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The Relative Influence of Diet and Physical Activity on Obesity in China

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ABSTRACT

The purpose of this study is to investigate the relative influence of diet and physical activity on obesity. The subjects were 155 adults aged 35 − 52 years from 24 neighborhood committees in 4 urban districts of Beijing (male : 78, female : 77). They were divided into normal weight, overweight and obese groups according to their BMI. The general information of the subjects was collected by interview-administered questionnaire. Dietary intake was obtained by three-day (two weekdays and one weekend day) food weighted method, physical activity was assessed by a validated combination of data obtained from activity monitors, bicycling information and activity records. There were no significant differences of age, gender, height, educational, family economic level, smoking and drinking between different groups. The proportion of flour intake was higher in obese group compared to normal weight and overweight groups, and that of vegetables is lower in obese group. The physical activity (PAL) was not significantly different between two groups of the normal, overweight and obese groups. After the adjustment for confounding factors using logistic regression model, we found that the proportion of flour intake was positively associated with obesity, while the proportion of vegetable intake was inversely associated with obesity. It is concluded that dietary patterns were associated with obesity and diets composed of more vegetables and less staple combined with physical activities could contribute to obesity prevention. (*J Community Nutrition* 6(3) : 125~130, 2004)

KEY WORDS : obesity · dietary pattern · physical activity.

Introduction

The report of 2002 China National Nutrition and Health Survey indicated that the prevalence of overweight and obesity in Chinese adults were 22.8% and 7.1%. It is estimated that there are 200 million overweight people, and more than 60 million obese people in China. Compared with the result of 1992 China National Nutrition Survey, the prevalence of overweight has increased 39%, while the prevalence of obesity has increased 97%. It is estimated that the obese population will continue to grow in the future since there is a large proportion of overweight people.

The underlying causes of the increasing prevalence of obesity are not well understood. Reducing fat intake, which means increasing carbohydrate-dense food intake has been the primary focus of dietary prevention and treatment of overweight and obesity for over 20 years. While several recent studies have shown that high-carbohydrate, low-fat diets are positively associated with obesity (Thomas et al. 1991 ; Febbraio 2000 ; Agu 2000 ; Slabber 1994 ; Pawlak 2000). It seems to be paradoxical. Thus, further studies are needed to investigate the influence of dietary patterns on obesity.

The relationship between physical activity and obesity is still under investigation. Several cross-sectional studies reported lower weight, BMI among people with higher levels of self-reported physical activity or fitness (Dipietro 1995 ; French et al. 1994 ; Slattery et al. 1992). Prospective studies have shown less consistent results. Ching et al. found that physical activity was inversely related to the risk of becoming overweight (Ching et al. 1996). Williamson et al. (1993) found no association between physical activity and subsequent weight change. Additionally, accurate measures of diet and physical activity are difficult to obtain due to a high degree of dietary underreporting (Schoeller 1990) and recently observed phy-

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sical activity overreporting (Irwin 2001 ; Duncan 2001). Therefore, studies using accurate methods for measuring dietary components and physical activity are urgently needed in order to more effectively determine the relative association of these factors with obesity.

The purpose of this study is to investigate the cross-sectional associations of dietary pattern and physical activity with obesity using validated methods for measuring all primary parameters. In the past decades, rapid social and economic development in China has resulted in changes in the dietary patterns and lifestyles among the Chinese population. The diet pattern and physical activity levels vary widely among individuals in China. We anticipated that the data from a population with very different dietary habits and activity patterns from Western populations would help to further elucidate the roles of diet and physical activity on obesity.

Subjects and Methods

1. Subjects

Five hundred adults aged 35 − 52 years from 24 neighborhood committees in 4 urban districts of Beijing were involved in the screen. An interview-administrated questionnaire was used for screening, 155 of 500 candidates qualified for the study. They were divided into normal weight, overweight and obese groups according to their BMIs (WHO/NUT/NCD 1998).

Normal weight : BMI 18.5 − 24.9kg/m2

Overweight : BMI 25.0 − 29.9kg/m2

Obesity : BMI > 30.0kg/m2

These subjects were equally selected from three groups during different study months in order to control for potential confounding by seasonal effects. Throughout the study, the subjects were able and encouraged to pursue their usual lifestyles and all continued their regular occupations, transportation and leisure activities.

2. Methods

A 7-day study was conducted involving collecting data on general information, anthropometry, physical activity, and dietary intake in each subject. The dietary survey was carried out at subject's home. Anthropometry measurements and interviews were conducted at the research unit of the Institute of Nutrition and Food Hygiene. All data collection was conducted by trained staff.

