

The Three-Factor Eating Questionnaire, body mass index, and responses to sweet and salty fatty foods: a twin study of genetic and environmental associations¹⁻³

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ABSTRACT

Background: The relation between body weight and energy-dense foods remains unclear.

Objective: We estimated the effects of genetic and environmental factors on cognitive and emotional aspects of dieting behavior, body mass index (BMI), and responses to fatty foods and on their relations.

Design: A total of 1326 adult twin persons (aged 17–82 y; 17% M and 83% F) from the United Kingdom and Finland completed the revised version of the Three-Factor Eating Questionnaire (TFEQ-R18) and reported the liking and use-frequency of 4 sweet-and-fatty and salty-and-fatty food items (6 items in the United Kingdom and 5 items in Finland). Genetic modeling was done by using linear structural equations.

Results: Heritability estimates were calculated separately for the countries and sexes; they were 26–63% for cognitive restraint, 45–69% for uncontrolled eating, and 9–45% for emotional eating, respectively. Of the variation in liking and use-frequency of fatty foods, 24–54% was attributed to interindividual genetic differences. No significant correlations were observed between BMI and fatty food use or liking. However, BMI was positively (mostly genetically) correlated (genetic $r = 0.16$ – 0.51) with all of the dieting behaviors, and they correlated with fatty food use and liking ratings. Uncontrolled eating was both genetically and environmentally associated with liking for salty-and-fatty foods (genetic and environmental $r = 0.16$), and emotional eating was genetically associated with liking for sweet-and-fatty foods (genetic $r = 0.31$).

Conclusions: The relation between BMI and diet appears to be mediated through dieting behaviors. Dietary counseling should focus on unhealthy dieting behaviors rather than only on direct advice on food use. *Am J Clin Nutr* 2008;88:263–71.

INTRODUCTION

The increased availability of palatable high-energy foods over the past decades has made diet-related choices a challenge. In attempts to control excess body weight, a conscious effort to restrain eating often arises. However, dietary restraint can lead to the development of other eating disorders, such as binge eating (1). Loss of control over eating also may have other disadvantageous consequences (2). Furthermore, these eating behaviors are associated with body adiposity (3).

Many questionnaires have been developed to measure dieting behaviors, especially dietary restraint (4–6). The Three-Factor

Eating Questionnaire (TFEQ) published by Stunkard and Messick in 1985 (6) consists of 51 items and measures 3 dimensions of eating behavior—restraint (cognitive restraint of eating), disinhibition, and hunger. The factors have been shown to differentiate between the reported and desired use-frequency and liking for several sugar- and fat-containing foods among dieting women (7). Karlsson et al (8) evaluated the construct validity and scaling properties of the TFEQ in large samples of obese subjects and constructed a revised and shortened version of the TFEQ with 18 items (TFEQ-R18), which measures the factors cognitive restraint, uncontrolled eating, and emotional eating. It has been shown that the TFEQ-R18 distinguishes among different eating patterns in the French general population (9) and that the restraint factor of the original TFEQ is negatively associated with daily energy intake (10). However, the validity of the restraint scales (eg, the restraint factor of the TFEQ) as measures of short-term dietary restriction has been questioned (11).

The relation between diet and body weight is far from clear (12). Although the general assumption is that overweight begins to develop when a person ingests more energy than he or she expends, the equation is not that simple. For example, epidemiologic studies suggest that the intake of sugars may be negatively associated with body weight (13). Body mass index (BMI) is known to be largely genetically determined, and its heritability is as high as 80% in Western populations (14); in addition, there is evidence that genetic effects contribute to the variation in the responses to fatty foods (15, 16). The heritability of the TFEQ-R18 factors has not been studied earlier, but twin studies

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estimating the heritability of the factors of the original 51-item TFEQ were conducted (10, 17). Results of these studies are somewhat contradictory, but they suggest that these behaviors are influenced by genetic effects.

The aim of the present study was to examine the relations among dieting behaviors, BMI, and responses to fatty foods. Associations among dieting behaviors, body weight, and diet, all of which are partly influenced by genetic factors, have been reported (9, 18). The bivariate modeling of twin data allowed estimation of whether a correlation between 2 variables is due to common underlying genetic or environmental factors and thus allowed the estimation of the underlying causes of the correlation. First, the effect of genetic and environmental factors on variance in TFEQ-R18 factors, BMI, and liking and use-frequency of fatty foods was evaluated in a sample of monozygotic (MZ) and dizygotic (DZ) twins. Furthermore, the genetic and environmental correlations among these factors were examined. Because of their high energy density and possible effects on changes in body weight, we decided to include only fatty foods (19).

SUBJECTS AND METHODS

Subjects

The data were collected in British and Finnish twin research units. The British data ($n = 1027$ twin persons) were collected from twins in the UK Adult Twin Registry (20) during 2005, and the present study was approved by the Guy's and St Thomas's Hospital Ethics Committee. All British participants were adults; the age range was 17–82 y ($\bar{x} \pm SD$ age: 55.6 ± 12.7 y). The Finnish data were derived from the ongoing fourth wave assessment of the FinnTwin12 study (21), which is based on 5 consecutive and complete-year cohorts of Finnish twins born from 1983 through 1987. At the time of the analysis, the responses were available from 299 persons who had a same-sex twin. In addition, 100 persons who had an opposite-sex twin had participated in the FinnTwin12 study but were excluded from all the analyses because of the small number of complete opposite-sex twin pairs ($n = 38$). All participants in the FinnTwin12 study were born from 1983 through 1984 and assessed in 2006 and 2007, and, thus, all Finnish subjects were young adults aged 22–24 y (mean age: 22.9 ± 0.5 y). The present study was approved by the Coordinating Ethics Committee of Helsinki University Hospital.

