibition were analysed (Internal and External Disinhibition and Rigid and Flexible Restraint), Internal Disinhibition accounted for independent variance in change in weight, change in % FM, and change in waist circumference (see table 2). Energy intake was not significantly associated with weight loss parameters. These stepwise regression analyses suggest that the higher the initial level of Disinhibition, particularly Internal Disinhibition, the greater the success in change in weight loss parameters.

Table 2 about here

Baseline TFEQ scores and energy intake

Baseline Hunger correlated significantly with energy intake (r = 0.38, df = 55, p = 0.004). However there was no significant correlation with either Restraint (r = -0.15, df = 55, p = 0.27) or Disinhibition (r = 0.25, df = 55, p = 0.057). Of the sub-factors, Internal Disinhibition was positively associated with energy intake (r = 0.20, df = 55, p = 0.05). However the remaining sub-factors failed to reach significance: Rigid Restraint (r = -0.26, df = 55, p = 0.052), Flexible Restraint (r = 0.001, df = 55, n.s.) and External Disinhibition (r = -0.15, df = 55, p = n.s.)

The stepwise regression revealed that baseline Hunger scores significantly predicted energy intake, while BMI, Disinhibition and Restraint failed to reach significance (see table 3).

However, none of the sub-factors were significantly associated with changes in energy intake. These data demonstrate that a high baseline Hunger is associated with an increased energy intake.

Table 3 about here

Exercise-induced changes in TFEQ as predictors of weight change

Change in Disinhibition was significantly and positively correlated with changes in weight loss and waist circumference (r = 0.32, df = 56, p=0.015; r = 0.41, df = 56, p=0.001, respectively). A reduction in Hunger was also significantly associated with reductions in body weight loss (r = 0.31, df = 56, p=0.019). Whereas an increase in Restraint was associated with weight loss (r = -0.33, df = 56, p=0.13) and waist circumference (r = -0.44, df = 56, p = 0.01). These associations demonstrate show a decrease in Disinhibition and Hunger combined with an increase in Restraint are associated with weight loss parameters.

The residualized changes in TFEQ factors and sub-factors after 12 weeks of exercise were entered in to stepwise multiple regressions to determine their influence on residualized weight loss parameters. The analysis revealed that an increase in Restraint and a decrease in Disinhibition significant, independent predictors of a greater reduction in waist circumference. Whereas an increase in Restraint was associated with a greater loss in weight (see table 4). Upon examination of the change in TFEQ sub-factors, an increase in Flexible Restraint and a decrease in External Disinhibition were independent predictors of weight loss. The increase in Rigid Restraint predicted change in % FM and waist circumference. Changes in energy intake did not significantly predict changes in weight loss parameters.

Table 4 about here

Exercise-induced changes in TFEQ as predictors of energy intake

An increase in Restraint was significantly associated with a decrease in energy intake (r = -.32, df = 55, p = 0.015) - more specifically an increase in Flexible Restraint (r = -.28, df = 55, p = 0.037). Changes in the remaining TFEQ factors Disinhibition and Hunger were not significantly associated with changes in energy intake (r = -.10, df = 55, n.s.; r = 0.28, df = 55, n.s. respectively). Nor were the sub-factors of Internal Disinhibition, External Disinhibition or Rigid Restraint significantly associated with changes in energy intake (r = -.094 df = 55, n.s.; r = .08, df = 55, n.s.; r = -.16, df = 55, n.s. respectively).

A stepwise regression examining whether residualised changes in energy intake could be predicted by changes in TFEQ factors and sub-factors (residualized) revealed no significant associations.

Individual variability in weight loss

Responders and non-responders comparison

The responders showed a significantly greater reduction in weight ($F_{(3, 162)}$ = 27.41, p<0.001), BMI ($F_{(3, 162)}$ = 25.54, p<0.001) fat mass ($F_{(3, 147)}$ = 18.88, p<0.001), % fat mass ($F_{(3, 147)}$ = 22.85, p<0.001) and waist circumference ($F_{(3, 162)}$ = 4.41, p<0.01) compared to the non-responders. However there was no statistically significant difference between the two groups in energy intake despite the responders reporting a decrease and the non-responders an increase (see table 5).

