**Eating behaviour traits, weight loss attempts, and vertebral dimensions among the general Northern Finnish population**

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KEY POINTS

- Cognitive eating restraint and diet-induced weight loss have been associated with deteriorated bone quality at various skeletal sites, but data on vertebral geometry have been lacking.
- We evaluated the associations of eating behaviour traits and weight loss attempts with vertebral size among the general Northern Finnish population (n = 1338).
- Women who reported multiple weight loss attempts or had rigid (or rigid-and-flexible) cognitive eating restraint had smaller vertebral CSA than those who did not.
- We conclude that rigid (or rigid-and-flexible) cognitive eating restraint and multiple weight loss attempts predict small vertebral size and thus decreased spinal health among middle-aged women.

MINI ABSTRACT

In a birth cohort sample of 1338 Northern Finns, the women who reported multiple weight loss attempts or rigid (or rigid-and-flexible) cognitive eating restraint had smaller vertebral size than those who did not. These means of eating and dieting seem to predict decreased spinal health among middle-aged women.

STRUCTURED ABSTRACT

**Study Design**: A population-based birth cohort study.

**Objective**: To evaluate the associations of eating behaviour traits and weight loss attempts with vertebral size among the general Northern Finnish population.

**Summary of Background Data**: Vertebral fragility fractures are a typical manifestation of osteoporosis, and small vertebral dimensions are a well-established risk factor for vertebral fracturing. Previous studies have associated cognitive eating restraint and diet-induced weight loss with deteriorated bone quality at various skeletal sites, but data on vertebral geometry are lacking.

**Methods**: This study of 1338 middle-aged Northern Finns evaluated the associations of eating behaviour traits (flexible and rigid cognitive restraint of eating, uncontrolled eating, emotional eating; assessed by the Three-Factor Eating Questionnaire-18) and weight loss attempts (assessed by a separate questionnaire item) with magnetic resonance imaging-derived vertebral cross-sectional area (CSA). Sex-stratified linear regression models were used to analyse the data, taking body mass index, leisure-time physical activity, general diet, smoking, and socioeconomic status as potential confounders.

**Results**: Women with rigid or rigid-and-flexible cognitive eating restraints had 3.2–3.4% smaller vertebral CSA than those with no cognitive restraint ($p \leq 0.05$). Similarly, the women who reported multiple weight loss attempts in adulthood and midlife had 3.5% smaller vertebral size than those who did not ($p = 0.03$). Other consistent findings were not obtained from either sex.

**Conclusions**: Rigid cognitive eating restraint and multiple weight loss attempts predict small vertebral size and thus decreased spinal health among middle-aged women, but not among men. Future longitudinal studies should confirm these findings.

KEY WORDS

Epidemiology, birth cohort study, magnetic resonance imaging, lumbar spine, vertebral geometry, eating behaviour, weight loss

LEVEL OF EVIDENCE

3

## INTRODUCTION

Osteoporosis is a systemic skeletal disease which weakens the quality and quantity of bone to the extent that fractures occur after minimal trauma [1,2]. The geometry of a bone influences its strength independently of bone mineral density (BMD) [3,4]. Vertebral fragility fractures are a typical manifestation of osteoporosis [5,6], and small vertebral dimensions are a well-established risk factor for vertebral fracturing [3,7]. Interestingly, vertebrae enlarge in size well beyond adolescence [8,9], and previous studies have associated lifestyle choices in adulthood with midlife vertebral size [10-12]. Therefore, further data on the association between lifestyle-related factors and vertebral size across the lifespan may provide valuable tools for fracture risk estimation and fracture prevention.

Body weight and long-term obesity have a positive association with bone size and BMD, especially at weight-bearing bone sites such as the lumbar spine [12,13]. Correspondingly, diet-induced weight loss has been associated with a decrease in BMD at several weight-bearing sites [14,15], even over a follow-up period of only one year [16]. Weight cycling (i.e., weight loss followed by regain) has also been associated with low BMD in the spine [17].

The term ‘eating behaviour’ refers to the sum of factors which influence our food intake, such as the preference and quantity of food, and meal timing [18]. Successful weight loss and long-term weight control seem to be characterized by flexible cognitive eating restraint without excessive uncontrolled or emotional eating [19]. In contrast, several traits of disordered eating behaviour have been identified (e.g., rigid cognitive restraint of eating, uncontrolled eating, emotional eating) [20-23]. These may potentially lead to unhealthy weight control practices such as multiple unsuccessful weight loss attempts and weight cycling [24,25] which seem to have a pronounced negative influence on bone quality [26,27]. Eating behaviour traits are varyingly assessed by validated questionnaires such as the Three-Factor Eating Questionnaire (TFEQ) [20-22].