Data on weight and height were available for 89.3% ($n = 267$) of the Finnish and 99.9% ($n = 1026$) of the British participants. The BMI of most of the twins in Finland and all of the twins in the United Kingdom was measured (in kg/m^2) by a nurse during a clinic visit. In addition, 58 Finnish twins self-reported their weight and height. The zygosity of the twins was determined by questionnaire—in the United Kingdom by using the Peas in the Pod questionnaire (22, 23) and in Finland with the use of a deterministic algorithm using questions on physical similarity during school years, which has been shown to have high validity in another Finnish twin cohort (24). If the zygosity was still uncertain, it was checked by genotyping (partially underway in Finland).

The pooled data of the 2 datasets were used in multivariate analyses. The pooled data comprised 17.4% men and 82.6% women, of whom 22.5% were from Finland and 77.5% from the

United Kingdom. The pooled data contained 641 complete same-sex twin pairs with determined zygosity, of whom 314 were MZ and 327 were DZ, and 44 persons whose twins had not participated in the study.

Collection and analysis of food behavior questionnaires

Karlsson et al (8), evaluating the construct validity of the TFEQ (6) in obese men and women, revised the instrument to a 18-item questionnaire, the TFEQ-R18, based on the original items. Three factors emerged: cognitive restraint (6 items), uncontrolled eating (9 items), and emotional eating (3 items).

The TFEQ-R18 was administered and the scores were calculated as described by de Lauzon et al (9), who tested the reliability and applicability of the questionnaire with respect to the general population. Accordingly, each of the 18 items was scored from 1 to 4, and the scores were summed to obtain scale scores for cognitive restraint, uncontrolled eating, and emotional eating. The theoretical ranges for the items were 6–24 for cognitive restraint, 9–36 for uncontrolled eating, and 3–12 for emotional eating. The missing values of individual items (average: 1.1%; range: 0.6–1.5%) were replaced by the individual mean of the items of the factor in question. The reliability of the factors was measured by using Cronbach's alpha values, which, in the pooled data, were 0.79 for cognitive restraint, 0.82 for uncontrolled eating, and 0.89 for emotional eating.

In addition, the subjects filled in questionnaires describing their liking or disliking and use-frequency of 34 food items in the United Kingdom and 38 food items in Finland. The response alternatives for liking and disliking were on a scale from 1 to 7: 1, dislike very much; 2, dislike moderately; 3, dislike slightly; 4, neither like nor dislike; 5, like slightly; 6, like moderately; and 7, like very much. In Finnish, pleasantness or unpleasantness [from 1 (very unpleasant) to 7 (very pleasant)] was evaluated instead of liking or disliking, because the Finnish language lacks a word meaning "dislike." For use-frequency, the response alternatives were 1, never; 2, a couple of times a year or less; 3, a couple of times a month; 4, a couple of times a week; 5, once a day; and 6, several times a day. The foods were categorized by factor analysis with maximum likelihood extraction and orthogonal Varimax rotation. Two groups of fatty foods were identified—sweet-and-fatty foods, which included 4 items (chocolate, ice cream, sweet pastry, and sweet desserts), and salty-and-fatty foods, which included 6 items in the UK data set and 5 items in the Finnish dataset (fried potatoes or French fries, salty snacks, pizza, and hamburgers plus fish fried in batter and fried foods in the United Kingdom and salty patties in Finland). The scores for liking and use-frequency of the food groups were calculated as means of ratings given to the items. Thus, the theoretical ranges were 1–7 for the liking and 1–6 for the use-frequency variables of sweet-and-fatty and salty-and-fatty foods. Cronbach's alpha values for liking and use-frequency of sweet-and-fatty foods were 0.83 and 0.67, respectively. Because the variables of salty-and-fatty foods were calculated on the basis of different foods in the United Kingdom and Finland, Cronbach's alpha values also had to be calculated separately; those values were 0.78 in the United Kingdom and 0.84 in Finland for liking and 0.68 in the United Kingdom and 0.74 in Finland for use-frequency. The questionnaires were completed in English (the original language of the TFEQ) in the United Kingdom and in Finnish in Finland.



Quantitative genetic analysis

Classic twin modeling relies on the assumption that MZ twins are genetically identical, whereas DZ twins share, on average, half of their segregating genes (26). Genetic variance can be divided into additive genetic variance, which consists of the sum of the allelic effects on the phenotype over all relevant loci, and nonadditive genetic variance, which includes the interaction of alleles in the same locus (dominance). The epistatic effect—ie, interaction between alleles in different loci—is assumed to be absent. The correlations of both additive and nonadditive genetic effects are 1 within MZ pairs. Within DZ pairs, the correlations are 0.5 for additive and 0.25 for nonadditive genetic effects.

