보건학 석사학위 논문

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지도교수 성주헌

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부위원장 김 호 (인)

위 원 성주헌 (인)

ABSTRACT

Association between Personality Traits and Obesity indices: Family and Co-twin Analysis

양사라
유전체역학전공 보건학과
서울대학교 보건대학원

Personality traits of an individual affect one's attitude towards life and one's life style factors determining health status. Since emotional disruption, such as depression and mood disorders, and unhealthy life habits are established risk factors of obesity, investigating the association between personality, life style, and obesity will lead to development of efficient intervention or preventive measure for obesity, according to their personality profiles. To this end, we attempted to explore the associations between Temperament and Character Inventory (TCI)'s seven dimensions and obesity indices: body mass index (BMI), waist circumference, waist hip ratio (WHR), trunk and

total body fat percent measured by Dual-energy X-ray absorptiometry (DXA) in Korean twins and their families. Additionally, we aim to discriminate environmental and genetic effect of TCI on obesity using pair-wise analysis of each and combined monozygotic twins (MZ), dizygotic twins (DZ) and sibling pairs adjusted for age and sex. We have expected that estimating non-genetic association between personality traits and obesity will specifically show potential target chains interconnecting personality, life style and obesity.

A total of 3320 individuals (1333 men, 1987 females, 661 families) of the Healthy Twin Study in Korea were involved in this study. This population includes 545 MZ pairs, 122 DZ pairs, and 2695 sibling pairs. Association between TCI and obesity was analyzed adjusting for age, sex, smoking and alcohol consumption history. A random effect model (REM) was applied to adjust familial correlations. For co-twin and sib-pair analyses pair-wise regression models using pairwise-difference values were used.

In conventional regression analyses (REM), among seven domains of TCI, novelty seeking and harm avoidance had the positive association with obesity. Decreased persistence (β =-0.0003), self-directedness (β =-0.0002), cooperativeness (β =-0.0003), and self-transcendence (β =-0.0002) had significant association with WHR and showed paralleled result with other obesity indices. In pair-wise regression model, an association between novelty seeking and persistence, and obesity were

further dissected; β_W in MZ data showed stronger association than β_W in DZ-sibling data and pooled data, indicating that novelty seeking and persistence are associated with obesity and in this association, there are more environmental effects than genetic effect.

The results from this study confirm some of the previous findings. By comparing the β_W of different dataset, we could conclude that there is high environmental effect on the association, and that there is more environmental effect on the TCI associated obesity than genetic effect. Suggesting an individual's personality profiles can be integrated in to personalized intervention of obesity.

Keyword: Personality, Temperament and Character Inventory, TCI, Obesity, Family-Twin analysis

Student Number: 2011-22104

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INTRODUCTION

Increased obesity prevalence has been known as one of the most important public health issues worldwide. In 2008, 10% of men and 14% of women in the world were obese, compared with 5% for men and 8% for women in 1980; the statistic has been more than doubled. [1] Ever since Asian culture has been westernized, the prevalence of obesity in Asian countries has also been increasing. In an obesity report by OECD in 2012, the graph shows constant increase in seven OECD countries' obesity and overweight rates. Among these countries, Korea has the lowest rate when compared with other western countries. However despite its low level, the rate itself has been steadily increasing since 1997.[2] (Figure 1) This indicates that environmental factors play a crucial role for the epidemic, since the gene pool of the population cannot change that rapidly.

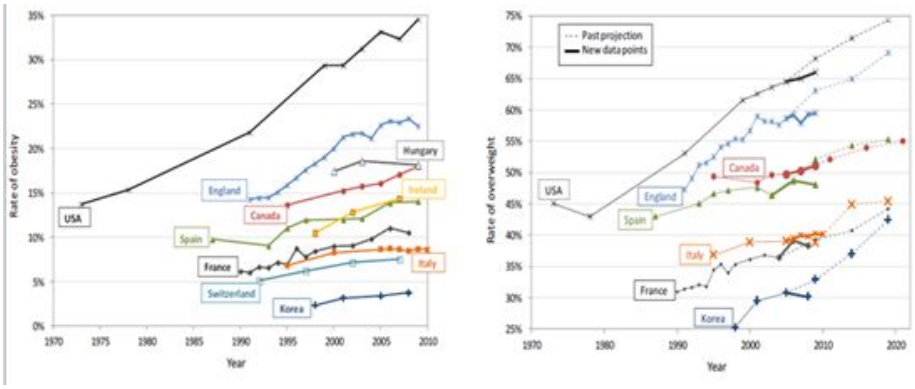

Figure 1. Progression of obesity and overweight rates, respectively, in seven OECD countries, along with previous OECD projections (dotted lines) for overweight (adapted from OECD report[2])

In a survey conducted by Korean Ministry of Health and Welfare in 2010, obesity rate of men aged 19 and older has been increasing since 1998, while women's rate decreased. (Figure 2) Because of increased variance of obesity in the population, genetic influence on obesity is expected and this suggest that there can be different genetic effects depended upon environmental factor, representing gene-environment interaction (GxE). [3]

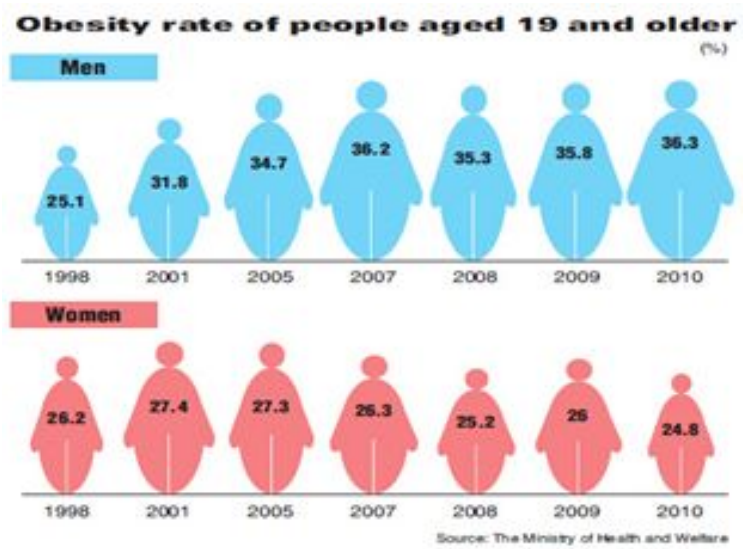

Figure 2. Korean Obesity rate from 1998~2010, by Korean Ministry of Health and Welfare

Personality traits of an individual may affect one's attitude towards life and their life style.[4,5] Since much obesity is caused by emotional disruption and unhealthy life habits, by looking at the association between Temperament and Character Inventory (TCI)'s seven dimensions: Novelty seeking (NS), Harm

Avoidance (HA), Reward Dependence (RD), Persistence (PE), Self-Directedness (SD), Cooperativeness (CO), Self-Transcendence (ST), and obesity measuring indices : Body Mass Index (BMI), Waist circumference, Waist Hip Ratio (WHR), trunk fat percent, and total body fat percent measured by Dual-energy X-ray absorptiometry (DXA) in Korean samples, we might be able to explain how personality influences one's body weight and develop effective treatment for overweight or obesity.