The aims of this study were two-fold. First, we aimed to describe the association of eating behaviour traits (flexible and rigid cognitive restraint of eating, uncontrolled eating, emotional eating), assessed by the Three-Factor Eating Questionnaire-18 (TFEQ-18) scores, with magnetic resonance imaging (MRI)-derived vertebral size in midlife. Second, we aimed to explore the association between self-reported history of weight loss attempts and vertebral size. A population-based Finnish birth cohort study provided this study with its material. We hypothesized that disordered eating behaviour and multiple weight loss attempts would be associated with small vertebral size.

## MATERIAL AND METHODS

### Study population

We used the Northern Finland Birth Cohort 1966 (NFBC1966) dataset to conduct this study. The NFBC1966 is a birth cohort study that was initiated in Northern Finland (provinces of Oulu and Lapland) in 1966 when pregnant women were recruited into the cohort [28]. Initially, the NFBC1966 comprised 12 231 live births, with a coverage of 96% of all births in Northern Finland at the time. Major adulthood data collections (health and lifestyle) were organised when the NFBC1966 members were 31 and 46 years old (6033 and 5861 participants, respectively). These data have been supplemented with registry-based data across the life course. In addition, individuals who attended the 46-year follow-up and resided in the Oulu area underwent a lumbar MRI scan (1540 participants). We have previously concluded that the MRI subsample is representative of the general Northern Finnish population [29].

**Figure 1** illustrates the outline of the study. The present study sample comprised individuals with 1) MRI-based data on vertebral dimensions from the age of 46 (outcome), 2) data on confounders from the age of 46, and 3) at least one of the following: data on eating behaviour from the age of 46 (n = 1334), or data on weight loss attempts from the ages of 31 and 46 (n = 701). Individuals with bone-affecting medications and/or vertebral pathologies were excluded.

### Vertebral cross-sectional area (outcome)

Lumbar MRI was performed with a 1.5 T scanner (Signa HDxt, General Electric, Milwaukee, WI, USA). The protocol included T2-weighted fast-recovery fast spin-echo images in sagittal and transverse planes. Further details of the MR scans are published elsewhere [10].

One blinded researcher (P.O., a medical student) evaluated the scans after being trained by a senior musculoskeletal radiologist (J.N.). The scans were accessed using NeaView Radiology Software version 2.31 (Neagen Oy, Oulu, Finland). First, each scan was screened for vertebral pathologies (segmentation error, endplate erosion, severe disc degeneration, spondylodesis, Schmorl's nodes), ensuring that only healthy vertebrae were measured. Then, several dimensions of the fourth lumbar vertebra (L4) were recorded to an accuracy of 0.1 mm. These included maximum width, minimum width, cranial depth, midaxial depth, and caudal depth. **Figure 2** shows an annotated MRI scan accordingly. Vertebral cross-sectional area (CSA, $mm^2$), a parameter that affects the vertebra's load-bearing capacity [30] and fracture risk [7], was calculated using the validated ellipsoid formula [31,32]: CSA = a/2 x b/2, in which a = mean of width measurements and b = mean of depth measurements. The reliability and precision of our measurements have been established as high [10].

Eating behaviour (Predictor 1)

At the age of 46, eating behaviour was evaluated using the TFEQ-18 tool. The full version of the tool [21] and its Finnish validation [22] can be found elsewhere. In brief, the TFEQ-18 is a short, revised version of the original 51-item TFEQ tool [20], and includes 18 questions and statements that address three subtypes of eating behaviour: 1) cognitive restraint of eating, i.e., 'tendency to constantly and consciously restrict one's food intake' (six questions); 2) uncontrolled eating, i.e., 'tendency to overeat, with the feeling of being out of control' (nine questions); and 3) emotional eating, i.e., 'tendency to eat in response to negative emotions' (three questions) [22]. Each question and statement has four to eight response alternatives (e.g., definitely true/ mostly true/ mostly false/ definitely false), which are scored according to a specific scheme [21,22]. The total score of each eating behaviour subtype is projected to a scale of 0–100, in which higher scores indicate a stronger presence of the respective behaviour. The TFEQ-18 has shown to effectively distinguish between behavioural eating patterns in the general population [33]. As previously recommended [33], we applied the half-scale method to each subscale in order to compensate for individual missing responses. In addition to analysing the total scores of each subscale, we divided each one into tertiles (T1–T3) which were compared with each other.