1) General information

The general information of the subjects was collected using an interview-administered questionnaire by trained staff. Family property and income of family members were recorded to evaluate the subject's family economic levels. Smoking index (cigarettes per day*years) and alcohol drinking (g) were used to evaluated smoking and drinking, respectively.

2) Anthropometric measurement

The height and weight of the subjects were measured following a standardized procedure by trained staff. The BMI was calculated as weight (kg) divided by height (m^2).

3) Dietary assessment

Three-day (two weekdays and one weekend) food weighted method was used for collecting information on dietary intakes. A detailed description of the measurement procedure was described elsewhere (Yao 2003).

4) Physical activity

The energy expenditure of physical activity was assessed using CSA activity monitor (model 7164, Computer Science Applications, Inc., Shalimar, FL). The monitor was worn in a pouch at the subjects' waist along the right anterior axillary line. This instrument is an uniaxial accelerometer designed to measure and record accelerations in the vertical direction. The acceleration signal was filtered and digitized, and the output values in counts were then summed over a user-specified time interval (epoch) and stored internally. For the current study, a 60-s epoch was used and activity counts were expressed as the average counts per minute.

Subjects kept a diary of the type and duration of activities performed when CSA monitor was not worn (eg. swimming or bathing), and energy expenditure of these activities was predicted using literature values for METs. Energy expenditure during sleeping was assumed to equal 90% of REE. Since the CSA monitor is insensitive to bicycling, which requires little vertical movement, and bicycling is a common form of transport in China, the average daily distance and speed of bicycling was also determined by connecting a motion detector (Bike Computer Model 800, Sigma Sport, Olney, IL) to the bicycle of each subject. Bicycling duration, distance and speed were recorded daily. Energy expenditure was then predicted using published MET values for bicycling at different speeds (Ainsworth 2000). Total energy expenditure (TEE) was determined by summing the above activity components

and the physical activity level (PAL) was also calculated as a ratio of TEE to REE.

3. Statistical analysis

The statistical analysis was conducted using a SAS program package (SAS Institute Inc. 1995). Values were expressed as median and inter-quartile range ; difference between the three groups was compared using ANOVA analysis. Difference of rate between three groups was compared using χ^2-test. Statistic significance was accepted at $P < 0.05$. Logistic regression models were developed to evaluate the effect dietary pattern and physical activity on obesity after adjustment for possible confounding and interactive effects.

The studies were conducted with ethical approval obtained from the Human Investigations Review Committees at Chinese Academy of Preventive Medicine.

Results

1. Subjects

A total of 155 subjects (78males, 77females) completed the study. Their age, gender, height, weight, BMI, education, family economic level, smoking and drinking are shown in Table 1. There were no significant differences of age, gender, height, education, family economic level, smoking and drin-

Table 1. The characteristics of the subjects in three groups

		Normal weight	Overweight	Obesity
Gender				
Male	N	26	26	26
Female	N	26	26	25
Total	N	52	52	51
Age (yrs)				
Male	Mean ± Std[1)]	43.8 ± 3.8	42.9 ± 4.0	41.8 ± 3.8
Female	Mean ± Std	43.5 ± 3.4	43.1 ± 3.5	42.2 ± 4.2
Educational				
Junior middle school and less	%[2)]	32.7	34.6	43.1
Senior middle school	%	48.1	42.3	39.2
University and college	%	19.2	23.1	17.6
Family economic level				
Low	%	19.2	13.5	27.5
Middle	%	40.4	36.5	35.3
High	%	40.4	50.0	37.3
Height (cm)				
Male	Mean ± Std	170.8 ± 4.7	170.9 ± 6.1	172.2 ± 7.7
Female	Mean ± Std	159.7 ± 6.7	158.3 ± 3.8	159.7 ± 6.1
Body weight (kg)				
Male	Mean ± Std	66.7 ± 6.8^a	79.2 ± 7.7^b	95.7 ± 9.7^c
Female	Mean ± Std	56.9 ± 16.9^a	69.6 ± 3.9^b	83.4 ± 11.4^c
BMI (kg/m^2)				
Male	Mean ± Std	22.8 ± 1.8^a	27.1 ± 1.2^b	32.2 ± 2.0^c
Female	Mean ± Std	22.2 ± 2.0^a	27.8 ± 1.4^b	32.6 ± 3.3^c
Smoking (Cigarette*yrs/d)				
0	%	53.8	65.4	52.9
0 – 500	%	38.5	25.0	25.5
> 500	%	7.7	9.6	21.6
Drinking (alcohol) (g/day)				
0	%	23.1	30.8	29.4
0 – 25	%	65.4	51.9	56.9
> 25	%	11.5	17.3	13.7

1) ANOVA test, mean with same letter in each group was not significantly different, and with different letter was significantly different

2) χ^2-test, rate with same letter in each group was not significantly different, and with different letter was significantly different

king between each two groups. Significant differences were found of weight and BMI between the normal, overweight and obese groups.