Background Information

TCI was developed by an American psychiatrist named C.R. Cloninger. He first described three traits of temperament in his Tridimensional Personality Questionnaire (TPQ) which consisted only of Harm Avoidance, Novelty Seeking and Reward Dependence. Then he added another dimension, Persistence, as the fourth temperament trait. From further research on personality traits, Cloninger again learned that temperament did not fully describe complexity of human personality and added three more dimensions of character. There are a total of seven dimensions in the most recently revised version of TCI: Novelty Seeking (NS), Harm Avoidance (HA), Reward Dependence (RD), Persistence (PE) in Temperament and Self-Directedness (SD), Cooperativeness (CO), and Self-Transcendence (ST) in Character.[6,7]

Cloninger claims that four traits of temperament are organized early in life and set by the automatic neurotransmitter responses to emotional stimuli, which in other words, are determined by genes. NS is thought to be influenced by dopamine and related to behavioral activation system. HA is related to serotonin activity and behavioral inhibition system. RD is influenced by norepinephrine and related to behavioral maintenance system. PE does not have hypothesized neurotransmitter system yet.[8]

The temperament dimensions were established to measure variances between individuals in response to novelty, punishment, and reward.[9] Individuals with high NS tend to be quick-tempered, excitable, enthusiastic, and disorderly. They are very quick in engaging with new and unfamiliar things while showing quick disengagement, which leads to inconsistencies and instability. High HA is associated with cautious, careful, fearful and doubtful pessimistic individuals, and they are in need of reassurance and encouragement then normal people and are very sensitive to criticism and punishment. Individual with high RD are tender-hearted, loving and warn, dedicated, open to communication, and loss of objectivity. Highly PE persons tend to be ambitious overachiever, industrious, hard-working and stable while lower scorer of PE are inactive, unreliable, unstable and erratic.[7,8]

On the other hand, character traits are thought to change with age and maturation, and are affected by surrounding

environment and social learning status. SD dimension can be referred to as autonomous component and executive component of individual's mental self-government; while CO as legislative component, and ST as judicial component. [10] From Cloninger's argument, we can assume that character traits will show less genetic effect compared to temperament dimensions.[11]

The character refers to the ability of an individual to control, regulate, and adapt to various situations. SD are widely used as indicator for presence of absence of personality disorder.[12] People with high SD scores are described as mature, strong, self-sufficient, and goal oriented. Individuals who score high on CO are described as empathetic, compassionate, supportive, and principled. In contrast, low scorers on CO are unhelpful, revengeful, and opportunistic. People with high ST scores tend to be patient, creative, selfless, and spiritual. They are perceived as enlightened, wise and thankful individuals.[7,8]

Previous Studies

From the previous studies of TCI, it has been reported that HA may have an association with mood disorders, and that there is evidence suggesting that high HA is linked with binge eating disorder [13]. Individuals with Bulimia Nervosa showed higher NS, HA and low SD in personality profile, and women with Anorexia had significantly higher score on HA, PE, and lower score on SD than normal women.[14,15] In a recent study

with small number of Korean normal population, individuals with high HA showed increased sympathetic nervous function and concluded that high PE may have protective effect on CVD. [16]

There are some previous studies proving that personality traits are actually related to obesity. Several studies are done with BIG 5 inventory, which is another widely used personality measuring tool. The results say that low conscientiousness and openness, and high extraversion, agreeableness, and neuroticism are associated with obesity.[17-20] Also when Association between TCI and BMI was looked at, higher scores of NS, HA, RD, CO, ST and lower scores of SD, PE showed significant association.[21-25] and these traits were somewhat responsible for the development and treatment failure of obesity.[18] Lower SD and higher scores of NS and HA were shown in group of obese patients with binge eating disorder.[17]One longitudinal study reported that higher HS and lower RD predicted higher BMI in future.[25] Another study demonstrated that obese subjects have different personality profile compared to control group. Additionally, the same obese group showed significant differences when clinical syndrome scales of MCMI-II were compared.[26]

Goal

Results on all 7 dimensions of TCI has been reported, but most of the studies are done with obese patients in medical settings and do not represent a normal population who are not looking for any treatments. Also conflicts are present among reported results, and there is no previous report on association between TCI and Obesity using regression models for twins. In this study, we first aim to confirm the previous study results and find personality dimension's influence on obesity in healthy population. Also for most of the studies, only BMI and waist circumference is used as an index to explain the obesity status. In this study, other obesity indices, such as WHR, trunk fat percent, and total fat percent measured by DXA are used to see possible association. Second goal for this study is to compare environmental and genetic effect of TCI on obesity using simple paired-difference analysis with monozygotic twins and dizygotic twins plus sibling pairs. From this analysis, we intend to dissect the effect of personality on obesity.

METHODS

Study Population & Measurements

A total of 3320 individuals (1333 men, 1987 females, 661 families) in the Healthy Twin Study, Korea were involved in this study. This population includes 198 monozygotic male twins, 347 monozygotic female twins, 53 dizygotic male twins, 69 dizygotic female twins, 386 brother pairs, 1109 sister pairs, and 1200 opposite-sex sibling pairs. Individual twins and their families who participated in the Healthy Twin study completed a questionnaire and visited one of the medical centers in order to complete a physical examination, clinical tests, biochemical testes, and body measurements. Written informed consent was obtained from all participants, and the study protocol was approved by the ethics committees at the Samsung Medical Center and Busan Paik Hospital. Demographics are shown on Table1.

For the personality survey, the Korean version of Temperament and Character Inventory-Revised-Short (TCI-RS)[27] with a total of 140 questionnaires was used. The survey was self-administered, and then was reviewed by an examiner. The scores were calculated by summing the values of responses.

Weight (kg), height (cm), waist circumference (cm), and other body composition measurement were made in light clothing using standardized scale and a stadiometer. Weight was divided by squared hight (kg/m^2) in order to calculate body mass index (BMI), and waist measurement was divided by hip circumference

to compute waist hip ratio (WHR). Total fat and trunk fat percent of individuals were measured using Dual-energy X-ray absorptiometry technique(DXA).