Further, the cognitive restraint of eating consists of two subdimensions, namely rigid and flexible control of eating [25]. Rigid control can be seen as an 'all or nothing' approach to eating and weight and is associated with unsuccessful weight management. In contrast, flexible control indicates a more advanced approach to eating and dieting, with the ability to plan and self-regulate healthy eating including small quantities of 'fattening foods'. These are assessed by the following items of the TFEQ-18 [25]:

- Flexible: 'I deliberately take small helpings as a means of controlling my weight' (definitely/mostly true); 'I consciously hold back at meals in order not to gain weight' (definitely/ mostly true); 'How likely are you to consciously eat less than you want?' (moderately/very likely)
- Rigid: 'I do not eat some foods because they make me fat' (definitely true/ mostly true); 'How frequently do you avoid 'stocking up' on tempting foods?' (usually/ almost always)

We considered the bracketed responses to be indicative of the respective eating behaviour, and classified individuals into cognitive eating restraint subtypes as follows: 1) No cognitive restraint (no indicative responses in either the 'flexible' or the 'rigid' category), 2) Flexible only (at least one indicative response in the 'flexible' category and none in the 'rigid' category), 3) Rigid only (at least one indicative response in the 'rigid' category and none in the 'flexible' category), 4) Both flexible and rigid cognitive restraint (at least one indicative response in both categories).

Westenhoefer et al. [25] did not originally mention TFEQ-18 item no. 12 ('I do not eat some foods because they make me fat') as an indicator of rigid cognitive restraint. However, their division between rigid and flexible subdimensions was initially based on the items' correlation with TFEQ's Disinhibition factor; the rigid subdimension showed a higher correlation with disinhibition than the flexible subdimension. Hence, as the TFEQ-18's Uncontrolled Eating and Emotional Eating factors are strongly correlated with the TFEQ's Disinhibition factor [21], and in our data TFEQ-18 item no. 12 showed a moderate positive correlation with the uncontrolled eating and emotional eating subscores (R = 0.124—0.207), we decided to use this item as an indicator of rigid cognitive restraint. Importantly, the items that represented the flexible subdimension showed mostly lower or negative correlations with the uncontrolled eating and emotional eating subscores, justifying our use of them as indicators of the flexible subdimension.

Weight loss attempts (Predictor 2)

Previous weight loss attempts were self-reported at the ages of 31 and 46 by responding to the question: 'Have you attempted to lose weight in a serious manner? 1) No, never; 2) Yes, once; 3) Yes, multiple times.' Based on their responses, each individual was classified into one of the following categories: 1) ≤ 1 weight loss attempt at 31 and 46 years, 2) multiple attempts at either 31 or 46 years, 3) multiple attempts at both 31 and 46 years.

Confounders

We assessed sex, body mass index (BMI), leisure-time physical activity, general diet, smoking, and socioeconomic status as potential confounders. Detailed descriptions of all these variables have been given in two previous papers [10,12]. In brief, BMI (kg/$m^2$, continuous) was based on objective height and weight measurements at the age of 46. We included individuals whose BMI was within the range of 15–40 kg/$m^2$ in order to exclude clear outliers. Physical activity (daily, 4–6 times/week, 2–3 times/week, once/week, 2–3 times/month, once/month, or less often; first and last two categories combined due to small group sizes), general diet (vegetarian, lactose-free, gluten-free, food allergy, diabetes, cholesterol-lowering, weight loss, low-salt; recategorized due to small group sizes as follows: no specific diet, vegetarian, weight loss, other diets), smoking history (non-smoker, former smoker, current smoker), and socioeconomic status (<9, 9–12, >12 years of education) were self-reported at the age of 46. Age was not included, as the sample was coeval.

Statistical analysis

The data were administered using SPSS version 24 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated as frequencies and percentages (categorical variables), means and standard deviations (SD) (continuous variables with normal distributions), and medians with interquartile ranges (IQR) (continuous variables with skewed distributions).

We analysed the associations of the TFEQ-18 subtype scores (continuous and divided into tertiles), cognitive eating restraint subtypes (categorical) and weight loss attempts (categorical) with vertebral CSA (continuous outcome, $mm^2$) using linear regression models. Both crude and adjusted models were run. The final covariates were selected as follows: First, we explored the univariate associations between each confounder candidate and vertebral CSA. If a covariate candidate showed a statistically significant univariate association with vertebral CSA at the $p \leq 0.05$ level, it was taken further to a multivariable analysis. If a covariate candidate showed a significant association with the outcome in the multivariable model, it was included in the final adjusted model. We collected the beta coefficients (β) and their 95% confidence intervals (CI) from each model, and considered p values of $\leq 0.05$ statistically significant. We stratified all analyses by sex due to significant sex interactions.

Ethical approval

Ethical approval was obtained from the Ethics Committee of the Northern Ostrobothnia Hospital District. The study protocol was in accordance with the Declaration of Helsinki. Informed consent was collected from the study population and the data were administered using anonymous identification codes.

RESULTS

The sample comprised 1338 individuals, 54.2% of whom were women. Most had attended school for 9 to 12 years, were non-smokers, exercised ≥ 2 times a week, and did not follow a specific diet (**Table 1**). Women had smaller vertebral CSA (**Table 1**) but higher TFEQ-18 scores in all the studied eating behaviour subtypes than men (**Table 2**). Most men and women reported having attempted to lose weight at the age of 31, 46 or at both time points (**Table 2**).