Table 5 about here

Changes in TFEQ

There was no significant time*group interaction ($F_{(3, 141)}$ = .38, n.s.) or significant difference between the groups ($F_{(1, 47)}$ = .71, n.s.) in changes in Disinhibition. However, there was a significant group*time interaction for Restraint ($F_{(3,141)}$ = 2.65, p = 0.05). The responders experienced a marked increase in Restraint following 12 weeks of exercise, whereas the non-responders experienced a modest increase (see table 6). There was a significant main effect of group on Restraint, showing that responders had a higher Restraint score overall ($F_{(1, 47)}$ = 8.46, p<0.01). Hunger was resistant to change during the exercise intervention ($F_{(3, 141)}$ = .12, n.s.) and the scores were not significantly different between the two groups ($F_{(3, 141)}$ = .90, n.s.).

Table 6 about here

The sub-factor analysis showed similar results. There was a significant reduction in External Disinhibition (see table 6) after 12 weeks ($F_{(3, 141)}$ = 4.40, p<0.01), but no significant time*group interaction ($F_{(3, 141)}$ = 2.21, n.s.) or difference between the groups ($F_{(1, 46)}$ = .02, n.s.). Internal Disinhibition decreased significantly following the intervention ($F_{(3, 141)}$ = 5.35, p<0.01), but there was no time*group interaction ($F_{(3, 141)}$ = .93, n.s.) or main effect of group ($F_{(1, 46)}$ = 2.81, n.s.). Rigid Restraint score was consistently higher in the responders compared with the non-responders ($F_{(1, 46)}$ = 6.35, p = 0.01). The responders also experienced a greater increase in Flexible Restraint compared to the non-responders ($F_{(1,141)}$ = 2.89, p<0.05), and a consistently higher Flexible Restraint score ($F_{(1, 46)}$ = 4.56, p<0.05).

Discussion

The main outcomes of this study show that the variability in exercise-induced weight and body composition changes are associated with eating behaviour traits. The data also highlight that eating behaviour characteristics are predictive of weight loss. Higher baseline Disinhibition was associated with a greater reduction in weight and waist circumference. In essence the study demonstrated that 12 weeks of supervised exercise alters eating behaviour traits, which is reflected in a reduced tendency to eat opportunistically (Disinhibition) and an increased deliberate control over eating (Restraint). This has positive implications for the role of exercise in weight management. The magnitude of change in eating behaviour scores is a predictor for successful weight loss. Individuals who experience the largest decrease in Disinhibition and increase in Restraint (particularly Rigid Restraint) concomitantly experience the largest reduction in weight, BMI and waist circumference.

These data suggest that baseline Disinhibition is a predictor of a greater reduction in weight and waist circumference, contrary to previous evidence (Teixeira et al., 2005) which has generally indicated that TFEQ factors are poor predictors of subsequent success with weight loss parameters. Disinhibition is a trait which is typically associated with resistance to lose weight and promotion of weight regain (e.g. McGuire et al., 1999). The identification of significant predictors in the current study could be due to the employment of a single method of energy balance intervention, rather than a combination of dietary, behavioural and physical activity interventions used in previous studies (e.g. Teixeira et al., 2005; Chaput et al., 2005; Cuntz, Leibbrand, Ehrig et al., 2001). Furthermore, the relatively short duration and supervision and mandatory control of the exercise intervention are likely to have influenced the outcomes. This means that it is likely that high Disinhibition individuals would benefit more from supervised exercise in which the performance of the exercise is structured and obligatory. A key feature of this study was that the exercise sessions were supervised and mandatory. In most exercise weight loss interventions (e.g. Niemeier et al., 2007), increased physical activity is encouraged but tends not to be not formally assessed or monitored. Therefore, the responsibility and motivation to adhere to the exercise is strongly placed on the individual. High Disinhibition individuals have been characterised by low levels of habitual physical activity (Bryant, Kiezebrink, King, Blundell, 2010; Lawson, Williamson, Champagne et al., 1995), which seems likely to be related to a low self-efficacy to be physically active (Mata, Silva, Vieira et al., 2009). However, when the exercise is structured and supervised, high Disinhibition individuals respond better.