In order to ascertain the zygosity of samples, PerkinElmer's AmpFℓSTR Identifiler kit (PerkinElmer, Norwalk, CT), 16 short tandem repeat (STR) markers (15 autosomal short tandem repeat markers + 1 sex determining marker) were used in 67% of the twin pairs. [28] For the rest of the twins, zygosity of a pair was determined using self-administered zygosity questionnaire with validation of 94.3% accuracy through a STR marker study. [29]

Table1. Mean scores of the seven TCI dimensions and five Obesity measuring indices of total population in this study, stratified across sex

		Male		Female		
		n		n		P value*
Age ± SD		1333	44.32±14.10	1987	43.60±13.06	0.13
Smoke (%)	Never	1252	370(29.55)	1976	1797(90.94)	
	Past		387(30.91)		70(3.54)	
	Present		495(39.54)		109(5.52)	
Alcohol (%)	Never	1333	174(13.05)	1986	744(37.46)	
	Past		112(8.40)		193(9.72)	
	Present		1047(78.54)		1049(52.82)	
Novelty Seeking ± SD		1325	30.19±9.64	1976	27.63±10.34	<0.0001
Harm Avoidance ± SD		1331	34.94±10.26	1972	38.55±10.68	<0.0001
Reward Dependency ± SD		1330	40.88±8.02	1972	42.29±8.58	<0.0001
Persistence ± SD		1329	42.15±10.48	1975	39.82±10.14	<0.0001
Self-Directedness ± SD		1329	45.89±10.54	1974	44.63±10.39	0.0007
Cooperativeness ± SD		1330	51.50±10.29	1974	53.03±9.74	<0.0001
Self-Transcendence ± SD		1327	24.71±11.23	1979	26.32±11.33	<0.0001
Body Mass Index, kg/m^2±SD		1333	24.51±3.06	1987	23.14±3.33	<0.0001
Waist, cm ± SD		1330	96.39±5.90	1987	77.83±9.02	<0.0001
Waist Hip Ratio ± SD		1330	0.88±0.06	1986	0.83±0.07	<0.0001
Total fat percent (DXA), % ± SD		1329	22.02±5.89	1980	32.52±6.19	<0.0001
Trunk fat percent (DXA), % ± SD		1318	24.81±7.50	1970	32.81±10.00	<0.0001

*obtained by paired t test SD=Standard Deviation

Table2. Composition of Monozygotic (MZ) twins, Dizygotic (DZ) twins, and sibling pair samples

		Monozygotic Twins		Dizygotic Twins		Sibling	
		# of pairs		# of pairs		# of pairs (# of individuals)	
Age± S.D		545	38.00±7.51	122	38.84±7.34	2695(1938)	38.64±9.41
Sex n (%)	Male	545	198 (36.33)	122	53 (43.44)	2695	386 (14.32)
	Female		347 (63.67)		69 (56.56)		1109 (41.15)
	Opposite Sex		N/A		N/A		1200(44.53)

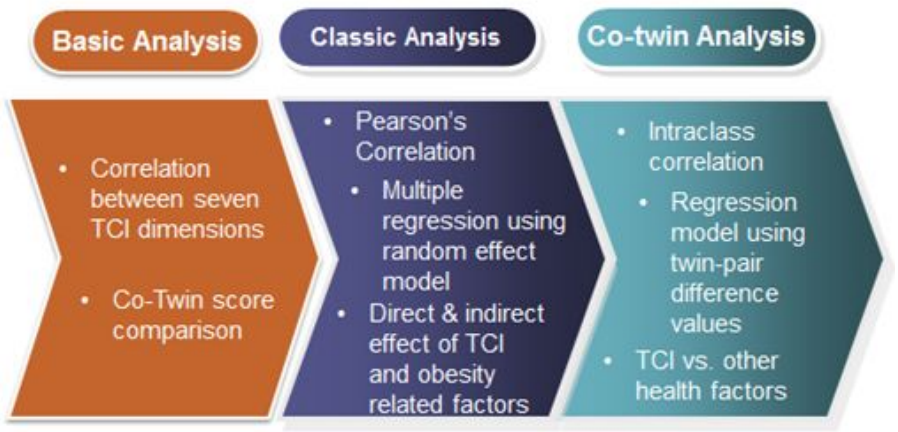

Figure 3. Flow diagram of study analysis process

Statistical analyses

Correlation coefficients between seven TCI dimensions were calculated to demonstrate the relationship between different personality traits in the study population. Also before any co-twin analysis were conducted, scatter plot matching scores of seven dimensions between MZ twins and DZ twins were plotted to see if there is visual difference in the regression line.

Pearson's Correlation Coefficient was calculated in order to present relationship between TCI and obesity indices in study individuals. Simple association between TCI and obesity was analyzed using multiple regression models to test whether TCI were predictive of obesity indices. Adjusted variables were age, sex, smoking history and alcohol consumption history. Random effect model (REM) was applied to adjust for familial correlations since the population is mostly consist of families. For this model,

dependent variables were five obesity measuring indices, and independent variables were TCI's seven dimension. To understand the pathway of the association, direct, indirect, and total effect of TCI and related factors, which are blood pressures, blood lipid level, total calorie intake, and exercise frequency, on BMI, the most widely used obesity index, were calculated using Proc Calis.[30]

For co-twin analyses, in order to dissect environmental and genetic effect of TCI on obesity, Intraclass Correlation coefficient was calculated between siblings and twin pairs were compared. For pair-wise association analyses of co-twin, regression model with twin-pair difference values were used. The value is estimated by performing regression on the differences with the constraint that the regression line must pass through the origin. [31]

$$\mathrm{E}\left(D_i^X\right) = \beta_w D_i^X \quad (1)$$

As demonstrated in the equation (1), if we define the differences between X and Y are calculated with values ordered accordingly, both the term β_0 and between-pair effect (β_B)are canceled out by the subtraction. So by conducting the pair-difference regression, we can calculate the within-pair effect (β_w).

$$\beta_w = E \quad (MZ) \quad (2)$$

$$\beta_w = \frac{1}{2} A + E \quad (DZ/Sib) \quad (3)$$

In order to fully understand the calculated, we have to suppose that a phenotype is determined by ACE model (Figure 4). A stands for additive genetic factors, C for common environmental factors, and E for specific environmental factors. We assume that MZ twins share 100% of A and C, and the variation between the pair is caused by E (equation 2). Also for DZ/sib, the assumption is that they share average of 50% of A, and 100% of C, and the variation is explained by half of A and E (equation 3).