2. The proportion of food intakes

The proportions of different food intakes are shown in Table 2. The proportions of most foods were not significantly different between the normal, overweight and obese groups. There was a tendency that the proportions of flour intake were higher in obese group compared to normal weight and overweight groups. The proportions of floor intake of normal weight, overweight and obese group were 13.4%, 14.5% and 18.7%, respectively.

The proportions of vegetable intake in normal weight, overweight and obese groups were 17.4%, 18.3% and 13.7%, respectively. By ANOVA analysis with no adjustment for other variables, the proportion of vegetable intake in obese group tended to be significantly lower than that in normal weight and overweight groups ($P < 0.05$). No difference was found in the proportion of the other food intake between normal weight, overweight and obese groups.

Table 2. The proportions of different foods intake of three groups (%)

Food item (%)	Normal weight		Overweight		Obese	
	Med[1,2]	Q3_Q1	Med	Q3_Q1	Med	Q3_Q1
Rice	10.3	11.5	13.3	13.5	11.7	14.3
Flour	13.4[a]	12.6	14.5[a]	13.2	18.7[b]	17.5
Bean	3.3	7.4	2.7	5.9	1.4	5.2
Rhizome	0.2	1.2	0.1	0.9	0.2	1.3
Vegetable	17.4[a]	12.2	18.3[a]	12.0	13.7[b]	12.7
Fruit	9.8	17.8	11.4	12.7	14.6	18.2
Nut	0.5	1.0	0.5	1.3	0.3	0.8
Meat	13.0	7.9	12.4	7.8	11.9	11.1
Milk	5.6	7.6	2.9	4.6	2.9	5.5
Cake and sweetmeat	3.6	6.7	1.7	4.6	2.0	6.2
Soft drink	2.0	4.9	3.3	7.2	2.7	6.6
Alcohol	2.6	22.8	0.3	12.6	1.7	11.2
Plant oil	3.0[ab]	2.3	3.0[a]	1.8	2.3[b]	1.7

1) Expressed as (grams from group/daily total grams) × 100%
2) Median with same letter in each group was not significantly different, and with different letter was significantly different

3. Physical activity

The total energy expenditures of normal weight, overweight and obese group were 2469.2kcal, 2782.3kcal and 3107.7kcal, respectively. The PAL index of normal weight, overweight and obese group was 1.8, 1.7 and 1.7, respectively. No significant differences were found between the normal, overweight and obese groups.

4. Logistic regression analysis

Logistic regression model predicting the influence of dietary pattern and physical activity on obesity are summarized in Table 3. As shown in the model, logistic regression analysis of the associations of dietary pattern and physical activity with obesity revealed that physical activity expressed as the PAL index was inversely associated with obesity after adjusted for total intake per day. The proportion of vegetable intake was also inversely associated with obesity, while the proportion of flour intake was positively associated with obesity. Interactions between dietary variables and PAL were also tested but were not significant.

Discussion

The major finding of this study of urban Chinese adults was that the proportion of flour intake was positively associated with obesity, while the proportion of vegetable intake was inversely associated with obesity. These findings are consistent with results of Wu's study (Wu 1999) and suggest that the diet pattern in Beijing has been transmitting and was not as healthy as the traditional diet pattern.

We found that the proportion of flour intake was significantly associated with obesity. The possible explanation was that foods made of flour have higher glycemic index than did

Table 3. Logistic regression model predicting the influence of dietary pattern and physical activity on obesity

Factors	Estimate	Standard error	Wald Chi-square	Pr > ChiSq	Standardized estimate	Odds ratio	95%CI
Intercept 3	1.5736	1.4671	1.1505	0.2835			
Intercept 2	3.2216	1.4849	4.707	0.0300			
Total food intake per day	0.4062	0.1506	7.272	0.0070	0.2505	1.501	1.117 – 2.017
Proportion of flour intake	0.4658	0.1353	11.8492	0.0006	0.3295	1.593	1.222 – 2.077
Proportion of vegetable intake	−4.0382	1.8401	4.8162	0.0282	−0.1949	0.018	0.001 – 0.649
PAL	−0.5034	0.1397	12.987	0.0003	−0.3655	0.604	0.460 – 0.795

rice (Kaye 2002). Ludwig reported that functional hyperinsulinemia associated with high GI diets may promote weight gain by preferentially directing nutrients away from oxidation in muscle and toward storage in fat (David 2000). Studies in laboratory animals show that consuming a high glycemic index starch diet for 3wk led to deleterious effects on key lipogenic enzymes, which may lead eventually to increases in plasma lipids and fat accumulation (Morvarid 1998).