These changes in eating behaviour traits and body composition occurred independently of any marked changes in energy intake. However the data suggest that participants were experiencing a relative decrease in energy intake over the 12-weeks; where energy expenditure was increased by approx. 2500kcal every week, while energy intake remained fairly stable. This supports evidence suggesting exercise does not drive up energy intake (King et al., 1994), and also demonstrates that eating behaviour traits change independently of energy intake. The reduction in opportunistic eating and increase in restraint is reflected in the stable nature of energy intake, as intake is not being up-regulated by the exercise.

A mechanism by which exercise could be beneficial for high Disinhibition individuals is associated with changes in appetite peptide concentrations (Martins, Morgan, Truby, 2008). Levin et al (2004) demonstrated a positive relationship between leptin and Disinhibition, and a negative relationship between ghrelin and Disinhibition, suggesting some degree of resistance to the action of these peptides. In support of this, Blundell et al (2008) reported that Disinhibition was positively related to leptin and negatively related to ghrelin and adiponectin in women of varying weight status. In addition, a recent finding also suggests that women with a combination of high Disinhibition and high Restraint show a blunted CCK response following a meal (Burton-Freeman & Keim, 2008). The action of these tonic and episodic appetite related peptides could relate to the opportunistic eating behaviour characteristic of individuals with a high Disinhibition. Interestingly, in contrast to Disinhibition, Restraint has been found to be positively associated with ghrelin and unrelated to leptin and insulin (Schur et al., 2008) in weight stable individuals, thus highlighting the complexity of the relationship between appetite peptide profiles and eating behaviour traits. The revelation of a significant relationship between Disinhibition and Restraint scores and peptides (ghrelin, leptin adiponectin and cholecystokinin) known to play significant roles in energy homeostasis (e.g. Klok, Jakobsdottir, Drent, 2007; Woods, Benoit, Clegg, Seeley, 2004), provides more evidence for the influential role of Disinhibition and Restraint in energy homeostasis. The variations in concentrations and sensitivity to the relevant peptides could contribute to the opportunistic and overeating behaviour seen in high Disinhibition and high Restraint individuals. Our hypothesis is that leptin resistance is associated with high Disinhibition (Blundell et al., 2008) which, in turn, predicts successful exercise-induced weight loss (when the exercise is obligatory). However, high leptin resistance and Disinhibition would be less likely to lead to good compliance (and weight loss) where exercise was simply prescribed but not supervised.

Post-hoc examination of the TFEQ sub-factors data yielded some useful findings. The recent emergence of the Internal and External Disinhibition sub-factors (Niemeier et al., 2007) has uncovered Internal Disinhibition as a particularly useful trait in predicting less success at weight loss (Niemeier et al., 2007; Butryn et al., 2009; Thomas, Bond, Pohl et al., 2009). In this study however, there was a trend for a higher baseline Internal Disinhibition to be associated with a greater success at reduction in weight loss parameters. However a decrease in both Internal and External Disinhibition at the end of the intervention were associated with an improvement in weight loss – an effect supported by Butryn et al (2009). The exclusive use of exercise and the intense supervision of the intervention could explain this discrepancy. As individuals with a high Internal Disinhibition are characterised by a tendency to eat in response to negative affect, it is hypothesised that increasing physical activity was beneficial in reducing this tendency. Mood was not measured as an outcome during this study, however it is hypothesised that increasing levels of exercise positively influenced mood as has been previously reported (e.g. Teychenne et al., 2008). In addition, an increase in Flexible Restraint was associated with weight loss while increases in Rigid Restraint were associated with reductions in %BF and reductions in waist circumference. This supports existing literature citing a role for an increased Flexible Restraint with improved weight loss (e.g. Andrade et al., 2010; Provencher et al., 2007). Of course the causal relationship of this is yet to be confirmed.

The phenomenon of individual variability in response to an exercise intervention has recently re-emerged (e.g. King et al., 2007; King et al., 2009; Colley, Hill, O'Moore-Sullivan et al., 2008; Snyder & Jacobsen, 1997). Data from the current study demonstrated that those individuals who experienced the most successful weight loss (responders) had a different eating behaviour profiles (in terms of TFEQ eating behaviour traits) to those who were not as successful (non-responders). The responders experienced the greatest increase in Restraint and decrease in Disinhibition. This supports previous evidence using a very low calorie diet intervention (Westerterp-Plantenga et al., 1998; Pekkarinen et al., 1996).