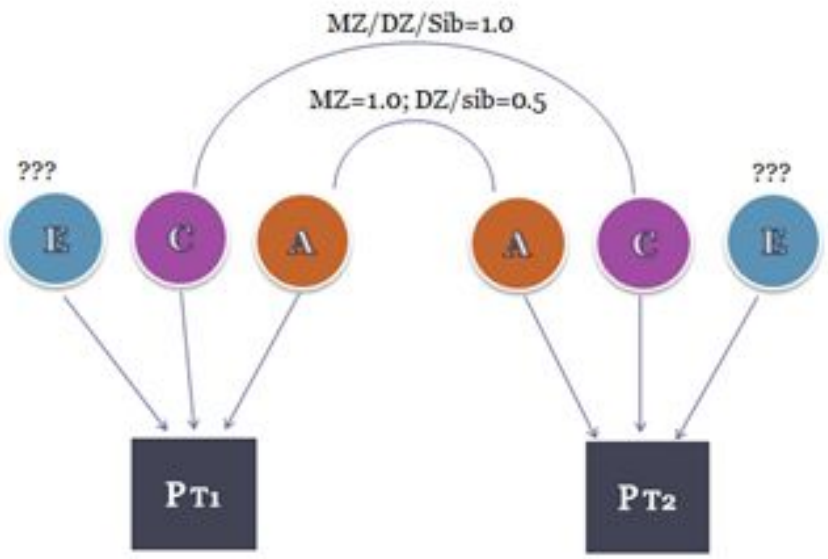

Figure 4. ACE model used in the simple paired-difference analysis

The interpretations are that if β_w from pooled data (MZ+DZ+siblings)is smaller than β_w from MZ data, then we can

assume that there is considerably high environmental effect on the phenotype since MZ shares 100% of gene. If β_w from pooled data is smaller than β_w from DZ and sibling data (adjusted for sex and age, assume that they share an average of 50% of gene), then we can both assume that there are both considerable environmental and genetic effects on the phenotype. If β_w from MZ is larger than β_w from DZ and sibling data, then we can assume that there is more environmental effect on the phenotype than genetic effect. Statistical analysis was done with SAS statistical package (SAS Institute, Cary, NC, USA).

RESULTS

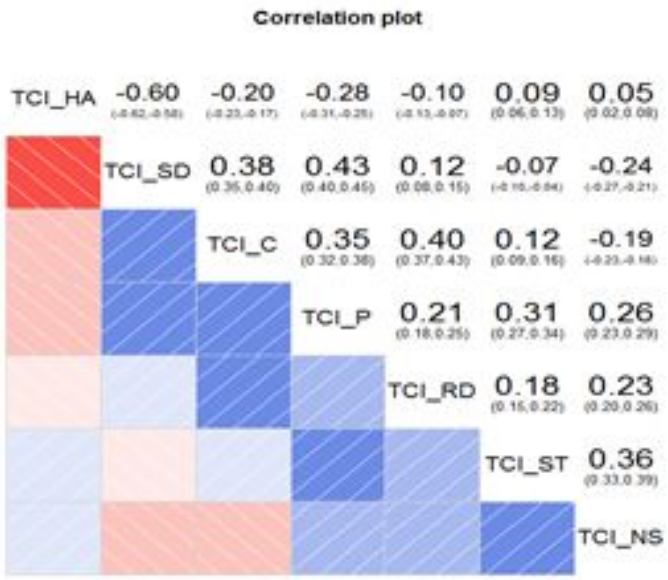

Figure 5. Correlation plot between seven TCI dimensions (Red indicates negative correlation and blue indicates positive correlation. The shades represent degree of correlation)

Correlation level and coefficients are shown on Figure 5. HA and SD had highest negative correlation (-0.60), while PE and SD had highest positive correlation (0.43). Scatterplot of twin pairs TCI score and fitting regression line is presented in supplementary (Figure S2). For all of the TCI dimensions, slope of MZ twin pairs were closer to 1 than DZ twins.

There were several Pearson coefficients that were significant. NS and BMI, waist circumference, trunk fat percent, and total body fat percent had significant positive

correlation(r=0.045, r=0.048, r=0.049, r=0.064, respectively). Correlation between HA and WHR was positive(r=0.04), while PE, SD, and CO showed significant negative correlation coefficients with some obesity indices.(Table 3) ST also had negative correlation with BMI, waist circumference, WHR, and total body fat percent(r=-0.037, r=-0.073, r=-0.044, r=-0.049, respectively).

Only NS had the significant parameter estimates (β =0.019, p=0.001), when association between BMI and TCI was looked at. Out of 5 obesity-measuring-indices analyzed with Novelty Seeking, 4 indices, which are BMI, waist circumference, total fat percent, and trunk fat percent measured by DXA, had statistically significant positive associations. This shows parallel result from the correlation analysis. Also when association between WHR and TCI was looked at, out of 7 TCI dimensions, 5 dimensions, which are HA, PE, and all character dimensions, had significant parameter estimates(β=0.0002, -0.0003, -0.0002, -0.0003, -0.0002, all $p<0.05$). By looking at the significant result, we can conclude that increased NS and HA, and decreased PE, SD, CO, and ST (mainly waist circumference and WHR) has statistical significant association with obesity. For more parameter estimates, see Table 4.

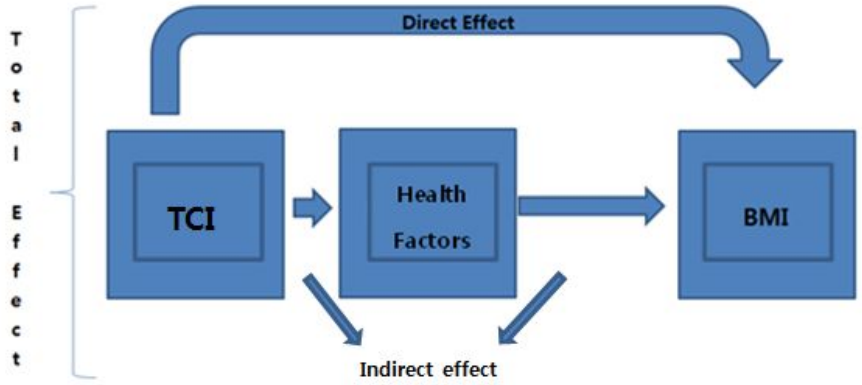

Figure 6. Diagram of pathway analysis conducted Indirect effect

Direct and indirect effects of personality on BMI via health factors are demonstrated on Table S2. Direct effect of the NS on BMI was positive, which is constant with the regression result, but with negative indirect effect via blood pressures and lipid level, total effect was very minimal. HA, RD, and CO had significant negative total effect on BMI, and this is also constant with simple regression analysis with other obesity indices. Positive indirect effect was observed only when calorie intake was inserted into the pathway. Interestingly, exercise frequency had 0 indirect effects on BMI in all seven dimensions. Only significant positive direct effect was observed in NS when systolic blood pressure was in the pathway. RD, PE, SD, and CO showed positive indirect effect when total calorie intake (kcal) was in the pathway.