Environmental variation can be divided into environmental factors shared and unshared within twin pairs, and there is a similar effect on MZ and DZ pairs. The shared environment includes all environmental factors that make the twin pair similar for the trait, such as nonheritable maternal factors, shared childhood experiences, parental socioeconomic status, and shared friends and peers. The unshared environment includes all environmental factors and experiences that make siblings in the family dissimilar, including measurement error. Thus, the correlations of shared and unshared environmental effects are defined as 1 and 0, respectively, within both MZ and DZ twin pairs. Random mating with respect to the traits in question and the absence of gene \times environment interactions are also assumed in the model (25).

On the basis of these assumptions, the phenotypic variance of a trait can be decomposed to additive genetic effect (A), dominant (nonadditive) genetic effect (D), shared (common) environmental effect (C), and specific (unshared) environmental effect (E). In genetic modeling, these variance components are treated as latent (unmeasured) and standardized independent variables, which are used to explain the variation of the trait, treated as the dependent variable in the model. The variance components explaining the total observed phenotypic variance can be calculated by squaring the path coefficients (regression coefficients) in the model. Because these data included only twins reared together—not adopted twins or other relatives—we were unable simultaneously to estimate effects due to C and D. The decision between the ACE and ADEs model as the starting point for the analysis was based on the within-pair MZ and DZ correlation patterns of the variables: if within-pair MZ correlations are less than double the DZ correlations, C is likely to be present (ACE model). If the MZ correlations are higher than twice the DZ correlations, D is probably involved (ADE model).

We first built univariate models estimating relative proportions of A, C or D, and E on the variation of each trait separately. The assumptions of the twin model, which imply equal means and variances for MZ and DZ twins, were tested by comparing the chi-square change related to the change in df ($\Delta\chi^2_{df}[r]$) between the twin model and the saturated model, which did not make any of these assumptions. Then we studied whether the magnitude of the parameter estimates was equal in men and women and in the 2 datasets. Finally, we examined which model best described the variation of the trait.

Relying on the final univariate models and on the correlations between the phenotypes, we hypothesized which traits may have common underlying genetic or environmental effects and analyzed the correlations by a bivariate Cholesky decomposition.

Cholesky decomposition assumes that specific genetic and environmental factors affect each phenotype, but the underlying factors of 2 traits can also be correlated. Thus, we could study whether a correlation between phenotypes was due to shared genetic or environmental factors. First, starting with the full model, we tested whether all 3 variance components—A, C, and E—were necessary to explain the variance of and covariance between the traits. Second, we tested whether the correlation of the factors between the 2 traits was significant.

The fit of the model was estimated by using chi-square goodness-of-fit statistics and Akaike's Information Criterion values. If the change in the chi-square values compared with the change in the df measured by a *P* value was >0.05 between 2 nested models, the more parsimonious model was assumed to provide a better fit to the data. In addition, a model with a lower Akaike's Information Criterion value was considered to fit the data better.

Statistical analysis

The differences of means between sexes and countries were tested by using STATA software (version 9.0; Stata Corporation, College Station, TX) using the Wald test. The effect of the sample design clustered by twin pair on SEs was taken into account by using the "svy" option in STATA. All of the other basic statistical analyses were conducted by using SPSS statistical software (version 15.0.01; SPSS Inc, Chicago, IL). Genetic modeling was carried out with MX statistical software [version 1.7; Virginia Commonwealth University, Richmond, VA (25)].

RESULTS

The mean (\pm SD) ratings by country and sex are presented in **Table 1**. Significant ($P < 0.05$) sex differences were found for cognitive restraint, emotional eating, and liking and use-frequency of salty-and-fatty foods. Women rated higher than men on cognitive restraint (13.4 and 11.4, respectively) and emotional eating (6.4 and 4.8, respectively). Men reported significantly higher liking (5.7 and 4.9, respectively) and use-frequency (2.9 and 2.5, respectively) of salty-and-fatty foods than did women. Differences between the countries were found for all of the variables, except for the use-frequency of sweet-and-fatty foods: the mean of the Finnish dataset was higher for all of the other variables except cognitive restraint, emotional eating, and BMI. Age correlated significantly with BMI ($r = 0.30$), cognitive restraint ($r = 0.17$), uncontrolled eating ($r = -0.25$), liking for sweet-and-fatty foods ($r = -0.09$), and liking ($r = -0.44$) and use-frequency ($r = -0.31$) of salty-and-fatty foods.

Correlations of the variables within MZ and DZ twin pairs are shown in **Table 2**. The ratio of MZ correlations to DZ correlations averaged 2; the range was 1.6 (liking for sweet-and fatty foods) to 2.5 (use-frequency of sweet-and-fatty foods), which suggests that genetic effects underlie the traits.