A limitation of the study however, was the absence of a control group. The main strength of the study is the structured and supervised exercise sessions, which maintained compliance in the participants. However it is acknowledged that this structured laboratory intervention would be difficult to apply in the free-living. This study was not designed to assess the efficacy of exercise as a public health intervention – the aim was to assess the effect of exercise on appetite, eating behaviour traits and weight.

In conclusion, these data indicate that a higher baseline Disinhibition is a significant predictor of exercise-induced reduction in BMI and waist circumference. Furthermore, a decrease in Disinhibition combined with an increase in Restraint is a predictor of successful weight loss and other anthropometric markers. Further research exploring the effectiveness of structured exercise interventions for individuals with a high Disinhibition is needed.

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Tables

Table 1 – Changes in body weight, BMI, body composition and energy intake during the 12 week exercise intervention (n = 58)

	Baseline	**Week 4**	**Week 8**	**Week 12**	**Change (Δ)**
BMI	31.82 (4.46)	31.35 (4.46)	31.09 (4.42)	30.66 (4.40)	-1.16 (1.17)***
Weight	90.85 (12.12)	89.72 (12.40)	88.76 (12.37)	87.59 (12.39)	-3.26 (3.33)***
Fat Mass	31.88 (9.39)	30.42 (9.59)	30.11 (9.75)	28.32 (9.39)	-3.56 (2.66)***
% Fat Mass	34.80 (7.75)	33.58 (8.27)	33.36 (8.44)	31.91 (8.97)	-2.60***
Waist circumference	101.37 (12.11)	99.75 (12.17)	97.86 (11.69)	96.28 (11.68)	-5.09 (3.23)***
Energy Intake	2337.02 (579.04)	2331.32 (645.31)	2340.36 (652.97)	2399.73 (723.58)	62.71 (556.91)

Change (Δ) represents difference between baseline (week 0) and week 12

***p<0.001

Table 2 stepwise regression model predicting change in weight loss parameters (residualized) with baseline TFEQ traits and their sub-factors

	Model	Predictor	B	SE B	β	Model R^2	ANOVA
Δ Weight	1	Disinhibition (baseline)	-.09	0.39	-0.29	0.08	p=0.03
Δ Waist circumference (cm)	2	Disinhibition (baseline)	-0.10	.04	-0.34	0.34	p=0.01
Δ Weight	3	Internal Disinhibition (baseline)	-0.15	0.05	-0.34	0.34	p=0.01
Δ % fat mass	4	Internal Disinhibition (baseline)	-0.12	0.05	-0.28	0.28	P=0.035
Δ waist circumference (cm)	5	Internal Disinhibition (baseline)	-0.12	0.06	-0.29	0.29	p=0.015

Variables included in the Model 1 and 2: baseline BMI, baseline energy intake, baseline Disinhibition, Restraint and Hunger

Model 3, 4 and 5: baseline BMI, baseline energy intake, Internal Disinhibition, External Disinhibition, Rigid Restraint and Flexible Restraint

Table 3 stepwise regression model predicting change in energy intake (residualized) with baseline TFEQ traits

	Predictor	B	SE B	β	Model R^2	ANOVA
Energy Intake	Hunger (baseline)	0.099	0.03	0.37	0.14	0.019

Variables included in the Model 1: baseline BMI, baseline Disinhibition, Restraint and Hunger

Table 4: stepwise regression model predicting change in weight loss parameters (residualized) with change in TFEQ traits (residualized) and sub-factors (residualized)

Outcome	**Model**	**Predictor**	**B**	**SE B**	**β**	**Partial R^2**	**Cumulative R^2**	**ANOVA**
Δ Weight	1	Δ Restraint	-0.37	0.13	-0.36	.	0.13	p=0.005
Δ Waist circumference	2	Δ Restraint	-0.42	0.12	-0.42	0.18	.	p=0.001
		Δ Disinhibition	0.25	0.12	0.26	0.07	0.25	p<0.001
Δ Weight	3	Δ Flexible Restraint	-0.35	0.12	-0.35	.	0.15	p=0.003
		Δ External Disinhibition	0.33	0.12	0.33	0.10	0.25	p<0.001
Δ % body fat	4	Δ Rigid Restraint	-0.29	0.14	-0.29	.	0.08	p=0.036
Δ waist circumference (cm)	5	Δ Rigid Restraint	-0.40	0.13	-0.40	.	0.16	p=0.002