All of the dimensions of TCI had positive correlation between pairs. Also when the intraclass correlation coefficients were compared between different dataset, MZ pairs had higher correlation than DZ/sibling pairs indicating strong environmental effect on the TCI. This trend is also found in intraclass correlations of obesity indices between twin-sibling pairs. For more results, see table 5, and 6.

Regression analyses using twin-pair difference values showed several significant associations between TCI and obesity (TableS1). Interestingly, only NS and PE showed constant significant outcome. Differences in TCI measures between MZs were more strongly associated with obesity than those between DZ/siblings, indicating the association is caused by environment. However in the case of NS, none of the obesity indices showed significant association in all three types of subjects, making a complete comparison unattainable. In the case of PE, all except for total fat percent of the β_W of obesity indices in MZ data was significant. Also β_W of waist, WHR, and total fat percent in DZ-sibling data and pooled data were significant. When the β_W of waist circumference and WHR were compared, β_W in MZ data (-0.094, -0.00066) showed negatively stronger association than β_W in DZ-sibling data (-0.030, -0.00042) and pooled data (-0.038, -0.00044). This result indicates that variance in score of PE is associated with obesity, and in this association, there are more environmental effects than genetic effect. (Table 7)

Table3. Pearson Correlation Coefficients between Obesity indices and TCI

	Novelty Seeking	Harm Avoidance	Reward Dependency	Persistence	Self-Directedness	Cooperativeness	Self-Transcendence
BMI	0.045*	-0.032	0.004	-0.006	-0.02	-0.016	-0.037*
Waist	0.048*	0.008	-0.004	-0.041*	-0.043*	-0.017	-0.073**
WHR	0.021	0.04*	0.007	-0.052**	-0.044*	-0.047*	-0.044*
Trunk fat percent (DXA)	0.049*	0.001	0.0004	-0.018	-0.019	0.015	-0.019
Total fat percent (DXA)	0.064**	0.011	-0.013	-0.026	-0.033	0.024	-0.049**

*pvalue of <0.05 **pvalue of <0.005

Table4. Parameter estimates of regression analysis of Obesity indices and TCI

	Novelty Seeking	Harm Avoidance	Reward Dependency	Persistence	Self-Directedness	Cooperativeness	Self-Transcendence
BMI	0.019± 0.006**	-0.007± 0.005	-0.001± 0.007	-0.002± 0.005	-0.007± 0.005	-0.011± 0.006	-0.007± 0.005
Waist	0.051± 0.015**	0.010± 0.013	-0.003± 0.017	-0.026± 0.014	-0.031± 0.014*	-0.054± 0.015**	-0.016± 0.013
WHR	0.0002± 0.0001	0.0002± 0.0001*	-0.00002± 0.00013	-0.0003± 0.0001*	-0.0002± 0.0001*	-0.0003± 0.0001*	-0.0002± 0.0001*
Trunk fat % (DXA)	0.048± 0.016**	0.007± 0.015	0.010± 0.019	-0.016± 0.015	-0.019± 0.015	-0.018± 0.016	0.006± 0.014
Total fat % (DXA)	0.040± 0.011**	0.011± 0.010	-0.001± 0.012	-0.015± 0.010	-0.020± 0.010*	-0.025± 0.011*	0.007± 0.009

*pvalue of <0.05 **pvalue of <0.005

Estimates were rounded to the thousandth place, unless very minimal

Table5. Intraclass correlation of TCI between twin-sibling pairs

	Novelty Seeking	Harm Avoidance	Reward Dependency	Persistence	Self-Directedness	Cooperativeness	Self-Transcendence
MZ Pairs	0.378	0.417	0.366	0.434	0.429	0.439	0.461
DZ/Sib Pairs	0.131	0.126	0.131	0.149	0.151	0.239	0.229
Pool	0.168	0.173	0.171	0.196	0.195	0.275	0.266

MZ=monozygotic twin pair, DZSib=dizygotic twin pairs and siblings (sex and age adjusted)

Pool= all twin and sibling pairs

Table6. Intraclass correlation of Obesity Indices between twin-sibling pairs

	BMI	Waist	WHR	Trunk fat % (DXA)	Total fat % (DXA)
MZ Pairs	0.717	0.624	0.385	0.657	0.654
DZ/Sib Pairs	0.208	0.176	0.177	0.161	0.247
Pool	0.282	0.243	0.219	0.213	0.315

MZ=monozygotic twin pair, DZSib=dizygotic twin pairs and siblings (sex and age adjusted)

Pool= all twin and sibling pairs

Table7. Regression analysis of twin-sibling pair differences of TCI dimensions and twin-sibling pair differences of obesity indices as dependent variables (Partial, whole table available in Table S1)

	Novelty Seeking			Persistence		
	MZ	DZSib	Pool	MZ	DZSib	Pool
BMI	0.011± 0.009	0.016± 0.006*	0.015± 0.005**	-0.023± 0.009*	-0.001± 0.006	-0.004± 0.005
Waist	0.030± 0.027	0.046± 0.015**	0.044± 0.014**	-0.094± 0.026**	-0.030± 0.015*	-0.038± 0.013**
WHR	-0.00001± 0.00029	0.00027± 0.00010*	0.00024± 0.00009*	-0.00066± 0.00028*	-0.00042 ±0.00010**	-0.00044± 0.00010**
Trunk fat % (DXA)	0.069± 0.028*	0.038± 0.020	0.042± 0.018*	-0.060± 0.027*	-0.026± 0.021	-0.030± 0.018
Total fat % (DXA)	0.050± 0.021*	0.020± 0.011	0.024± 0.010*	-0.037± 0.020	-0.024± 0.011*	-0.026± 0.010*

*pvalue of <0.05 **pvalue of <0.005 MZ=monozygotic twin pair, DZSib=dizygotic twin pairs and siblings (sex and age adjusted) Pool= all twin and sibling pairs

Estimates were rounded to the thousandth place, unless very minimal

DISCUSSION

Increased NS is associated with increased BMI, Waist Circumference, total fat percent, and trunk fat percent measured by DXA, suggesting strong relationship between NS dimension and Obesity. Lower scores of PE, SD, CO, and ST showed significant association with obesity. This confirms some of previous study results, but also shows conflict. This occurrence may be caused since the population used in this study is not in clinical setting, and represents normal Korean population.[25] Aside from the mentioned results, simple association and correlation between TCI and Obesity measuring indices were looked at, and several significant relationships were analyzed, and we can conclude personality is associated with obesity. Also when the results were compared with correlation between the seven dimensions of TCI, direction were constant with association results, strengthening the conclusion.

