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Dietary Restraint Is Non-Genetically Associated with Change in Body Mass Index: The Healthy Twin Study

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Purpose: We aimed to examine if past and more recent body mass index (BMI) changes are associated with eating behavior (EB) traits and whether these associations are due to non-genetic factors. **Materials and Methods:** In 1321 Korean twins and family members, recent and past BMI change groups were defined using quartiles of BMI change between first and second visits over 2.4±0.9 years and BMI change between 20 years old and second visit, respectively. We applied linear mixed analysis for relationships of past or recent BMI change groups and each EB (restrained, external, and emotional EB using the Dutch Eating Behavior Questionnaire) assessed at second visit after adjusting for household effect and covariates (age, gender, education, medical history of diabetes, hypertension, and dyslipidemia, alcohol use, physical activity, smoking habit, and calorie intake). In monozygotic twin pairs, paired t-test for within-pair comparison and conditional logistic regression analysis were conducted regarding EB. **Results:** Greater past BMI change was associated with higher restrained eating scores (*P* for trend=0.031), whereas greater recent BMI change was associated with higher external eating scores (*P* for trend=0.046). In co-twin-control analysis, twins with greater past BMI change were more likely to have higher restrained eating scores as compared with their co-twins with lower past BMI change (odds ratio 1.80; 95% confidence interval 1.13–2.87), whereas there were no associations between recent BMI change and external eating scores. **Conclusion:** Greater BMI change since 20 years old is associated with higher dietary restraint, and non-genetic factors explain this relationship.

Key Words: Dietary restraint, non-genetic factor, BMI change, twin

INTRODUCTION

Prevention of weight gain and obesity are not problems restricted only to western societies. An increase in the prevalence of obesity [defined as a body mass index (BMI) ≥25 kg/m^2] in Koreans over the last decade[1] indicates the need for behavioral approaches such as interventions that focus on eating behaviors to attenuate this trend. Regulating eating behaviors to prevent weight gain may be an inevitable strategy needed to resist the dietary temptations inherent in the current "obesogenic" food environment.[2] However, excessive dietary restraint (the perception that one monitors and makes an effort to limit dietary intake to achieve or maintain a certain body weight)[3] may lead to counter-regulatory behavior, disinhibition (defined as susceptibility to overeating due to a loss of eating control),[3] and may result in weight gain.[4-7] Lowe, et al.[8] reviewed evidence suggesting that dieting and restrained eating behaviors in non-obese individuals may indicate future weight gain. On the contrary, higher dietary restraint and suppressed disinhibition may prevent weight gain or predict weight loss.[9-12] Therefore, the nature of the associations between eating behaviors and body weight still remains controversial.[13]

Although eating behaviors have been mostly studied as predictors for weight change or weight status,[4-12] some weight-loss studies found the impact of weight-loss on eating behaviors.[13,14] After short-term weight reduction, dietary restriction scores increased, while disinhibition scores decreased.[13,14] Similarly, random digit dial surveys in populations indicated that avoidance of flexibility in the diet (i.e., consistent eating pattern) was one key factor in individuals who were successful at long-term weight loss maintenance.[11] Thus, these studies suggest that eating behaviors may be reactions to maintain previously lost weight. However, as these results were derived from individuals who had dieting intention which might influence that relationship,[15,16] the impact of natural course of weight change on eating behaviors in population-based samples is still uncertain.

In Korean twins and their families, we found that greater weight gain from 20 years old was cross-sectionally associated with higher restrained and emotional eating,[17] and increase in external eating was independently associated with weight gain after adjustment for first bodyweight and eating behavior scores in a second study over the average of 2.4±0.9 years.[18] In previous studies, however, we did not examine if more recent weight change was associated with restrained eating as shown in the past weight change and if non-genetic effects explained the associations. There is evidence that genetic and familial factors may explain the mechanism for the association between weight change and dieting attempt,[19] and genetic and non-genetic factors may contribute to the association between recent weight change and dietary restraint.[20] However, to the best of our knowledge, there is no twin study evaluating the effects of non-genetic factors on the associations between past weight change and eating behaviors including external and emotional eating. We hypothesized that individuals who had greater past and recent weight changes will have higher scores in each eating behavior trait and that non-genetic factors will contribute to the associations. Then, we investigated if past and more recent BMI changes are associated with eating behaviors and also whether these associations are due to non-genetic factors.