Significant sex interactions were detected in the data ($p < 0.05$), and all analyses were stratified by sex. Of the remaining covariate candidates (BMI, leisure-time physical activity, diet, smoking, education), only the addition of BMI had an influence on the models. Thus, we used BMI as a covariate in the adjusted models.

**Tables 3–5** present the associations of TFEQ-18 subscores, cognitive eating restraint subtypes, and weight loss attempts with vertebral CSA. The full multivariable models are presented in **Supplementary Tables 1–3**. As regards the TFEQ-18 subscores, the emotional eating subscore (continuous) was associated with larger vertebral CSA among men in one model ($p = 0.02$), but this finding was not replicated in the tertile-based comparisons (**Table 3**). Other subscores showed no association with vertebral CSA among either men or women (**Table 3**). However, closer scrutiny of the cognitive eating restraint subtypes revealed that women with rigid or rigid-and-flexible cognitive eating restraint had ~3% smaller vertebral CSA than those with no cognitive restraint ($p \leq 0.05$; **Table 4**). Among women, a history of multiple weight loss attempts at both the ages of 31 and 46 was associated with ~4% smaller vertebral CSA than no weight loss history ($p = 0.03$; **Table 5**).

## DISCUSSION

This study of 1338 Northern Finns aimed to evaluate the associations of eating behaviour traits and weight loss attempts with vertebral size. Among women, rigid (or rigid-and-flexible) cognitive eating restraint at the age of 46, and multiple weight loss attempts between the age of 31 and 46 predicted small vertebral size and thus decreased spinal health at the age of 46. Among men, no such associations were detected.

Previous studies have associated cognitive eating restraint, as determined by eating behaviour questionnaire scores, with deteriorated bone quality at various skeletal sites [34-37]. Several studies have also associated diet-induced weight loss [14,15] and repeated weight loss attempts with negative bone outcomes at various skeletal sites [17,38,39]. However, despite this knowledge, data on vertebral geometry have been lacking. The present study, which aimed to address this knowledge gap, showed mostly similar findings to previous studies, underlining the role of eating behaviour and dieting in skeletal health.

In our data, the women with rigid (or rigid-and-flexible) cognitive eating restraint had 3.2–3.4% smaller vertebral CSA than those with no cognitive restraint. Similarly, the women who reported multiple weight loss attempts in adulthood and midlife had 3.5% smaller vertebral size than those who did not. Other eating behaviour traits, i.e. uncontrolled and emotional eating, were not consistently associated with vertebral size. Even though the effect sizes were of minor magnitude, they seem to be comparable to that of lifelong physical inactivity (3.2% smaller vertebral size among inactive females [10]). Importantly, the present associations remained significant despite the inclusion of several confounders such as physical activity, general diet and BMI. We suggest that repetitious short-term changes in body weight (due to the alternation of rigid dieting and binge relapses) may be one mechanism explaining these associations. Hence, it seems advisable for women to avoid multiple weight loss attempts and the features of rigid cognitive restraint in eating behaviour in order to maintain optimal spinal health. Correspondingly, health care professionals should encourage patients to pursue permanent weight control instead of fluctuating between rigid diets and binge eating.

Among men, no consistent associations were detected between eating behaviour traits, weight loss attempts and vertebral size, suggesting that weight loss attempts and/or eating behaviour do not influence the male vertebrae. Furthermore, in light of previous epidemiological research on vertebral size [10,11], the female vertebra seems to be more inclined to adjust its size according to lifestyle factors. Although the present results comply with previous findings, the underlining factors remain obscure.

The strengths of this study stem from the large sample and multifaceted approach to nutritional behaviour in adulthood (eating behaviour traits and weight loss attempts). Importantly, we had longitudinal data on weight loss attempts from the ages of 31 and 46. The sample consisted of the general Northern Finnish population with healthy vertebrae, which improves the generalizability of our findings. We chose to investigate vertebral size at the age of 46, because the incidence of vertebral fractures rises towards the end of midlife [2].

This study had several weaknesses. First, the TFEQ-18 questionnaire was conducted at only one time point at 46 years. Thus, the eating behaviour data were cross-sectional in nature, which prevented us from drawing conclusions regarding causality. Second, the assessment of weight loss attempts was based on self-reported data which could not be confirmed by objective measurements. This was due to the large cohort sample, which could not be followed up in a sufficiently frequent manner to detect short-term changes in body weight. Major follow-ups of the cohort were organized at the ages of 31 and 46, that is, 15 years apart. Third, it is worth noting that BMI may act as a partial mediator of the association between eating behaviour, weight loss attempts, and vertebral size, which would complicate its use as a covariate in the models. In our data, however, the inclusion of BMI did not attenuate the crude associations between eating behaviour/weight loss attempts and vertebral size, suggesting that these concepts have an independent association with vertebral size. Importantly, we present both the unadjusted models (without BMI) and the adjusted models (with BMI) in the paper.