On the basis of the within-pair MZ and DZ correlation patterns, the ACE model was chosen as the starting point for quantitative genetic analysis. The ACE models fitted the data better than did the saturated model, which did not make any of the assumptions of the twin model. For all of the variables, exclusion of C did not significantly worsen the model fit, and, for one variable—emotional eating—A also was nonsignificant in explaining variation in men. Constraining the magnitudes of the parameter estimates of men and women to be equal significantly



TABLE 1Variables in the pooled data by sex and country¹

Variable	All (n = 1326)			United Kingdom (n = 1027)		Finland (n = 299)	
	Theoretical range	Min–Max	Value	Men (n = 108)	Women (n = 919)	Men (n = 123)	Women (n = 176)
TFEQ-R18							
Cognitive restraint ^{2,4}	6–24	6.0–24.0	13.0 ± 3.7 ⁵	12.8 ± 3.0	13.4 ± 3.6	10.1 ± 3.0	13.3 ± 3.7
Uncontrolled eating ²	9–36	9.0–35.0	16.6 ± 4.8	15.8 ± 4.9	16.1 ± 4.8	18.3 ± 4.6	18.2 ± 4.4
Emotional eating ^{2,3}	3–12	3.0–12.0	6.1 ± 2.7	5.2 ± 2.1	6.4 ± 2.8	4.5 ± 1.8	6.3 ± 2.3
Sweet-and-fatty foods							
Liking ^{2,4}	1–7	1.5–7.0	5.8 ± 1.0	5.8 ± 1.0	5.8 ± 1.0	5.7 ± 1.8	6.1 ± 1.0
Use-frequency ⁴	1–6	1.0–5.3	3.0 ± 0.6	3.1 ± 0.6	3.0 ± 0.6	2.9 ± 0.6	3.1 ± 0.5
Salty-and-fatty foods							
Liking ^{2,4}	1–7	1.3–7.0	5.0 ± 1.2	5.2 ± 0.9	4.8 ± 1.2	6.1 ± 0.7	5.7 ± 1.0
Use-frequency ^{2,4}	1–6	1.0–4.0	2.6 ± 0.5	2.8 ± 0.5	2.5 ± 0.5	3.0 ± 0.4	2.7 ± 0.4
BMI ^{2,6}		15.8–48.6	25.3 ± 4.5	26.4 ± 3.9	25.8 ± 4.7	24.0 ± 3.6	22.8 ± 3.4

¹ TFEQ-R18, the shortened (18-item) Three-Factor Eating Questionnaire–R18.² Significant difference between countries, $P < 0.05$ (2-tailed t test).³ Significant difference between the sexes, $P < 0.05$ (2-tailed t test, pooled data).⁴ Significant sex × country interaction, $P < 0.05$.⁵ $\bar{x} \pm SD$ (all such values).⁶ BMI data were available for 1026 British and 267 Finnish subjects.

worsened the model fit for 3 variables (cognitive restraint, emotional eating, and liking for salty-and-fatty foods), and, thus, separate models were estimated for men and women. In women, constraining of the estimates of the UK and Finnish datasets to be equal significantly worsened the data fit for 4 variables (emotional eating, uncontrolled eating, use-frequency of sweet-and-fatty foods, and BMI); in men, the country differences were apparent for 2 variables (liking for salty-and-fatty foods and BMI). Because of these observations, the parameters were also estimated separately for the 2 datasets. For the model fit estimates for the univariate models in men and women, see Tables S1 and S2, respectively, under “Supplemental data” in the current online issue.

The parameter estimates for TFEQ-R18 factors, food groups, and BMI in men and women in the UK and Finnish datasets are

presented separately in **Figure 1**. Of the TFEQ-R18 factors, the highest heritability estimate (proportion of A, a^2) was obtained for uncontrolled eating, accounting for 45–69% of the total phenotypic variation. Emotional eating, in turn, had the lowest heritability estimate: in women, the effect of A on the variance of the trait remained significant (45% in the United Kingdom and 31% in Finland), whereas, in men, genetic effects were not significant and all of the variation in the trait could be explained by E. Approximately 45% of the variation in liking and use of fatty foods was explained by A, which varied in UK men from 24% (use of salty-and-fatty foods) to 54% (liking for sweet-and-fatty foods). The heritability estimates of the BMI were high: 56–75%.

Many of the variables correlated significantly (**Table 3**). The bivariate modeling was fitted for all the significant correlations

TABLE 2Within-pair intraclass correlations (Pearson correlation coefficients) of monozygotic (MZ) and dizygotic (DZ) pairs¹

	United Kingdom				Finland				Pooled	
	MZM	DZM	MZF	DZF	MZM	DZM	MZF	DZF	MZ	DZ
Complete pairs (n)	30	24	203	247	32	22	49	34	314	327
TFEQ-R18										
Cognitive restraint	0.39 ²	0.06	0.55 ³	0.23 ²	0.26	0.28	0.60 ³	0.47 ³	0.55 ³	0.29 ^{2,4}
Uncontrolled eating	0.61 ³	0.04	0.53 ³	0.34 ²	0.47 ³	0.45 ²	0.69 ³	0.41 ²	0.58 ³	0.35 ^{3,4}
Emotional eating	0.25	0.12	0.47 ³	0.16 ²	0.05	0.18	0.30 ²	0.36 ²	0.43 ³	0.22 ^{3,4}
Sweet-and-fatty foods										
Liking	0.41 ²	0.50 ²	0.51 ³	0.24 ³	0.31	0.30	0.29 ²	0.40 ²	0.45 ³	0.28 ^{3,4}
Use-frequency	0.38 ²	0.49 ²	0.51 ³	0.13 ²	0.37 ³	0.24	0.34 ²	0.47 ²	0.48 ³	0.19 ^{3,4}
Salty-and-fatty foods										
Liking	0.52 ³	0.35	0.54 ³	0.26 ³	0.39 ³	0.19	0.32 ²	0.16	0.59 ³	0.34 ^{3,4}
Use-frequency	0.35	0.21	0.53 ³	0.25 ³	0.50 ³	0.44 ²	0.48 ³	0.07	0.54 ³	0.31 ^{3,4}
BMI	0.64 ³	0.25	0.75 ³	0.39 ³	0.79 ³	0.16	0.62 ³	0.52 ³	0.74 ³	0.41 ^{3,4}