MATERIALS AND METHODS

Participants and procedure

The subjects were participants in the Healthy Twin Study, which has been conducted as a part of the Korean Genomic Epidemiologic Study since 2005. Participants typically included a twin pair and their first-degree family members.[17,18,21,22] Zygosity of twins was determined by a questionnaire that achieved greater than 90% accuracy and genetic analysis using 16 short tandem repeat markers (15 autosomal-markers and one sex-determining marker; Amp*Fl*STR Identifier Kit; Perkin Elmer, Waltham, MA, USA).[23] A total of 3077 individuals (1217 men and 1860 women; 1062 monozygotic and 243 dizygotic twin individuals, five undetermined twin individuals, and 1767 non-twin family members) filled out the baseline questionnaire and provided weight and height measurements. Of the participants, 1321 individuals (455 men and 866 women; 545 monozygotic and 105 dizygotic twin individuals and 671 non-twin family members; age 44.4±12.5 years) with data for self-reported body weight at 20 years of age, measured body weight and height at first and second visits, or surveys for eating behaviors at second visit (follow-up 2.4±0.9 years, range 1.1–5 years) were included in the analyses. All participants provided written informed consent. All study procedures were approved by the Institutional Review Board of the participating institutions.

Measurements

Eating behavior was assessed using a validated Korean version of the Dutch Eating Behavior Questionnaire.[24] The questionnaire refers to three aspects of eating behaviors: restrained eating (10 items), emotional eating (13 items), and external eating (10 items). Higher scores reflect a greater tendency to exhibit that particular eating behavior trait. The internal reliability coefficients (Cronbach's alpha) were 0.92 for the restrained trait, 0.94 for the emotional trait, and 0.86 for external trait.[17]

The weight at 20-years-of-age was obtained by a question contained in a self-administered questionnaire. Trained research assistants measured the bodyweight and height of each participant using a digital balance (Tanita Co., Seoul, Korea) and stadiometer (Samwha Co., Seoul, Korea) at first and second visits. Body mass index was calculated by dividing the self-reported and measured weight (kg) by the square of the height (m). Information about education, alcohol consumption, pack-years of cigarette smoking, and physical activity using the Korean version of the International Physical Activity Questionnaire,[25] daily caloric intake using a validated 103-item semi-quantitative food frequency questionnaire,[26] and medical history of chronic diseases (hypertension, diabetes mellitus, dyslipidemia, and depression) were extracted from the baseline questionnaire.

Data-analysis

Past change in BMI was computed as BMI at second visit (using measured weight and height) minus BMI at 20 years old (using self-reported weight and measured height) and categorized into four quartiles. Recent change in BMI was computed as BMI at second visit minus BMI at first visit (using measured weight and height) and also categorized into four quartiles. The characteristics were compared by weight change groups using ANOVA (and post hoc comparison using the Scheffe test if there was a significant difference between groups and polynomial contrast test for a linear trend) or the chi-square test. The relationships between past and recent BMI changes and eating behaviors were analyzed using a linear mixed model, in which the correlation structures from family relationships was considered by adjusting for household effect as a random effect. Conventional covariates including gender, age, and lifestyle (smoking habit, alcohol consumption, calorie intake, and physical activity), and other covariates associated with weight change (education level and medical history of diabetes mellitus, hypertension, and dyslipidemia) were adjusted as fixed effects. To evaluate non-genetic association between BMI change and eating behaviors after controlling for the effects of genetic factors, we conducted a co-twin-control study in 190 pairs of monozygotic twins for the relationship with past BMI change and 256 pairs of monozygotic twins for the relationship with recent BMI change. Within-pair comparison of eating behaviors between twin with greater BMI change and co-twin with lower BMI change was conducted using paired t-test. Conditional logistic regression analysis with adjustment for lifestyle, education level, and medical history was applied for the association between BMI change and eating behaviors, in which an individual who had a greater BMI change than his/her co-twin was compared with the co-twin regarding the eating behaviors. The significance level was determined as $p<0.05$. The statistical analyses were conducted with the software package IBM SPSS statistics version 19.0.0 (IBM, New York, NY, USA).