Variables included in the Models 1 and 2: baseline BMI, residualized change in energy intake, Disinhibition, Restraint and Hunger

Models 3, 4 and 5: baseline BMI, residualized change in energy intake, Internal Disinhibition, External Disinhibition, Rigid Restraint and Flexible Restraint

Table 5 – Changes in body weight, fat mass, BMI and waist circumference in responders and non-responders during the 12 week exercise intervention (Responders = 32, non-responders = 26)

	Group	**Baseline**	**Week 4**	**Week 8**	**Week 12**	**Change (Δ)**
BMI	Responder	32.88 (4.62)	32.18 (4.74)	31.88 (4.61)	31.03 (4.74)	-1.85***
	Non-responder	30.52 (3.96)	30.37 (3.97)	30.15 (4.07)	30.21 (3.99)	-.31
Weight	Responder	92.85 (12.06)	91.17 (12.59)	89.93 (12.03)	87.65 (12.75)	-5.19***
	Non-responder	88.40 (11.96)	87.99 (12.18)	87.37 (12.54)	87.52 (12.17)	-.87
Fat mass	Responder	34.52 (9.77)	32.06 (10.34)	31.10 (10.28)	29.29 (10.42)	-4.92***
	Non-responder	28.83 (8.08)	28.52 (8.46)	28.83 (9.08)	27.20 (9.20)	-1.17
% Fat Mass	Responder	36.75 (7.98)	34.71 (8.97)	34.12 (9.23)	32.71 (9.44)	-3.53***
	Non-responder	32.55 (6.97)	32.27 (7.33)	32.45 (7.48)	30.98 (8.47)	-1.57
Waist circumference	Responder	103.23 (12.60)	101.35 (13.05)	99.35 (12.51)	97.00 (12.67)	-6.03***
	Non-responder	99.15 (11.36)	96.84 (10.97)	96.08 (10.59)	95.42 (10.58)	-3.73
Energy Intake	Responder	2280.23 (561.02)	2250.61 (592.39)	2224.23 (593.52)	2228.75 (641.92)	-38.15 (452.85)
	Non-responder	2407.83 (612.55)	2441.53 (705.24)	2474.41 (715.25)	2594.66 (783.60)	186.83 (651.02)

***p<0.001

Table 6 – Changes in TFEQ factors and sub-factors in responders and non-responders during the 12 week exercise intervention (Responders = 32, non-responders = 26)

	Group	Baseline	Week 12	Change (Δ)
Disinhibition	Responder	10.38 (3.16)	8.09 (3.89)	-2.29
	Non-responder	8.56 (3.28)	7.81 (3.42)	-0.75
Restraint	Responder	8.91 (4.57)	11.28 (4.53)	2.37*
	Non-responder	6.76 (4.06)	7.46 (4.61)	0.7
Hunger	Responder	6.38 (4.04)	5.56 (3.82)	-0.82
	Non-responder	5.24 (3.19)	5.73 (3.09)	0.49
External Disinhibition	Responder	3.77 (1.38)	2.66 (1.52)	-1.11
	Non-responder	3.38 (1.20)	3.15 (1.59)	-0.23
Internal Disinhibition	Responder	4.90 (2.18)	4.09 (2.59)	-0.81
	Non-responder	3.38 (2.25)	3.04 (2.29)	-0.34
Rigid Restraint	Responder	2.29 (1.49)	3.34 (1.79)	1.05
	Non-responder	1.92 (1.35)	2.35 (1.62)	0.43
Flexible Restraint	Responder	2.93 (2.24)	3.88 (2.08)	0.95*
	Non-responder	2.15 (1.71)	2.27 (1.89)	0.12