¹ MZM, monozygotic male pairs; DZM, dizygotic male pairs; MZF, monozygotic female pairs; DZF, dizygotic female pairs; MZ, monozygotic; Z, dizygotic; TFEQ-R18, the shorter (18-item) Three-Factor Eating Questionnaire.^{2,3} Significance of the correlation coefficient: ² $P < 0.05$, ³ $P < 0.01$.⁴ The difference between MZ and DZ correlations was significant as measured by Fisher z transformation.

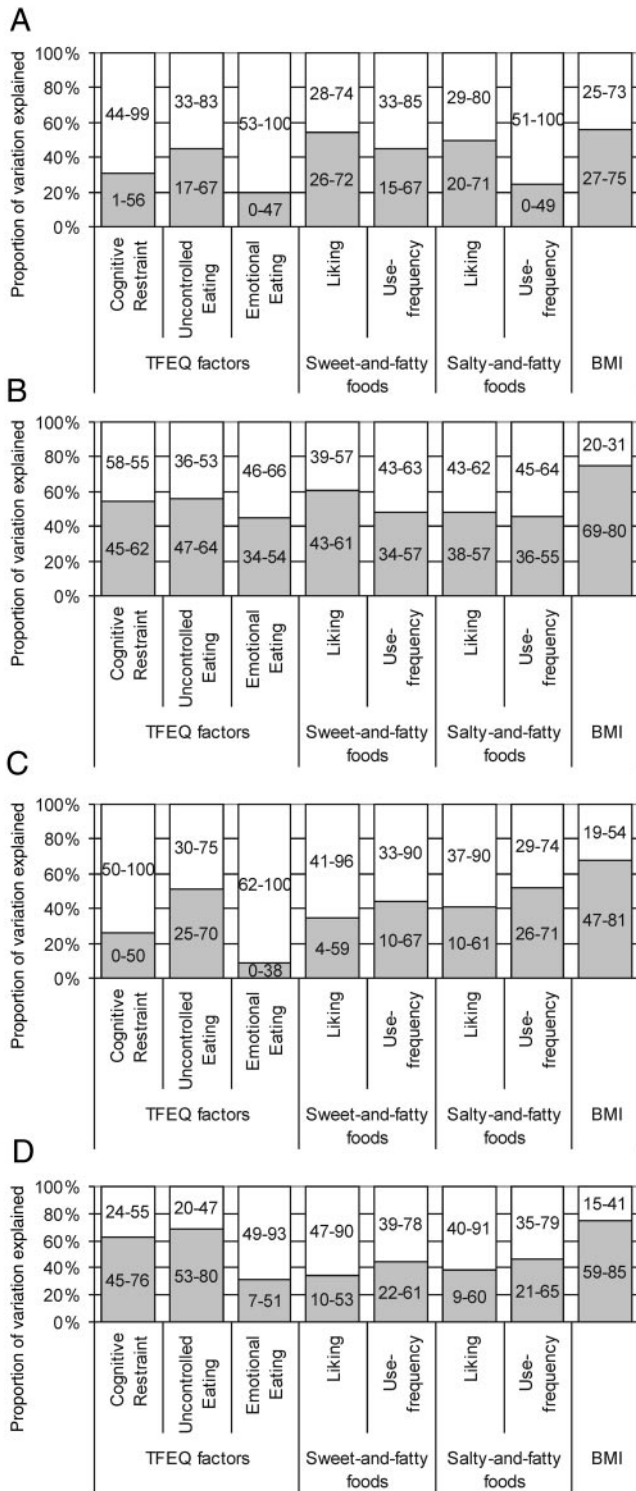


FIGURE 1. Proportion of variation of the traits explained by additive genetic (■) and specific environmental (□) effects separately for UK men (A; $n = 108$), UK women (B; $n = 919$), Finnish men (C; $n = 123$), and Finnish women (D; $n = 176$). The numbers within the bars are 95% CIs.

($P < 0.05$); for information on the model fit estimates, see Tables S3, S4, and S5 under “Supplemental data” in the current online issue. A and E correlations that remained significant are presented in **Tables 4, 5, and 6**. To increase the statistical power and to keep the volume of results presented reasonable, the bivariate

models were not built separately for sexes or data sets. Path diagrams of the bivariate models describing the correlations among BMI, emotional eating, and liking for sweet-and-fatty foods are shown in **Figure 2**. C effects on the variance or covariance of the traits were not significant in any bivariate models. The correlations of cognitive restraint with uncontrolled eating ($r = 0.06$), emotional eating ($r = 0.24$), and liking ($r = -0.18$) and use-frequency ($r = -0.30$) of salty-and-fatty foods were all due to genetic correlation between the traits, which suggests that these phenotypic correlations are largely due to common underlying genetic elements. The correlation between uncontrolled eating and liking for salty-and-fatty foods ($r = 0.25$) was mediated by both A and D factors and C and E factors, and the correlation between emotional eating and responses to sweet-and-fatty foods ($r = 0.12$ for liking and 0.06 for use-frequency) was mediated by A factors.