We conclude that rigid (or rigid-and-flexible) cognitive eating restraint and multiple weight loss attempts predict smaller vertebral size and thus decreased spinal health among middle-aged women, but not among men. Further studies using longitudinal approaches are needed to confirm these findings.

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Table 1. General characteristics of the sample (n = 1338). N varies due to missing data.

| | Men (45.8%; n = 613) | | Women (54.2%; n = 725) | |
|---|---|---|---|---|
| Age at follow-up (years) [a] | | | | |
| 31 years | 31.0 (0.3) | | 31.0 (0.3) | |
| 46 years | 46.8 (0.5) | | 46.8 (0.4) | |
| Height (cm) [a] | | | | |
| 31-year follow-up | 178.7 (6.1) | *n = 511* | 164.8 (5.8) | *n = 635* |
| 46-year follow-up | 178.7 (6.1) | *n = 613* | 164.8 (5.8) | *n = 725* |
| Weight (kg) [a] | | | | |
| 31-year follow-up | 79.9 (11.2) | *n = 511* | 64.4 (11.0) | *n = 630* |
| 46-year follow-up | 86.0 (12.4) | *n = 613* | 70.6 (12.6) | *n = 725* |
| Body mass index (kg/m$^2$) [a] | | | | |
| 31-year follow-up | 25.0 (3.2) | *n = 511* | 23.7 (3.9) | *n = 630* |
| 46-year follow-up | 26.9 (3.5) | *n = 613* | 26.0 (4.5) | *n = 725* |
| Education years [b] | | | | |
| < 9 | 3.4 | *n = 20* | 2.4 | *n = 17* |
| 9–12 | 72.8 | *n = 433* | 70.8 | *n = 498* |
| > 12 | 23.9 | *n = 142* | 26.7 | *n = 188* |
| Smoking history [b] | | | | |
| Non-smoker | 50.1 | *n = 294* | 59.3 | *n = 411* |
| Former smoker | 33.4 | *n = 196* | 25.1 | *n = 174* |
| Current smoker | 16.5 | *n = 97* | 15.6 | *n = 108* |
| Leisure-time physical activity at age 46 [b] | | | | |
| Once a month or less | 15.1 | *n = 89* | 10.6 | *n = 74* |
| 2–3 times a month | 13.8 | *n = 81* | 11.5 | *n = 80* |
| Once a week | 21.3 | *n = 125* | 20.2 | *n = 141* |
| 2–3 times a week | 33.8 | *n = 199* | 40.5 | *n = 282* |
| ≥ 4 times a week | 16.0 | *n = 94* | 17.2 | *n = 120* |
| Diet at age 46 [b] | | | | |
| No diet | 71.8 | *n = 336* | 64.4 | *n = 343* |
| Vegetarian | 1.1 | *n = 5* | 1.3 | *n = 7* |
| Weight loss | 1.1 | *n = 5* | 3.4 | *n = 18* |
| Other [c] | 26.1 | *n = 122* | 31.0 | *n = 165* |
| Lumbar magnetic resonance imaging at age 46 | | | | |
| Cross-sectional area of L4 (mm$^2$) [a] | 1324.9 (170.5) | *n = 613* | 1053.5 (131.1) | *n = 725* |

[a]Mean (standard deviation)

[b]Percentage

[c]Other diets included lactose-free, gluten-free, food allergy, diabetes, cholesterol-lowering and low-salt.

Table 2. Eating behaviour and weight loss attempts among the sample (n = 1338). N varies due to missing data.

| | Men (45.8%; n = 613) | | Women (54.2%; n = 725) | |
|---|---|---|---|---|
| Three-Factor Eating Questionnaire-18 subscores at age 46 [a] | | | | |
| Cognitive restraint | 38.9 (28.7—50.0) | *n = 611* | 50.0 (33.3—61.1) | *n = 723* |
| Uncontrolled eating | 22.2 (11.1—37.0) | *n = 611* | 25.9 (14.8—40.7) | *n = 723* |
| Emotional eating | 11.1 (0.0—33.3) | *n = 611* | 33.3 (0.0—55.6) | *n = 723* |
| Subtypes of cognitive eating restraint at age 46 [b] | | | | |
| None | 14.6 | *n = 88* | 9.5 | *n = 68* |
| Flexible only | 3.3 | *n = 20* | 3.1 | *n = 22* |
| Rigid only | 50.9 | *n = 307* | 38.3 | *n = 274* |
| Both flexible and rigid | 31.2 | *n = 188* | 49.2 | *n = 352* |
| Weight loss attempts (≥ 2) from age 31 to 46 [b] | | | | |
| No | 10.6 | *n = 32* | 25.6 | *n = 102* |
| At age 31 or 46 | 69.2 | *n = 209* | 46.1 | *n = 184* |
| At age 31 and 46 | 20.2 | *n = 61* | 28.3 | *n = 113* |