Change (Δ) represents difference between baseline (week 0) and week 12

*p<0.05

Figures

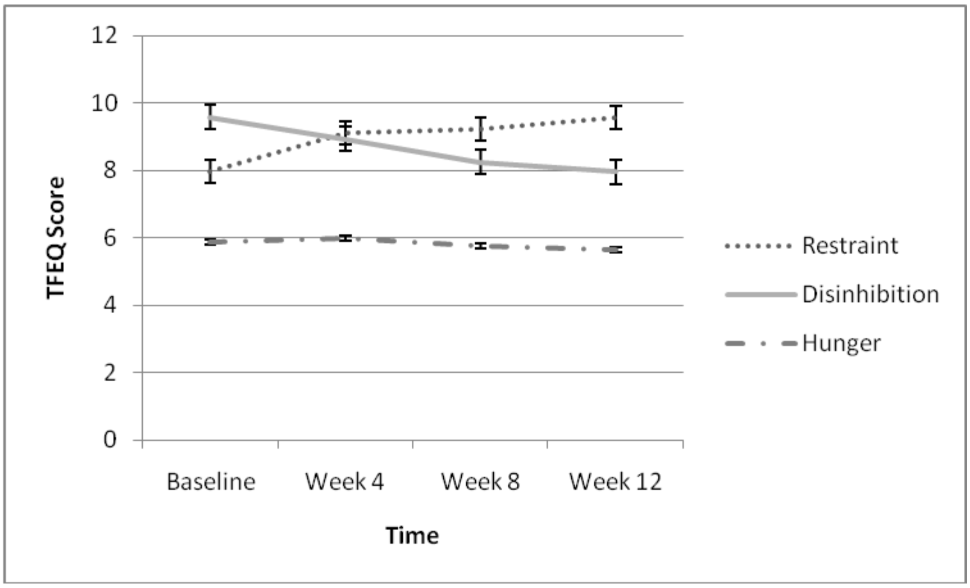

Figure 1 – Mean pooled changes in TFEQ factors during the 12 week exercise intervention

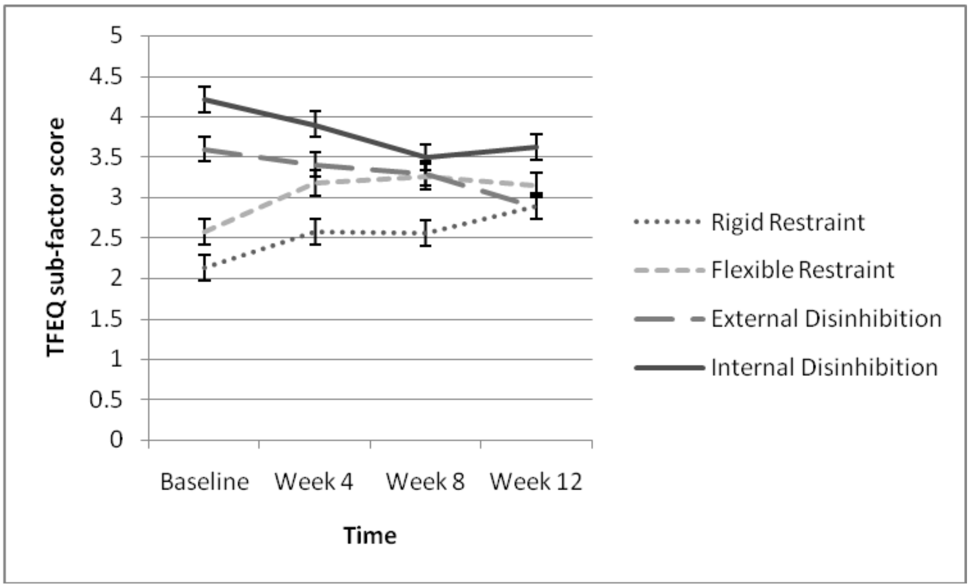

Figure 2 – Mean pooled changes in TFEQ sub-factor scores during the 12 week exercise intervention