DISCUSSION

Although it is generally assumed that weight gain is due to the ingestion of more energy than is expended, many studies have failed to find a relation between dietary energy density and body weight; for a review, see Hill and Prentice (13). Similarly, we did not observe correlations between BMI and fatty food use or liking ratings. However, both BMI and food ratings were associated with dieting behaviors, which implies that there is a complex relation between diet and BMI that may be mediated in part by dieting behaviors.

Factors explaining variations between men and women

Sex differences were significant for cognitive restraint and emotional eating and the liking and use-frequency scores of salty-and-fatty foods, whereas age correlated modestly and positively with BMI and cognitive restraint and negatively with uncontrolled eating. These findings are in line with the results of de Lauzon et al (9), and they encourage the consideration of sex and age effects in studies of eating behavior. If these effects are not considered, a significant source of variance in the data may be ignored, and the effect one is interested in may be obscured by age and sex effects. Furthermore, if eating behavior between 2 groups is compared, the groups should be matched for age and sex.

For women, the heritability estimates (proportion of total variation due to A) of cognitive restraint and uncontrolled eating were higher (54–69%) than those of emotional eating (31–45%). In men, all of the estimates were lower, and, in the case of emotional eating, the estimate of A was not significant. Tholin et al (18) examined the heritability of similar factors measured in male twins by using the revised 21-item version of the TFEQ, called the TFEQ-R21, and found a heritability of 59% for cognitive restraint, 60% for uncontrolled eating, and 45% for emotional eating. These estimates are very similar to the estimates for women in the present study. According to both studies, the heritability of emotional eating appears to be lower than that of the other 2 TFEQ-R18 factors. The sex differences in the magnitude of genetic and environmental influences were significant for cognitive restraint, emotional eating, and liking for salty-and-fatty foods. Because the data contain significantly more women than men, the results on sex differences were further examined by comparing the within-pair correlations of the 2



TABLE 3

Pearson correlation coefficients among the phenotypes for 1326 British and Finnish twin persons¹

	TFEQ-R18			Sweet-and-fatty foods		Salty-and-fatty foods		BMI
	Cognitive restraint	Uncontrolled eating	Emotional Eating	Liking	Use-frequency	Liking	Use-frequency	
TFEQ-R18								
Cognitive restraint	1							
Uncontrolled eating	0.06 ²	1						
Emotional eating	0.24 ³	0.56 ³	1					
Sweet								
Liking	-0.05	0.12 ³	0.14 ³	1				
Use-frequency	-0.14 ³	0.06	0.09 ³	0.54 ³	1			
Salty								
Liking	-0.18 ³	0.25 ³	-0.02	0.38 ³	0.09 ³	1		
Use-frequency	-0.30 ³	0.14 ³	-0.08 ³	0.11 ³	0.26 ³	0.61 ³	1	
BMI ¹	0.13 ³	0.14 ³	0.31 ³	-0.01	-0.01	-0.06 ²	-0.03	1

¹ TFEQ-R18, the shorter (18-item) Three-Factor Eating Questionnaire.² $P < 0.05$.³ $P < 0.01$.

data sets. The within-pair correlation patterns of the United Kingdom and Finland differ from each other, which suggests that the sex differences may vary by age or culture.

Heritability estimates for the liking and use-frequency of both sweet and salty fatty foods were significant (around 45%). The liking for sweet, aqueous solutions is partly inherited, whereas the liking for salty solutions is not (27). Thus, the heritability of the liking for and use-frequency of salty-and-fatty foods may be due to a genetic liability to prefer fatty perception rather than salty taste. It is noteworthy that saltiness is not the only sensory property of the foods classified as salty-and-fatty in this study. The sex differences in the variance components were significant for the liking for salty-and-fatty foods. In an earlier twin study by our group (15), the sex differences in food use were studied in more detail by using a larger dataset with roughly equal numbers of young men and women. Sex differences in the magnitude of the variance estimates were found for the use-frequency of sweet foods but not for that of high-fat foods. Here, too, the differences between the results may be due to the uneven sex distribution and the small number of men in the present study, and they should be

reconsidered after the accumulation of more data from the ongoing Finnish study. The heritability estimates obtained for BMI are similar to those found in earlier studies (14).

Bivariate models: genetic and environmental associations among the variables

Significant correlations were observed among all TFEQ-R18 factors; the correlation pattern is remarkably similar to that described by de Lauzon et al (9). The correlation between cognitive restraint and emotional eating was explained solely by genetic factors. The genetic factors influencing this association may be linked to those affecting body weight; obese people try to restrain their body weight, and the influence of emotions on eating is stronger in obese than in nonobese people (28). The correlation between uncontrolled eating and emotional eating implies that some of the same factors predispose a person to loss of control over eating in general (uncontrolled eating) and in emotional situations.