[a]Median (interquartile range)

[b]Percentage

Table 3. Regression coefficients for the association between TFEQ-18 subscores and vertebral CSA. The full multivariable models are presented in **Supplementary Table 1**.

| | Men (n = 611) | | | | Women (n = 723) | | | |
|---|---|---|---|---|---|---|---|---|
| | Crude model | | Adjusted model | | Crude model | | Adjusted model | |
| | Beta (95% CI) | P value | Beta (95% CI) | P value | Beta (95% CI) | P value | Beta (95% CI) | P value |
| Analysis of continuous scores | | | | | | | | |
| Cognitive restraint | 0.3 (-0.4; 1.1) | 0.385 | 0.1 (-0.6; 0.9) | 0.711 | -0.4 (-0.9; 0.2) | 0.172 | -0.4 (-1.0; 0.1) | 0.110 |
| Uncontrolled eating | 0.8 (-0.0; 1.5) | 0.059 | 0.4 (-0.4; 1.3) | 0.297 | 0.0 (-0.5; 0.5) | 0.988 | -0.3 (-0.8; 0.3) | 0.324 |
| Emotional eating | **0.8 (0.1; 1.4)** | **0.018** | 0.5 (-0.1; 1.2) | 0.117 | 0.1 (-0.3; 0.4) | 0.736 | -0.2 (-0.5; 0.2) | 0.405 |
| Comparison between tertiles | | | | | | | | |
| Cognitive restraint | | | | | | | | |
| T1 (reference) | | | | | | | | |
| T2 | 8.6 (-22.5; 39.7) | 0.586 | -1.7 (-33.4; 30.0) | 0.915 | -8.5 (-35.9; 18.9) | 0.542 | -15.2 (-42.9; 12.4) | 0.280 |
| T3 | 3.0 (-34.2; 40.3) | 0.873 | -6.6 (-44.2; 31.0) | 0.730 | -13.6 (-41.4; 14.3) | 0.338 | -18.8 (-46.7; 9.2) | 0.187 |
| Uncontrolled eating | | | | | | | | |
| T1 (reference) | | | | | | | | |
| T2 | -5.0 (-39.4; 29.5) | 0.778 | -6.6 (-41.0; 27.7) | 0.704 | 2.0 (-22.8; 26.9) | 0.872 | -1.9 (-26.7; 22.9) | 0.880 |
| T3 | 20.3 (-14.7; 55.2) | 0.255 | 6.7 (-29.6; 43.0) | 0.719 | -3.4 (-28.1; 21.3) | 0.786 | -13.5 (-39.0; 12.0) | 0.299 |
| Emotional eating | | | | | | | | |
| T1 (reference) | | | | | | | | |
| T2 | -10.2 (-44.8; 24.4) | 0.563 | -10.7 (-45.2; 23.7) | 0.542 | 5.0 (-25.1; 35.0) | 0.745 | 5.1 (-24.8; 35.0) | 0.738 |
| T3 | 28.2 (-3.3; 59.7) | 0.079 | 18.4 (-14.0; 50.7) | 0.265 | 2.9 (-19.9; 25.6) | 0.805 | -7.0 (-30.6; 16.6) | 0.559 |

CI = Confidence interval, T1—T3 = Tertile 1—3.

Table 4. Regression coefficients for the association between cognitive eating restraint subtypes and vertebral CSA. The full multivariable models are presented in **Supplementary Table 2**.

| | Men (n = 603) | | | | Women (n = 716) | | | |
|---|---|---|---|---|---|---|---|---|
| | Crude model | | Adjusted model | | Crude model | | Adjusted model | |
| | Beta (95% CI) | P value | Beta (95% CI) | P value | Beta (95% CI) | P value | Beta (95% CI) | P value |
| Presence of cognitive restraint | | | | | | | | |
| No (reference) | | | | | | | | |
| Flexible only | -13.9 (-96.7; 69.8) | 0.741 | -18.6 (-100.9; 63.7) | 0.657 | -18.5 (-80.8; 43.9) | 0.561 | -22.8 (-85.0; 36.4) | 0.473 |
| Rigid only | 6.8 (-33.6; 47.2) | 0.741 | 13.7 (-26.7; 54.2) | 0.505 | **-41.1 (-75.6; -6.7)** | **0.019** | **-36.0 (-70.5; -1.4)** | **0.041** |
| Both flexible and rigid | 23.1 (-20.1; 66.2) | 0.294 | 22.0 (-20.9; 64.9) | 0.314 | **-35.9 (-69.6; -2.3)** | **0.037** | **-33.4 (-67.0; 0.0)** | **0.050** |

CI = Confidence interval

Table 5. Regression coefficients for the association between self-reported weight loss attempts and vertebral CSA. The full multivariable models are presented in **Supplementary Table 3**.