From the pathway analysis, we can conclude that NS, HA, RD, and CO has negative indirect effect through blood pressure and lipid level resulting in minimal or negative total effect. It has been reported that RD in women and PE is associated with decreased SBP while HA in men is associated with increased SBP. [5,32] Also personality traits may have positive indirect effects on total daily calorie intake, but because of big direct effect, total effect results in negative value. Physical activity was did not show any indirect effect on BMI, and was

not in the pathway. This might be due to categorical measures of physical activity. The conflicting direction of direct and indirect effect is hard for interpretation, and because BMI showed association with only NS in the association analysis, further dissection of pathway between personality and obesity is needed.

In the scatter plot of matched score of twin pairs, MZ twins had slope closer to 1 than DZ twins indicating that our assumption of ACE modeling is accurate. When associations of pair differences were looked at, positive NS and negative PE had significant associations with pair-wise differences of obesity indices. Especially PE showed overlapping significant association in all of the dataset. By comparing the β_W of different dataset, we could conclude that there is high environmental effect on the association, and that there is more environmental effect on the NS and PE associated obesity than genetic effect.

In order to see the presence of variance in personality among different type of lifestyle, trend between sex and age adjusted NS and PE's score, and total calorie intake and frequency of physical exercise were compared (Figure S1). As NS and PE's score increased, total daily calorie intake also showed increasing trend, which supports the theory that increased NS is associated with obesity. Also when physical exercise trend was examined, increased NS showed decrease in exercise frequency and opposite result for increased PE. This trend represents the nature of the personality well since a person

with high NS tend to be inconsistencies and instability, while high PE scorer are hard-working and stable.

However we did not perform an analysis on the exact proportion of the environmental effect on the phenotype. In order to precisely dissect the effect of genetic and environment on TCI and obesity, further study of heritability analysis with Korean population is needed. It has been already reported that heritability of TCI among Japanese population ranges from .22~.49[33], and .71 on BMI with subjects from Korean Healthy Twin study.[24]One limitation is, because number of dizygotic twin pairs was small, we additionally used age and sex adjusted sibling pairs when using pair-wise model. This adjustment is theoretically correct, but shared environmental factor of sibling pair and twin pair is very different in reality and it should be more than just sex and age difference.

This study only examines personality's different dimensions separately, and shows a need of further study examining combination of multidimensional trait of personality and its association with obesity since one personality dimension is very much affected and depended upon another dimension of an individual.[9,25]

Conclusion

Personality is consists of perceptive, emotional, and behavioral aspects that might result in obesity and difficulties when facing interventions. [34] This explains the role of personality traits in the phenomenon and the results of this study may help to design more effective interventions. Instead of trying to modify one's personality, therapists should investigate patient's nature and focus upon the personalization of the intervention. For instance, a person with high score of NS should be encouraged constantly and introduced to novel way of healthy lifestyle. Since we can conclude that some dimensions of personality are associated with Obesity, and this association is effected more environmentally than genetically, an individual's personality profiles should be integrated into treatment for obesity.

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Table S1. Summary of Regression analysis of twin-sibling pair differences of TCI dimensions and twin-sibling pair differences of obesity indices as dependent variables

	Novelty Seeking			Harm Avoidance			Reward Dependence			Persistence		
	MZ	DZSib	Pool	MZ	DZSib	Pool	MZ	DZSib	Pool	MZ	DZSib	Pool
BMI	0.011± 0.009	0.016± 0.006*	0.015± 0.005**	0.093± 0.007	-0.004± 0.005	-0.004± 0.005	0.001± 0.010	0.0003 ± 0.0069	0.0004 ± 0.006	-0.023± 0.009*	-0.001± 0.006	-0.004± 0.005
Waist	0.030± 0.027	0.046± 0.015**	0.044± 0.014**	0.024± 0.025	0.014± 0.014	0.014± 0.013	0.015± 0.030	0.011± 0.018	0.012± 0.016	-0.094± 0.026**	-0.030± 0.015*	-0.038± 0.013**
WHR	-0.0000 1± 0.00029	0.0002 7± 0.0001 0*	0.0002 4±0.00 009*	0.0000 3±0.00 027	0.0001 1±0.00 010	0.00009 ±0.000 08	0.0003 0±0.00 033	0.0001 1±0.00 012	0.00012 ±0.000 12	-0.0006 6± 0.00028 *	-0.00042 ± 0.00010 **	-0.00044 ± 0.00010 **
Trunk fat %DXA)	0.069± 0.028*	0.038± 0.020	0.042± 0.018*	0.054± 0.026*	0.008± 0.019	0.014± 0.017	0.052± 0.031	0.064± 0.025*	0.062± 0.022**	-0.060± 0.027*	-0.026± 0.021	-0.030± 0.018
Total fat %DXA)	0.050± 0.021*	0.020± 0.011	0.024± 0.010*	0.035± 0.019	0.010± .010	0.013± 0.009	0.045± 0.023	0.016± 0.013	0.019± 0.012	-0.037± 0.020	-0.024± 0.011*	-0.026± 0.010*

*pvalue of <0.05 **pvalue of <0.005

Table S1 continued

	Self -Directedness			Cooperative			Self -Transcendence		
	MZ	DZSib	Pool	MZ	DZSib	Pool	MZ	DZSib	Pool
BMI	-0.006± 0.009	-0.003± 0.005	-0.003± 0.005	-0.001± 0.009	-0.003± 0.007	-0.003± 0.006	-0.001± 0.008	-0.006± 0.005	-0.005± 0.005
Waist	-0.019± 0.026	-0.001± 0.014	-0.002± 0.013	-0.003± 0.028	-0.019± 0.018	-0.016± 0.016	-0.020± 0.024	-0.013± 0.014	-0.014± 0.012
WHR	0.00021± 0.00028	-0.00003± 0.00010	0.000004 ± 0.00009	0.00013± 0.00030	-0.00017± 0.00012	-0.00012± 0.00011	-0.00004± 0.00026	-0.00013± 0.00010	-0.00012± 0.00009
Trunk fat %DXA)	-0.056± 0.027*	0.019± 0.020	0.010± 0.017	0.006± 0.029	0.002± 0.024	0.003± 0.021	0.032± 0.025	-0.011± 0.019	-0.006± 0.017
Total fat %DXA)	-0.032± 0.020	0.011± 0.010	0.006± 0.009	0.017± 0.022	0.007± 0.013	0.008± 0.011	0.024± 0.019	-0.015± 0.010	-0.010± 0.009