RESULTS

Table 1 shows the distribution of BMI at 20 years old and two visits, eating behaviors traits at second visit, and demographic according to quartile groups of past and recent BMI changes. Individuals in higher quartile groups of BMI change were more likely to have greater current BMI and lower past BMI. Individuals in higher quartile groups of past BMI change tended to score higher on the restrained eating trait (*P* for trend=0.001), while those in higher quartile groups of recent BMI change tended to give higher scores on the external eating trait (*P* for trend=0.003). Table 2 presents the associations between past and recent BMI changes and eating behaviors. Greater past BMI change was still associated with higher restrained eating score (*P* for trend=0.031), whereas greater recent BMI change was also associated with higher external eating score (*P* for trend=0.046) after adjustment for age, gender, household effect, lifestyle, education level, and medical history. However, past BMI change was not associated with external and emotional eating traits and recent BMI change was not associated with restrained and emotional eating traits. Table 3 shows the findings from co-twin-control analysis in monozygotic twins. After adjusting for lifestyle, education level, and medical history, twin with greater past BMI change, as compared with his/her co-twin with lower past BMI change, was 1.8 times (95% confidence interval, 1.13–2.87) more likely to have higher restrained eating trait. In contrast, external eating trait was not associated with the risk for having higher recent BMI change.

DISCUSSION

In this prospective cohort study on Korean twins and their families, individuals who scored higher on restrained eating trait were more likely to have greater BMI increase since 20 years of age, and those who scored higher on external

Table 1. The Comparison of Characteristics between Past and Recent Quartile Groups (Q1–Q4) of BMI Change

	BMI change between 20 yrs old and second visit (n=1082)						BMI change between first and second visits (n=1321)					
	Q1 (n=270)	Q2 (n=271)	Q3 (n=271)	Q4 (n=270)	$P_{between\ groups}$†	P_{trend}‡	Q1 (n=330)	Q2 (n=330)	Q3 (n=331)	Q4 (n=330)	$P_{between\ groups}$†	P_{trend}‡
BMI at 20 yrs old (kg/m^2)	22.1±2.8	20.6±1.9*	20.4±2.0*	20.1±2.3*	<0.001	<0.001						
BMI at first visit (kg/m^2)							24.6±3.6	23.8±3.2*	23.2±2.9*	23.2±2.9*	<0.001	<0.001
BMI at second visit (kg/m^2)	21.5±2.6	22.7±2.0*	24.1±2.1*	26.8±2.8*	<0.001	<0.001	23.2±3.2	23.6±3.2	23.7±3.0	24.7±3.0*	<0.001	<0.001
BMI change between 20 yrs old and second visit (kg/m^2)	-0.5±1.6	2.1±0.5*	3.7±0.5*	6.7±1.9*	<0.001	<0.001						
BMI change between first and second visits (kg/m^2)							-1.4±1.4	-0.1±0.2*	0.5±0.2*	1.5±0.7*	<0.001	<0.001
Restrained eating at second visit	2.5±1.0	2.5±0.9	2.6±0.9	2.7±0.9*	0.004	0.001	2.5±1.0	2.5±0.9	2.6±0.9	2.6±0.9	0.535	0.230
External eating at second visit	2.7±0.8	2.6±0.8	2.7±0.8	2.6±0.8	0.174	0.208	2.5±0.8	2.6±0.8	2.6±0.8	2.7±0.8*	0.022	0.003
Emotional eating at second visit	1.5±0.7	1.4±0.6	1.4±0.7	1.5±0.7	0.654	0.490	1.4±0.6	1.4±0.7	1.4±0.6	1.5±0.8	0.136	0.083
Age at second visit (yrs)	44.7±12.2	44.0±11.4	45.0±10.9	48.1±11.0*	<0.001	<0.001	48.2±13.1	47.0±12.3	47.1±12.3	44.8±12.1*	0.004	0.001
Monozygosity	115 (42.6)	118 (43.5)	126 (46.5)	105 (38.9)	0.353	0.545	116 (35.2)	143 (43.3)	134 (40.5)	152 (46.1)	0.031	0.014
Women	202 (74.8)	176 (64.9)	152 (56.1)	178 (65.9)	<0.001	0.006	216 (65.5)	217 (65.8)	213 (64.4)	220 (66.7)	0.940	0.849