BMI was positively (mostly genetically) correlated with all 3 TFEQ-R18 factors. In a study by de Lauzon-Guillain et al (3),

TABLE 4

Bivariate Cholesky models of the TFEQ-R18 factors and BMI¹

Correlated traits	Additive genetic correlation			Specific environmental correlation		
	r_g	95% CI	Proportion of trait correlation explained %	r_e	95% CI	Proportion of trait correlation explained %
Cognitive restraint and uncontrolled eating	0.20	0.10, 0.31	100	—		
Cognitive restraint and emotional eating	0.42	0.31, 0.54	100	—		
Emotional eating and uncontrolled eating	0.75	0.66, 0.83	58	0.50	0.42, 0.57	42
Cognitive restraint and BMI	0.16	0.06, 0.25	100	—		
Uncontrolled eating and BMI	0.29	0.19, 0.39	81	0.13	0.03, 0.24	19
Emotional eating and BMI	0.51	0.39, 0.62	81	0.16	0.05, 0.26	19

¹ TFEQ-R18, the shortened (18-item) Three-Factor Eating Questionnaire; r_g , additive genetic correlation; r_e , specific environmental correlation. The data from 314 monozygotic and 317 dizygotic pairs were used in the analyses. The correlations of the traits were separated into r_g and r_e .



TABLE 5

Bivariate Cholesky models among responses to fatty foods and the TFEQ-R18 factors¹

Correlated traits	Additive genetic correlation			Specific environmental correlation		
	r_g	95% CI	Proportion of trait correlation explained %	r_e	95% CI	Proportion of trait correlation explained %
Cognitive restraint and use-frequency of sweet-and-fatty foods	-0.18	-0.31, -0.04	61	-0.11	-0.21, -0.01	39
Cognitive restraint and liking for salty-and-fatty foods	-0.19	-0.31, -0.07	100	—		
Cognitive restraint and use-frequency of salty-and-fatty foods	-0.47	-0.57, -0.36	100	—		
Uncontrolled eating and liking for salty-and-fatty foods	0.16	0.02, 0.29	52	0.16	0.05, 0.25	48
Emotional eating and liking for sweet-and-fatty foods	0.31	0.18, 0.43	100	—		
Emotional eating and use-frequency of sweet-and-fatty foods	0.20	0.07, 0.33	100			

¹ /TFEQ-R18, the shortened (18-item) Three-Factor Eating Questionnaire; r_g , additive genetic correlation; r_e , specific environmental correlation. The data from 314 monozygotic and 317 dizygotic pairs were used in the analyses. The correlations of the traits are separated into r_g and r_e .

similar phenotypic correlations were found in adults but not in adolescents or young adults. On closer examination, the correlation between emotional eating and BMI was higher in overweight (BMI \geq 25) subjects ($r = 0.21$, $P < 0.001$) than in normal-weight (BMI $<$ 25) subjects ($r = 0.10$, $P = 0.009$). In the absence of longitudinal studies or controlled trials, the causal relation between the variables remains unclear. It would be crucial to find out whether the weight gain leads to emotional eating or whether persons with a tendency toward emotional eating gain weight more easily than do others.

Cognitive restraint scores correlated negatively with the use-frequency of both sweet-and-fatty and salty-and-fatty foods, which suggests that the influence of A and D on the restriction of food intake reaches the behavioral level. However, the effect of reporting bias on the correlation cannot be overruled; the individual's restriction of his or her diet may find a frequent use of

fatty foods socially undesirable, and, thus, the person may underreport their use (29). Uncontrolled eating was, in turn, associated with liking for salty-and-fatty foods ($r = 0.16$) and emotional eating was associated with liking ($r = 0.25$) and use-frequency ($r = 0.14$) of sweet-and-fatty foods. Thus, the 2 types of disinhibition of dietary restriction focus on different foods or tastes. These findings are in line with results of de Lauzon et al (9); in their study, cognitive restraint was negatively associated with the use-frequency of salty (French fries) and sweet (sugar and confectionery) fatty foods, uncontrolled eating scores were associated with energy-dense foods, and emotional eating was associated with sweet-and-fatty foods. A genetic correlation between emotional eating and liking for sweet-and-fatty foods may be associated with the craving for sweet foods during emotional stress. Sweet foods may relieve the stress because of the rewarding effects of the ingestion of sugars (30). An environmental

TABLE 6

Bivariate Cholesky models among responses to fatty foods¹

Correlated traits	Additive genetic correlation			Specific environmental correlation		
	r_g	95% CI	Proportion of trait correlation explained %	r_e	95% CI	Proportion of trait correlation explained %
Liking for sweet-and-fatty foods and use-frequency for sweet-and-fatty foods	0.66	0.56, 0.75	58	0.44	0.36, 0.52	42
Liking for salty-and-fatty foods and use-frequency of salty-and-fatty foods	0.65	0.54, 0.74	55	0.46	0.38, 0.53	45
Liking for sweet-and-fatty foods and liking for salty-and-fatty foods	0.47	0.34, 0.59	57	0.33	0.24, 0.42	43
Use-frequency of sweet-and-fatty foods and use-frequency of salty-and-fatty foods	0.38	0.24, 0.51	58	0.24	0.14, 0.33	42
Liking for sweet-and-fatty foods and use-frequency of salty-and-fatty foods	0.23	0.11, 0.35	100			
Use-frequency of sweet-and-fatty foods and liking for salty-and-fatty foods	0.24	0.12, 0.35	100			

¹ r_g , additive genetic correlation; r_e , specific environmental correlation. The data from 314 monozygotic and 317 dizygotic pairs were used in the analyses. The correlations of the traits were separated into r_g and r_e .