*pvalue of <0.05 **pvalue of <0.005

Table S2. Total, direct and indirect effects of health factors on BMI via personality

	Total effect	Systolic blood pressure		Diastolic blood pressure		Total Cholesterol		Total Calorie intake (kcal)	
		Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
Novelty Seeking	0.004	0.034*	-0.031**	0.021	-0.017**	0.012	-0.013**	0.003	0.001
Harm Avoidance	-0.062**	-0.050**	-0.006	-0.050**	-0.012*	-0.061**	-0.001	-0.061**	-0.000
Reward Dependency	-0.048*	-0.021	-0.028**	-0.037	-0.012*	-0.039*	-0.009*	-0.056**	0.007*
Persistence	-0.005	0.002	-0.008	-0.010	0.004	-0.003	-0.002	-0.004	0.002*
Self-Directedness	-0.004	-0.006	0.002	-0.010	0.006	-0.007	0.003	-0.009	0.005*
Cooperativeness	-0.042*	-0.036*	-0.006	-0.044*	0.002	-0.046*	0.004	-0.056**	0.014*
Self-Transcendence	-0.033	-0.023	-0.010	-0.027	-0.006	-0.020	-0.014*	-0.032	-0.001

*pvalue of <0.05 **pvalue of <0.005

Figure S1. Scatter diagram and regression line for Temperament and Character scores of twin pairs

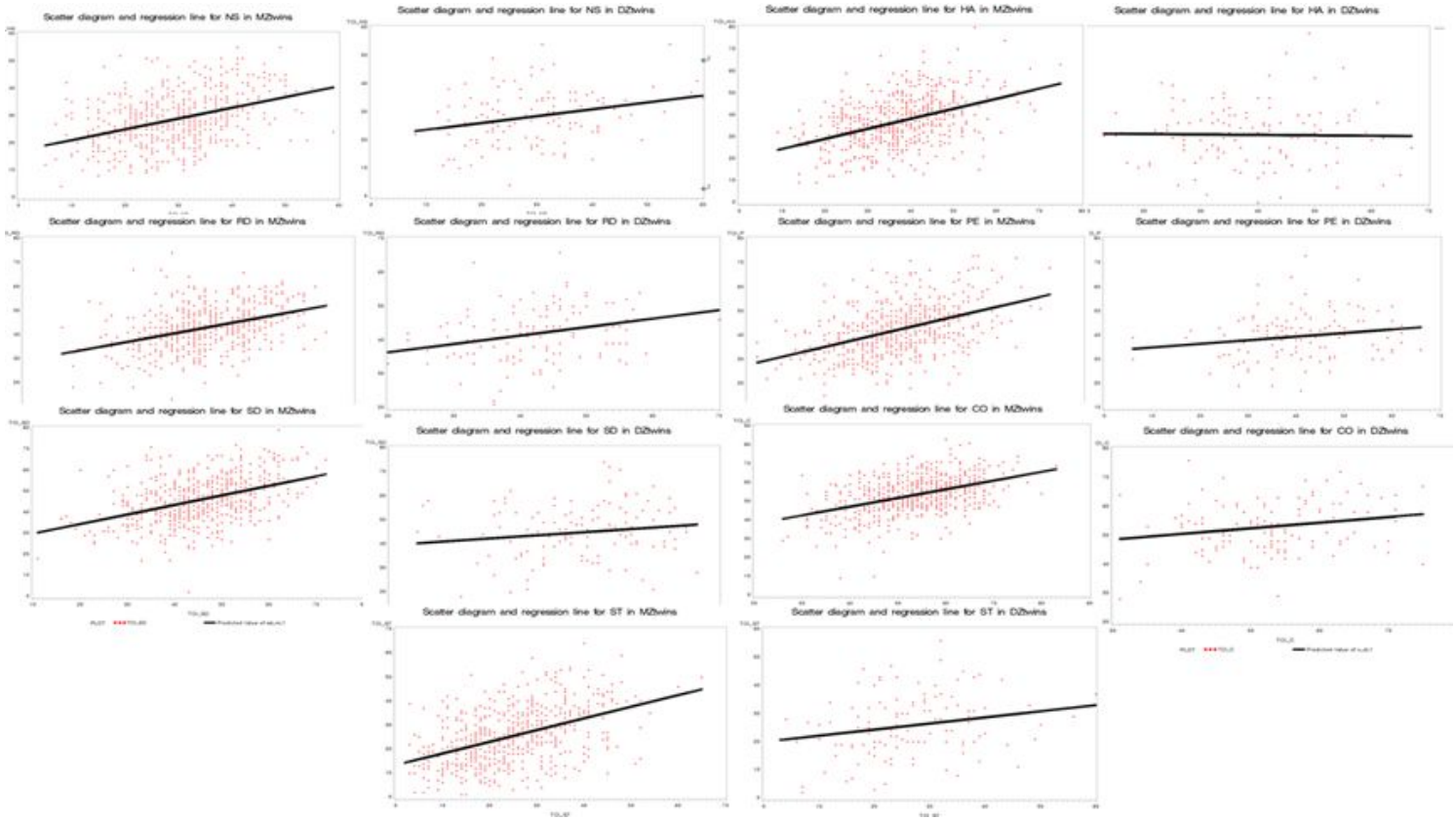
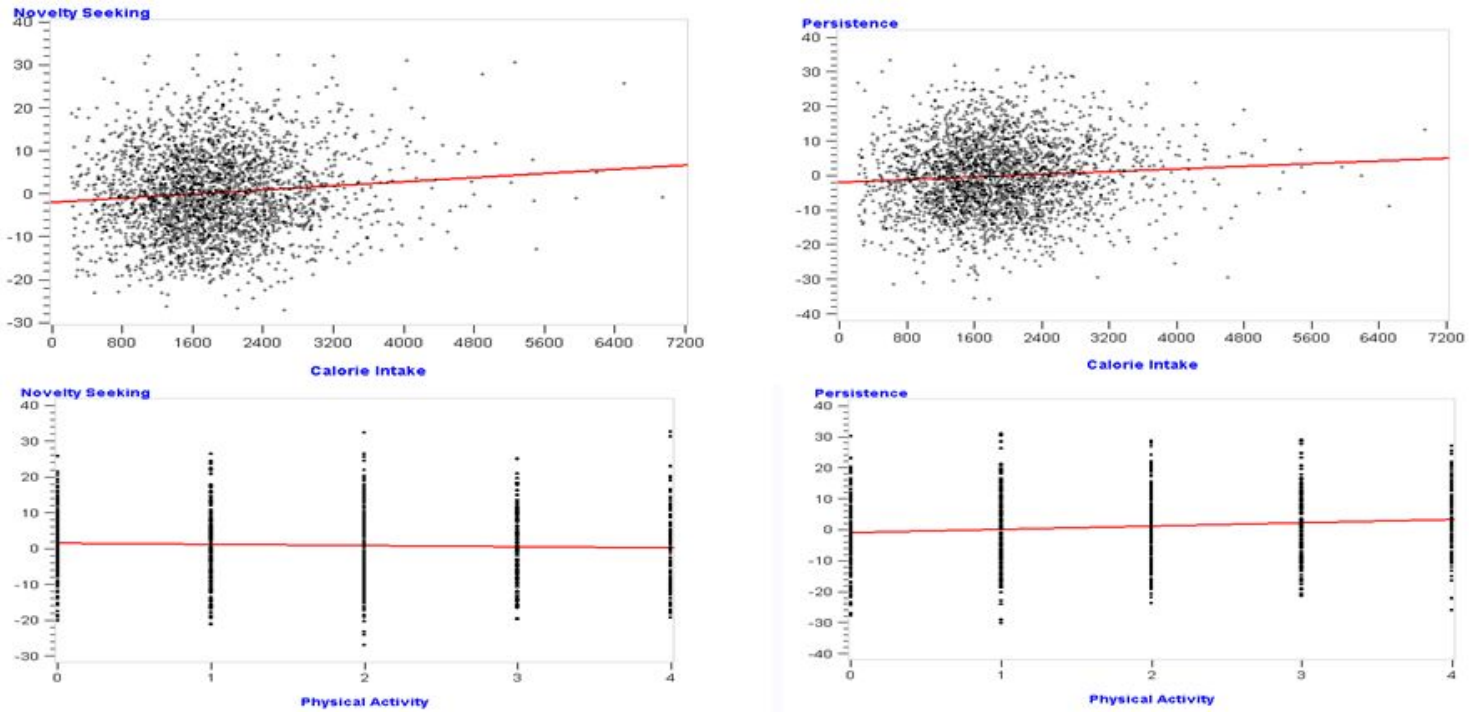