BMI, body mass index.
Values were mean±SD or n (%). BMI change between 20 yrs old and second visit was calculated as (BMI at second visit-BMI at 20 yrs old); BMI change between first and second visits was calculated as (BMI at second visit-BMI at first visit).
*p<0.05 compared to 1st quartile group using Scheffe test (post-hoc analysis).
†ANOVA or chi-squared test.
‡Polynomial test of ANOVA or chi-squared test for the trend.

Table 2. The Eating Behaviors Traits at Second Visit According to Past and Recent BMI Change

	BMI change between 20 yrs old and second visit (n=1082)						BMI change between first and second visits (n=1321)					
	Q1 (n=270)	Q2 (n=271)	Q3 (n=271)	Q4 (n=270)	$P_{between\ groups}$†	P_{trend}‡	Q1 (n=330)	Q2 (n=330)	Q3 (n=331)	Q4 (n=330)	$P_{between\ groups}$†	P_{trend}‡
Age, sex, household effect-adjusted												
Restrained eating	2.34±0.07	2.35±0.06	2.55±0.06*	2.71±0.07*	<0.001	<0.001	2.41±0.06	2.44±0.06	2.48±0.06	2.46±0.06	0.866	0.507
External eating	2.57±0.06	2.58±0.05	2.65±0.05	2.68±0.06	0.478	0.133	2.52±0.05	2.60±0.05	2.56±0.05	2.62±0.06	0.420	0.207
Emotional eating	1.40±0.05	1.41±0.05	1.40±0.05	1.48±0.05	0.651	0.325	1.44±0.04	1.39±0.04	1.35±0.04	1.41±0.04	0.501	0.582
Full model§												
Restrained eating	2.41±0.22	2.49±0.22	2.63±0.21	2.61±0.21	0.132	0.031	2.84±0.19	2.65±0.19	2.84±0.20	2.79±0.19	0.128	0.917
External eating	2.83±0.19	2.66±0.18	2.76±0.18	2.76±0.18	0.248	0.641	2.74±0.16	2.75±0.16	2.78±0.17	2.91±0.16	0.153	0.046
Emotional eating	1.80±0.17	1.64±0.17	1.70±0.16	1.72±0.17	0.262	0.466	1.74±0.15	1.68±0.15	1.67±0.15	1.75±0.15	0.554	0.952

BMI, body mass index.
Values were estimated mean±standard error. BMI change between 20 yrs old and second visit was calculated as (BMI at second visit-BMI at 20 yrs old); BMI change between first and second visits was calculated as (BMI at second visit-BMI at first visit).
*p<0.05 compared to the 1st quartile group using simple contrast test (†linear mixed model).
‡Using polynomial contrast test of linear mixed model.
§The models included sex, age, education level, history of diabetes mellitus, hypertension, dyslipidemia, means of smoking (pack-years), alcohol consumption (g/week), calorie intake (Cal/day), and physical activity (MET·min/week) at first visit as random effects and household effect as a fixed effect.