| | Men (n = 302) | | | | Women (n = 399) | | | |
|---|---|---|---|---|---|---|---|---|
| | Crude model | | Adjusted model | | Crude model | | Adjusted model | |
| | Beta (95% CI) | P value | Beta (95% CI) | P value | Beta (95% CI) | P value | Beta (95% CI) | P value |
| Multiple weight loss attempts | | | | | | | | |
| No (reference) | | | | | | | | |
| At age 31 or 46 | -32.0 (-96.4; 32.4) | 0.330 | -12.5 (-78.5; 53.4) | 0.709 | -21.7 (-52.5; 9.0) | 0.165 | 5.1 (-29.3; 39.6) | 0.770 |
| At age 31 and 46 | -42.1 (-116.1; 32.0) | 0.264 | -41.1 (-114.6; 32.4) | 0.273 | **-47.7 (-81.7; -13.7)** | **0.006** | **-37.2 (-71.4; -3.0)** | **0.033** |

CI = Confidence interval

FIGURE LEGENDS

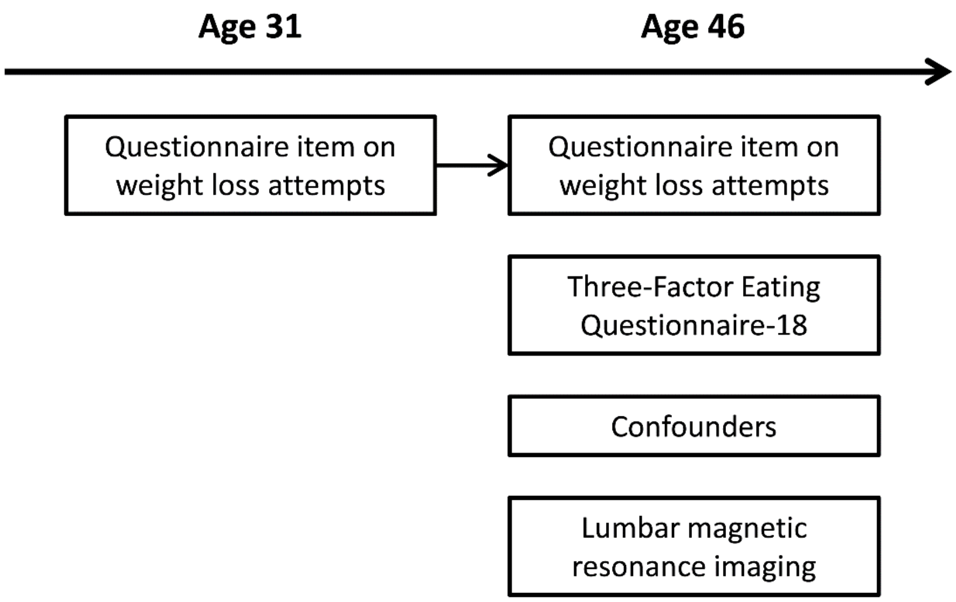


Figure 1. Outline of the study.

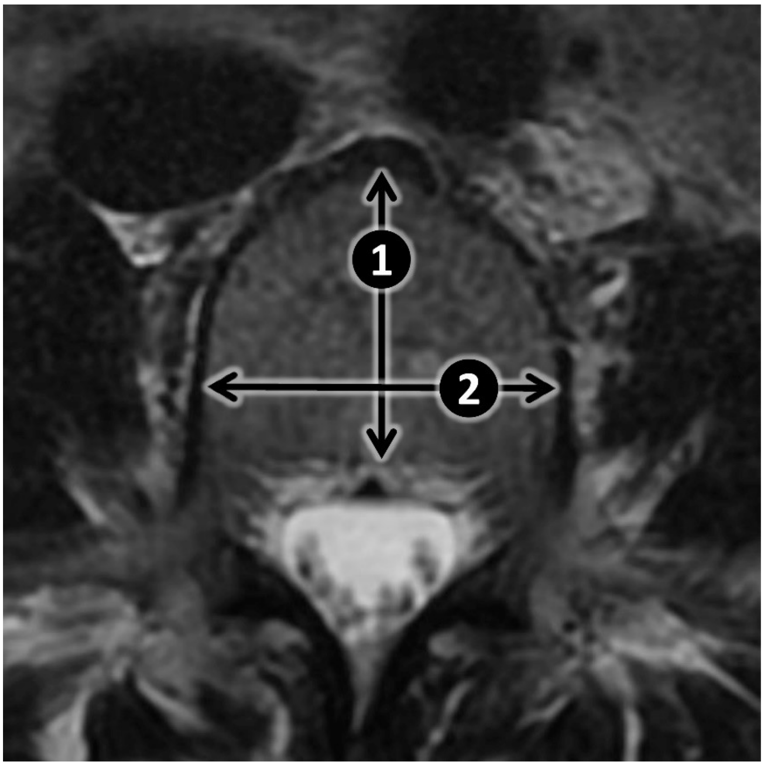


Figure 2. Axial MRI slice demonstrating L4 measurements: 1) depth (cranial, caudal and midaxial depths were recorded), 2) width (minimum and maximum widths were recorded).