We found that the proportion of vegetable intake was inversely associated with obesity is consistent with results from several previous studies. Lahti-Koski reported that consumption of vegetables showed an inverse association with obesity after other lifestyle variables were controlled (Lahti-Koski 2002). The weight loss action of vegetables has also been reported elsewhere (Li 2002). Vegetables provide less energy and contain more dietary fiber than a mixed diet, and the dietary fibers have an action of saturated. In addition, some vegetables content trigonellinelline that can prevent carbohydrate transmit to body fat. A recent cross-sectional analysis of dietary data from 71 healthy adult men and women aged 20 – 80y reported significant associations between long-term dietary variety from certain food groups and body fat. Consumption of a large variety of carbohydrate foods was positively associated with body fat, and consumption of a high variety of vegetables was negatively associated with fatness (McCrory 1999). The study indicates that high carbohydrate and low energy-dense items may promote overeating and lead to long-term increases in energy intake and body fat. These findings may explain the result of the present study.

The lack of significant differences in PAL between normal weight, overweight and obese group is an unexpected finding. A possible explanation for this finding is that the confounding factors had not been controlled. After adjusting for these factors, PAL was inversely associated with obesity. In previous studies, inactivity, such as the sedentary experience of passively watching television, has been shown to be positively related to body fatness (Dietz 1985 ; Gortmaker 1996). High levels of sedentary behavior, such as watching television, and low levels of physical activity have been related to obesity in different populations and study design (Obarzanek 1994). Andersen revealed that watching 4 or more hours/day of TV was associated with greater body fat and BMI than watching, 2hours/day (Andersen 1998). In observational studies, both overweight and obesity are correlated with physical activity, with sedentary persons having greater weight for height, BMI, and percent of body fat (Brown 1998 ; Coakley 1998). Data from controlled clinical trials have shown that increases in physical activity result in weight loss and changes in body composition and fat distribution (Stefanick 1998 ; Bouchard 1993).

An important element of this study was validation of the methods used for measurement of dietary intake and energy expenditure. Three-day food weighted method was golden criterion in dietary investigation. In addition, an 8-d doubly labeled water study was conducted to measure TEE in 73 subjects and used to validate determinations of predicted total energy expenditure (pTEE). There was a significant association between measured TEE and pTEE ($r = 0.81$, SEE = 1.233, $P < 0.001$), suggesting that the prediction approach was accurate. Cross-validation of this method in an independent population group is needed in future studies.

Summary and Conclusion

To study the relative influence of dietary pattern and physical activity on obesity and dietary intake was obtained by threeday (two weekdays and one weekend day) food weighted method, and physical activity was assessed by a validated combination of data obtained from activity monitors, bicycling information and activity records.

A total of 155 subjects (78males, 77females) completed the study. They were divided into normal weight, overweight and obese groups according to their BMIs. There were no significant differences of age, gender, height, education family economic level, smoking and drinking between different groups. The proportions of flour intake were higher in obese group compared to normal weight and overweight group, and that of vegetables is lower in obese group. The PAL was not significantly different among between the normal, overweight and obese groups.

After adjusting for confounding factors, we found that the proportion of flour intake was positively associated with obesity, but vegetable intake proportion was inversely associated with obesity. These findings highlight the potential importance of dietary patterns in influencing energy intake and obesity, and longitudinal studies are needed to examine broadly the role of different dietary patterns in energy regulation.

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References

Agus M (2000) : Dietary composition and physiologic adaptations to energy restriction. *Am J Clin Nutr* 71 : 901-907.