Table 3. Risk Estimation of Eating Behaviors for Having Higher Past or Recent BMI Change in Monozygotic Twins

	BMI change between 20 yrs old and second visit				BMI change between first and second visits			
	Twins with higher change (n=190), mean±SD†	Co-twins with lower change (n=190), mean±SD†	$P_{difference}$*	Odds ratio (95% CI)†	Twins with higher change (n=256) mean±SD†	Co-twins with lower change (n=256) mean±SD†	$P_{difference}$*	Odds ratio (95% CI)†
BMI change between 20 yrs old and second visit	4.0±2.7	2.0±2.5	<0.001					
BMI change between first and second visits					0.78±0.92	-0.32±1.00	<0.001	
Restrained eating at second visit	2.73±0.97	2.51±0.95	<0.001	1.80 (1.13, 2.87)	2.62±0.98	2.55±0.99	0.461	1.14 (0.89, 1.44)
External eating at second visit	2.67±0.83	2.68±0.81	0.483	0.76 (0.40, 1.44)	2.65±0.87	2.70±0.84	0.550	0.87 (0.65, 1.15)
Emotional eating at second visit	1.46±0.70	1.43±0.75	0.624	0.50 (0.21, 1.21)	1.45±0.77	1.44±0.70	0.886	1.05 (0.75, 1.48)

BMI, body mass index; CI, confidence interval; SD, standard deviation.
BMI change between 20 yrs old and second visit was calculated as (BMI at second visit-BMI at 20 yrs old); BMI change between first and second visits was calculated as (BMI at second visit-BMI at first visit).
*Paired t-test.
†Estimates for having higher BMI change than co-twin were assessed using conditional logistic regression analysis with an adjustment for education level, history of diabetes mellitus, hypertension, dyslipidemia, means of smoking (pack-years), alcohol consumption (g/week), calorie intake (Cal/day), and physical activity (MET·min/week) at first visit.

eating trait were more likely to experience a recent BMI increase. These findings suggest that the associations between BMI change and eating behaviors may be different according to the duration of BMI change. However, the apparent differences in these associations according to the period of BMI change may be also determined by the amount of BMI change over time. In other words, recent small BMI increase may be associated with higher external eating trait, while greater BMI increase over long-term period may be associated with higher dietary restraint.

At a first glance, this observation appears to be contrasted with previous weight-loss studies; i.e. those who maintain long-term successful weight loss have a sustained effort to monitor and control food intake[27] and obese participants of short-term weight-loss programs reported higher dietary restraint as they lost their weight.[13,14] However, this phenomena could be explained if we assume that individuals who experience more recent BMI increase due to higher external eating trait are more likely to control eating to prevent more weight gain or lose weight after a long period of time (as found in our study), and those who are able to lose their weight still tend to restrain their eating to prevent weight regain (as found in weight-loss studies).

In co-twin-control analysis, twins who had greater BMI increase since 20 years old than their co-twins were 1.8 times more likely to score higher on the restrained eating trait, despite their genetics were 100% controlled. Our findings are in good agreement with a previous study in a community-based sample of twins from Washington State.[20] In this study, restrained score was positively associated with weight gain in individual twins and this relationship in dizygotic twin pairs was stronger than that in monozygotic twin pairs.[20] There are differences between our and the previous studies in the assessment tool for restrained eating, the assessment method for weight change, and the weight change interval, nevertheless, these results provide evidence of non-genetic factors as a mechanism for the link between past BMI change and restrained eating trait, although our study could not indicate specific non-genetic factors. Further research is required to find the influential non-genetic factors in the association between individual twins' restrained eating trait and weight change and shared genetic factors in that relationship.

Several points need to be taken into account. Firstly, although we adjusted for potential confounders, associations could reflect confounding by unmeasured or poorly measured confounders such as dieting, body image, and weight concern. Secondly, current findings do not provide causality for the associations. In other words, we cannot demonstrate whether eating behaviors were responses to or risk factors for BMI change. Probably, restrained eating trait may interact with BMI change, and the associations could then be bidirectional. Thirdly, weight at 20-years-of-age was assessed by self-report and the BMI change was calculated using the difference between measured BMI at second visit and estimated BMI at 20 years old. Although previous studies have suggested a high correlation between self-reported past weight and actual weight,[28] the calculation using different assessment methods may result in a systemic bias due to a possibility of differential estimation according to weight status. Finally, we did not assess weight fluctuation, which might be related with eating behaviors, as suggested in a previous study.[29]

In summary, in Korean twins and their family members, higher restrained eating trait tends to be associated with long-term BMI change than recent BMI change and the association may be explained by non-genetic factors. Further work is needed to clarify the mechanisms involved in the associations.

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