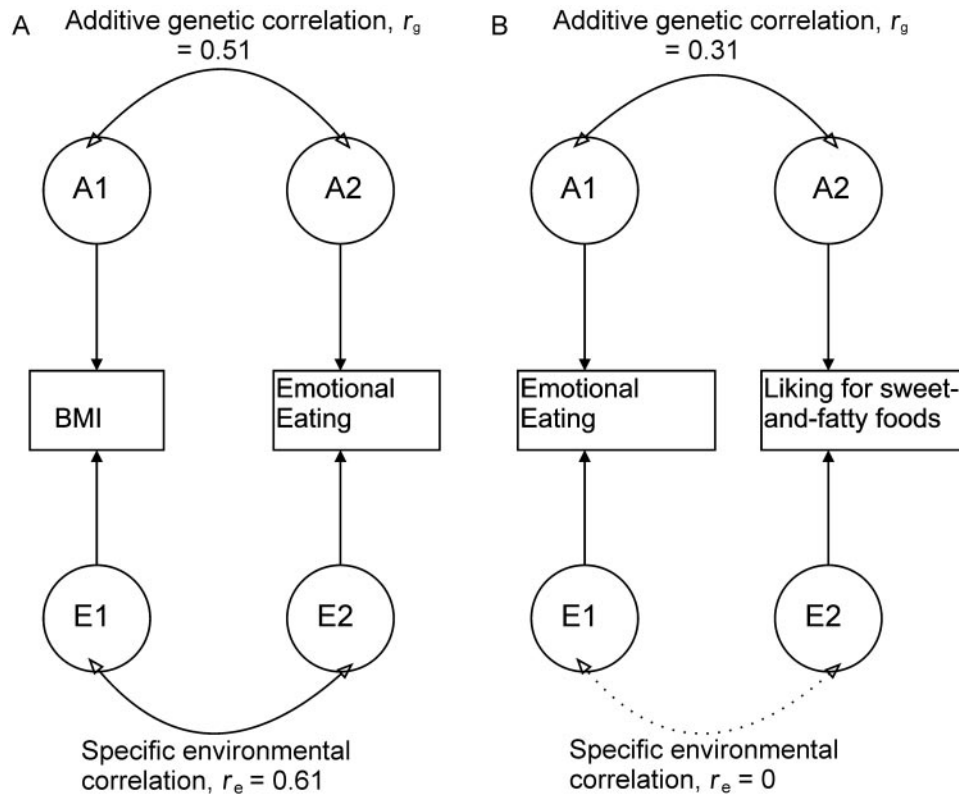


FIGURE 2. Path diagram of a bivariate Cholesky model for one member of a twin pair. A) The correlations between BMI and emotional eating are described; B) the correlations between emotional eating and liking for sweet-and-fatty foods are described. The variance of the traits was decomposed to additive genetic (A) and specific environmental (E) effects, and the covariance was decomposed to additive genetic (r_g) and specific environmental (r_e) correlations. The data were from 314 monozygotic and 317 dizygotic pairs used in the analyses.

correlation between uncontrolled eating and liking for salty-and fatty foods in turn suggests that the same environmental cues—such as the perception of having overeaten (28)—that lead to a disinhibition of dietary restriction may influence the use of salty-and-fatty foods.

Higher correlation of cognitive restraint with use-frequency ratings than with liking ratings of fatty foods is in concordance with the results of previous studies. Using the original TFEQ, Lähtenmäki and Tuorila (7) found that high cognitive restraint was associated with lower reported use-frequency of butter, margarine, cheese, and fruit and berry foods but not with lower liking and desired use-frequency ratings. The use-frequency and liking for the same foods are correlated (31). In an earlier twin study by our group (32), 63% of the correlation between liking and use-frequency of sweet foods ($r = 0.55$) was explained by A and D, and the remaining 37% was explained by E.

Methodologic considerations

The present data were based on self-reports, and misreporting thus may have occurred consciously or unconsciously. In genetic modeling, the measurement error is expressed as an increase in the estimates of specific environmental effects. The present study design allowed us to decompose the variance and covariance of the traits to genetic and environmental factors, but it did not specify which these affecting factors are. The strong associations among the variables indicated the functions of the elements, but the underlying genetic factors remain to be identified

by gene-mapping experiments and the environmental factors by more detailed epidemiologic studies.

Conclusions

Close consideration of the relations among BMI, dieting behaviors, and the use and liking ratings of fatty foods showed that the relation between diet and obesity is partly modified by dieting behaviors—ie, dietary restraint and disinhibition of the control over eating. The results provide insight into the background mechanisms of obesity and suggest that, in dietary counseling, attention should be paid to the dieting behaviors as well as to strict control over food intake.

The authors' responsibilities were as follows—KK, HT, AK, and MP: planned the study; TDS, LFC, and JK: collected the data; KK: analyzed the data and drafted the manuscript; KS: assisted in the quantitative genetic analyses; and all authors: the interpretation of the results and the writing of the manuscript and acceptance of the final version. None of the authors had a personal or financial conflict of interest.

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