Figure S2. Trend plot of Daily calorie intake and Frequency of Exercise/week with Novelty seeking and Persistence score (Age and Sex adjusted)



*Physical activity 1=1~2/week 2=3~4/week 3=5~6/week 4=Everyday

국문초록

성격 특성 및 비만 지수간의 역학적 연관성: 가족 쌍둥이 분석

양사라
유전체역학전공 보건학과
서울대학교 보건대학원

개인의 성격 특성은 삶에 대한 사람의 태도와 건강상태를 결정하는 라이프 스타일 요인에 영향을 미친다. 특히 우울증과 기분장애와 같은, 정서적 혼란, 그리고 그로 인한 건강에 해로운 생활습관이 이미 잘 알려진 비만의 위험요소이기 때문에, 성격과 생활스타일 및 비만 사이의 역학적 관계를 조사하는 것은 개개인의 개성적인 성격 프로파일에 따라 비만에 대한 효과적인 치료방법이나 예방조치의 개발로 이어질 것이다.

그리하여 이 논문에서는 가족쌍둥이 코호트에서 성격과 기질 설문지 (Temperament and Character Inventory (TCI))의 일곱 가지 측면과 다섯 개의 비만 지수(체질 량 지수 (BMI), 허리둘레, 허리 엉덩이 비율 (WHR), Dual-energy X-ray absorptiometry (DXA)로 측정한 트렁크 및 토털 바디 지방 퍼센트)를 사용하여 개인의 인격과 비만도의 연관 관계를 탐험하려고 한다. 또한 코호트의

일란성 쌍둥이와 이란성 쌍둥이 및 연령 및 성별로 보정한 형제 쌍을 사용하여 비만에 대한 TCI의 환경 및 유전 효과를 구별 하는 것을 목표로 한다. 이를 통해서 성격유형과 비만과의 비 유전적인 연관성을 확인하고 성격, 생활 스타일과 비만간의 구체적인 상호연결을 알아보려고 한다.

한국 가족 쌍둥이 코호트에 참여하고 있는 총 3320명의 대상자(남성 1,333 명, 여성 1987명, 661 가족)들이 이 연구에 사용되었다. 이 인구는 총 545쌍의 일란성 쌍둥이, 122쌍의 이란성 쌍둥이, 그리고 2695 형제 쌍을 포함한다. TCI와 비만 사이의 연관성은 연령, 성별, 흡연 및 알코올 섭취 여부를 보정하여 분석되었다. 그리고 이 연관성 분석에 Random effect model(REM)이 가족 상관관계를 조정하기 위해 적용 되었다. Co-쌍둥이/형제 분석은 쌍 간의 성격과 비만도의 차이 값을 사용하여 pair-wise regression 모델을 적용하였다.

기존의 회귀 (REM)분석에서 Novelty Seeking과 Harm Avoidance는 비만과 양의 관계를 가지는 것으로 나왔고, Persistence(β =-0.0003), Self-Directedness (β =-0.0002), Cooperativeness (β =-0.0003), 그리고 Self-Transcendence (β =-0.0002)의 감소가 WHR의 증가와 연관이 있다고 결과가 나왔다. 이는 다른 비만 지표와도 비슷한 결과이다. Pair-wise regression 모델 분석에서는 Novelty Seeking과 Persistence의 비만과의 연관성이 더 해부되었다. 일란성의 β_W 값이 이란$_{성}$/형제 쌍의 β_W 값이나 풀링된 데이터의 β_W 값 보다 강한 연관성을보여 Novelty Seeking과 Persistence와 비만과의 관련성에 유전효과보다 환경에 의한 영향이 더 크다는 것을 알 수 있었다.

본 연구의 결과는 일부의 이전 연구결과를 한국의 건강한 인구를 사용하여 확인해주고 있고 쌍둥이/형제 쌍의 연관성을 비교함으로써 성격과 비만의 연관성에 유전보단 환경 영향이 크다고 결론지을 수 있다. 이러한 결과는 개인의 성격 프로파일을 비만을 치료하는데 있어서 적용하면 더욱 더 효과적인 치료방법을 개발할 수 있음을 보여주고 있다.

주요어: 성격유형, Temperament and Character Inventory (TCI), 비만지수, 가족-쌍둥이 분석
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