Figures

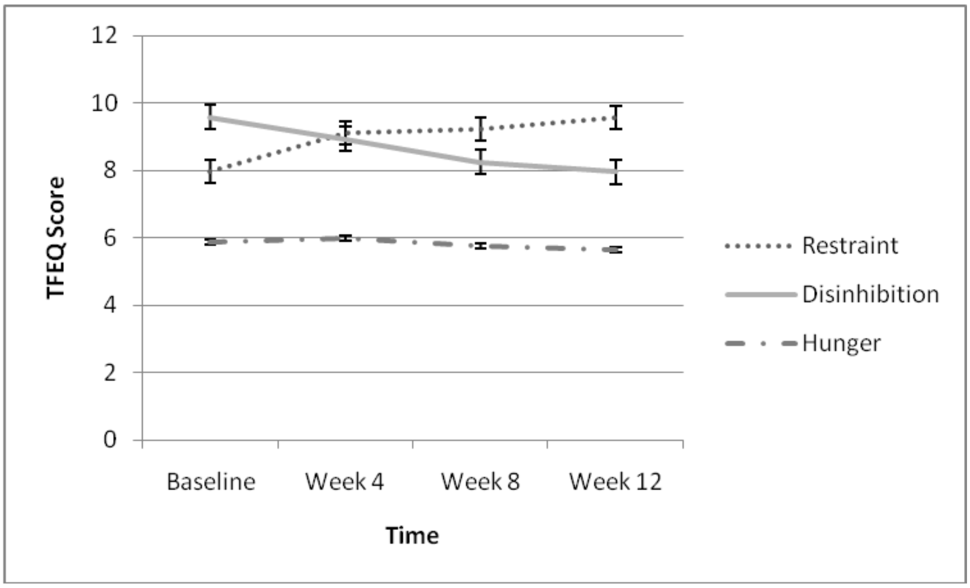

Figure 1 – Mean pooled changes in TFEQ factors during the 12 week exercise intervention

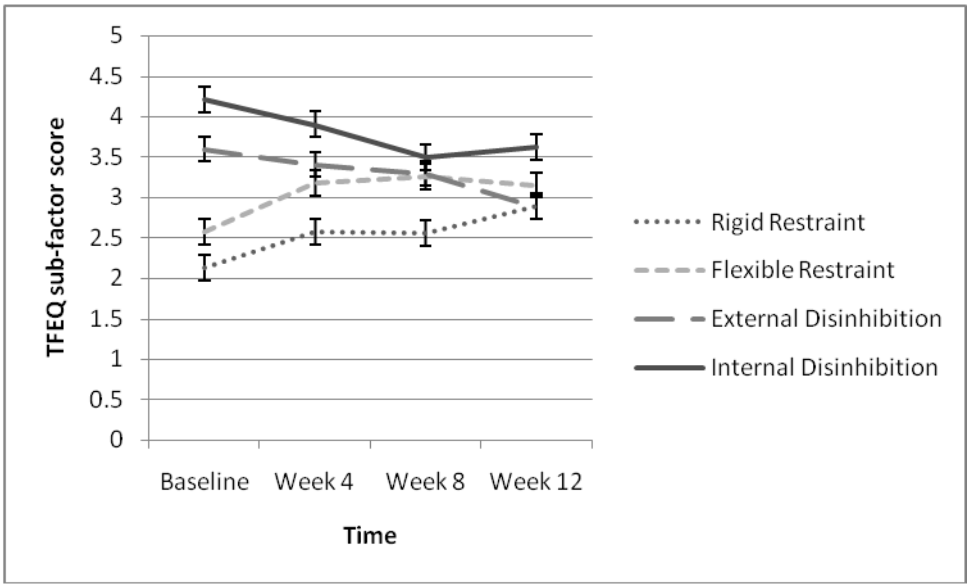

Figure 2 – Mean pooled changes in TFEQ sub-factor scores during the 12 week exercise intervention

Table 1 – Changes in body weight, BMI and body composition during the 12 week exercise intervention (n = 58)

	Baseline	**Week 4**	**Week 8**	**Week 12**	**Change (Δ)**
BMI	31.82 (4.46)	31.35 (4.46)	31.09 (4.42)	30.66 (4.40)	-1.16 (1.17)***
Weight	90.85 (12.12)	89.72 (12.40)	88.76 (12.37)	87.59 (12.39)	-3.26 (3.33)***
Fat Mass	31.88 (9.39)	30.42 (9.59)	30.11 (9.75)	28.32 (9.39)	-3.56 (2.66)***
Waist circumference	101.37 (12.11)	99.75 (12.17)	97.86 (11.69)	96.28 (11.68)	-5.09 (3.23)***

Change (Δ) represents difference between baseline (week 0) and week 12

***p<0.001

Table 2 stepwise regression model predicting change in weight loss parameters (residualized) with baseline TFEQ traits