Supplementary Table 1. Full multivariable regression models for the association between TFEQ-18 subscores and vertebral CSA (i.e. those adjusted for BMI).

| | Men (n = 611) | | Women (n = 723) | |
|---|---|---|---|---|
| | Beta (95% CI) | P value | Beta (95% CI) | P value |
| **Analysis of continuous scores** | | | | |
| Cognitive restraint | 0.1 (-0.6; 0.9) | 0.711 | -0.4 (-1.0; 0.1) | 0.110 |
| BMI | **5.6 (1.7; 9.4)** | **0.005** | **3.1 (1.0; 5.2)** | **0.004** |
| Uncontrolled eating | 0.4 (-0.4; 1.3) | 0.297 | -0.3 (-0.8; 0.3) | 0.324 |
| BMI | **5.0 (1.0; 9.0)** | **0.014** | **3.3 (1.1; 5.6)** | **0.004** |
| Emotional eating | 0.5 (-0.1; 1.2) | 0.117 | -0.2 (-0.5; 0.2) | 0.405 |
| BMI | **4.7 (0.7; 8.7)** | **0.020** | **3.3 (1.0; 5.6)** | **0.004** |
| **Comparison between tertiles** | | | | |
| Cognitive restraint | | | | |
| T1 (reference) | | | | |
| T2 | -1.7 (-33.4; 30.0) | 0.915 | -15.2 (-42.9; 12.4) | 0.280 |
| T3 | -6.6 (-44.2; 31.0) | 0.730 | -18.8 (-46.7; 9.2) | 0.187 |
| BMI | **5.8 (1.9; 9.7)** | **0.004** | **3.2 (1.0; 5.3)** | **0.004** |
| Uncontrolled eating | | | | |
| T1 (reference) | | | | |
| T2 | -6.6 (-41.0; 27.7) | 0.704 | -1.9 (-26.7; 22.9) | 0.880 |
| T3 | 6.7 (-29.6; 43.0) | 0.719 | -13.5 (-39.0; 12.0) | 0.299 |
| BMI | **5.3 (1.2; 9.3)** | **0.011** | **3.3 (1.1; 5.4)** | **0.003** |
| Emotional eating | | | | |
| T1 (reference) | | | | |
| T2 | -10.7 (-45.2; 23.7) | 0.542 | 5.1 (-24.8; 35.0) | 0.738 |
| T3 | 18.4 (-14.0; 50.7) | 0.265 | -7.0 (-30.6; 16.6) | 0.559 |
| BMI | **5.0 (1.1; 8.9)** | **0.013** | **3.3 (1.0; 5.5)** | **0.004** |

BMI = Body mass index, CI = Confidence interval, T1—T3 = Tertile 1—3.

Supplementary Table 2. Full multivariable regression models for the association between cognitive eating restraint subtypes and vertebral CSA (i.e. those adjusted for BMI).

| | Men (n = 603) | | Women (n = 716) | |
|---|---|---|---|---|
| | Beta (95% CI) | P value | Beta (95% CI) | P value |
| Presence of cognitive restraint | | | | |
| No (reference) | | | | |
| Flexible only | -18.6 (-100.9; 63.7) | 0.657 | -22.8 (-85.0; 36.4) | 0.473 |
| Rigid only | 13.7 (-26.7; 54.2) | 0.505 | **-36.0 (-70.5; -1.4)** | **0.041** |
| Both flexible and rigid | 22.0 (-20.9; 64.9) | 0.314 | **-33.4 (-67.0; 0.0)** | **0.050** |
| BMI | **5.6 (1.7; 9.5)** | **0.005** | **2.8 (0.7; 5.0)** | **0.009** |

BMI = Body mass index, CI = Confidence interval.

Supplementary Table 3. Full multivariable regression models for the association between self-reported weight loss attempts and vertebral CSA (i.e. those adjusted for BMI).

| | Men (n = 302) | | Women (n = 399) | |
|---|---|---|---|---|
| | Beta (95% CI) | P value | Beta (95% CI) | P value |
| Multiple weight loss attempts | | | | |
| No (reference) | | | | |
| At age 31 or 46 | -12.5 (-78.5; 53.4) | 0.709 | 5.1 (-29.3; 39.6) | 0.770 |
| At age 31 and 46 | -41.1 (-114.6; 32.4) | 0.273 | **-37.2 (-71.4; -3.0)** | **0.033** |
| BMI | **7.0 (1.1; 12.8)** | **0.020** | **5.1 (2.0; 8.1)** | **0.001** |

BMI = Body mass index, CI = Confidence interval.