Outcome	**Predictor**	**B**	**SE B**	**β**	**Model R^2**	**ANOVA**
Δ Weight	Disinhibition (baseline)	-.09	0.39	-0.29	0.08	p<0.05
Δ Waist circumference (cm)	Disinhibition (baseline)	-0.10	.04	-0.34	0.34	p=0.01

Variables included in the models: baseline BMI, baseline Disinhibition, Restraint and Hunger

Table 3: stepwise regression model predicting change in weight loss parameters (residualized) with baseline TFEQ subfactors

Outcome	**Predictor**	**B**	**SE B**	**β**	**Model R^2**	**ANOVA**
Δ Weight	Internal Disinhibition (baseline)	-0.15	0.05	-0.34	0.34	p=0.01
Δ % fat mass	Internal Disinhibition (baseline)	-0.12	0.05	-0.28	0.28	p<0.05
Δ fat mass (kg)	Internal Disinhibition (baseline)	-0.12	0.05	-0.28	0.28	p<0.05
Δ waist circumference (cm)	Internal Disinhibition (baseline)	-0.12	0.06	-0.29	0.29	p<0.05

Variables included in the models: baseline BMI, Internal Disinhibition, External Disinhibition, Rigid Restraint and Flexible Restraint

Table 4: stepwise regression model predicting change in weight loss parameters (residualized) with change in TFEQ traits (residualized)

Outcome	**Predictor**	**B**	**SE B**	**β**	**Partial R^2**	**Cumulative R^2**	**ANOVA**
	Δ Restraint	-0.37	0.13	-0.36	.	0.36	p<0.01
Δ Waist circumference	Δ Restraint	-.042	0.12	-0.42	0.18	.	p=0.001
	Δ Disinhibition	0.25	0.12	0.25	0.06	0.25	p<0.001

Variables included in the models: residualized change in Disinhibition, Restraint and Hunger

Table 5: stepwise regression model predicting change in weight loss parameters (residualized) with change in subfactors of TFEQ (residualized)

Outcome	**Predictor**	**B**	**SE B**	**β**	**Partial R^2**	**Cumulative R^2**	**ANOVA**
Δ Weight	Δ Flexible Restraint	-0.35	0.12	-0.35	.	0.15	p<0.01
	Δ External Disinhibition	0.33	0.12	0.32	0.10	0.25	p<001
Δ % body fat	Δ Rigid Restraint	-0.27	0.13	-0.28	.	0.08	p<0.05
Δ fat mass (kg)	Δ Rigid Restraint	-0.29	0.13	-0.30	.	0.08	p<0.05
Δ waist circumference	Δ Rigid	-0.40	0.12	-0.40	.	0.16	p<0.01

(cm)	Restraint						

Variables included in the models: residualized change in Internal Disinhibition, External Disinhibition, Rigid Restraint and Flexible Restraint

Table 6 – Changes in TFEQ factors and sub-factors in responders and non-responders during the 12 week exercise intervention (Responders = 32, non-responders = 26)

	Group	**Baseline**	**Week 12**	**Change (Δ)**
Disinhibition	Responder	10.38 (3.16)	8.09 (3.89)	-2.29
	Non-responder	8.56 (3.28)	7.81 (3.42)	-0.75
Restraint	Responder	8.91 (4.57)	11.28 (4.53)	2.37*
	Non-responder	6.76 (4.06)	7.46 (4.61)	0.7
Hunger	Responder	6.38 (4.04)	5.56 (3.82)	-0.82
	Non-responder	5.24 (3.19)	5.73 (3.09)	0.49
External Disinhibition	Responder	3.77 (1.38)	2.66 (1.52)	-1.11
	Non-responder	3.38 (1.20)	3.15 (1.59)	-0.23
Internal Disinhibition	Responder	4.90 (2.18)	4.09 (2.59)	-0.81
	Non-responder	3.38 (2.25)	3.04 (2.29)	-0.34
Rigid Restraint	Responder	2.29 (1.49)	3.34 (1.79)	1.05
	Non-responder	1.92 (1.35)	2.35 (1.62)	0.43
Flexible Restraint	Responder	2.93 (2.24)	3.88 (2.08)	0.95*
	Non-responder	2.15 (1.71)	2.27 (1.89)	0.12

Change (Δ) represents difference between baseline (week 0) and week 12

*p<0.05