Ainsworth BE, Haskell WL, Whitt MC (2000) : Compendium of physical activities : an update of activity codes and MET intensities. *Med Sci Sports Exerc* 32 : S498-S516

Andersen RE, Crespo CJ, Bartlett SJ (1998) : Relationship of physical activity and television watching with body weight and level of fatness among children : Results from the Third National Health and Nutrition Examination Survey. *JAMA* 279 : 938-942

Bouchard C, Despres JP, Tremblay A (1993) : Exercise and obesity. *Obes Res* 1 : 133-147

Brown WJ, Dobson AJ, Mishra G (1998) : What is a healthy weight for middle aged women? *Int J Obes Relat Metab Disord* 22 : 520-528

Ching PLYH, Willett WC, Rimm EB (1996) : Activity level and risk of overweight in male health professionals. *Am J Public Health* 86 : 25-30

Coakley EH, Kawachi I, Manson JE (1998) : Lower levels of physical functioning are associated with higher body weight among middle-aged and older women. *Int J Obes Relat Metab Disord* 22 : 958-965

David S, Ludwig (2000) : Dietary glycemic index and obesity. *J Nutr* 130 : 280S-283S

Dietz WH, Gortmaker SL (1985) : Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *Pediatrics* 75 : 807-812

DiPietro L (1995) : Physical activity, body weight, and adiposity an epidemiologic perspective. *Exercise and Sport Sciences Reviews* 23 : 275-303

Duncan GE (2001) : Can sedentary adults accurately recall the intensity of their physical activity? *Prev Med* 33:18-26

Febbraio MA (2000) : Pre-exercise carbohydrate ingestion, glucose kinetics, and muscle glycogen use : effect of glycemic index. *J Appl Physiol* 89 : 1845-1851

French SA, Jeffery RW, Forster JL (1994) : Predictors of weight change over two years among a population of working adults: the Healthy Worker Project. *Inter J Obes* 18 : 145-154

Gortmaker SL, Must A, Sobol AM, Peterson K (1996) : Television viewing as a cause of increasing obesity among children in the United States, 1986-1990. *Arch Pediatr Adolesc Med* 150 : 356-362

Institute of Nutrition and Food Hygiene (1991) : Chinese food composition table. Beijing : People's Medical Publishing House

Irwin ML (2001) : Estimation of energy expenditure from physical actiivty measures : determinants of accuracy. *Obes Res* 9 : 517-525

Kaye FP, Susanna HH, Janette CB (2002) : International table of glycemic index and glycemic load values. *Am J Clin Nutr* 76 : 5-56

Lahti-Koski M, Pietinen P, Heliovaara M (2002) : Associations of body mass index and obesity with physical activity, food choices, alcohol intake, and smoking in 1982-1997 FINRISK Studies. *Am J Clin Nutr* 75 : 809-817

Li Y, Ma G (2002) : Nutrition and health action of vegetable. *Nutrition and health*, p.2

McCrory MA, Fuss PJ, McCallum JE, Yao M, Roberts SB (1999) : Dietary variety within food groups: association with energy intake and body fatness in adult men and women. *Am J Clin Nutr* 69 : 440-447

Morvarid Kabir, Salwa W. Rizkalla, Annie Quignard-Boulange (1998) : A high glycemic index starch diet affects lipid storage-related enzymes in normal and to a lesser extent in diabetic rats. *J Nutr* 128 : 1878-1883

Obarzanek E, Schreiber GB, Crawford PB (1994) : Energy intake and physical activity in relation to indexes of body fat : the National Heart, Lung, and Blood Institute Growth and Health Study. *Am J Clin Nutr* 60 : 15-22

Pawlak D (2000) : Long term feeding with high glycemic index starch leads to obesity in mature rats. *Proc Nutr Soc Aust* 24 : 215 (abstr)

Schoeller DA (1990) : Inaccuracies in self-reported intake identified by comparison with the doubly labelled water method. *Can J Physiol Pharmacol* 68 : 941-949

Schoeller DA (1990) : How accurate is self-reported dietary energy intake? *Nutr Rev* 48 : 373-379

Slabber M (1994) : Effects of a low-insulin-reponse, energy-restricted diet on weight loss and plasma insulin concentrations in hyperinsulinemic obese females. *Am J Clin Nutr* 60 : 48-53

Slattery ML, McDonald A, Bild DE (1992) : Associations of body fat and its distribution with dietary intake, physical activity, alcohol, and smoking in blacks and whites. *Am J Clin Nutr* 55 : 943-950

Stefanick ML, Mackey S, Sheehan M (1998) : Effects of diet and exercise in men and postmenopausal women with low levels of HDL cholesterol and high levels of low density lipoprotein (LDL) cholesterol. *N Engl J Med* 339 : 12-20

Thomas DE, et al (1991) : Carbohydrate feeding before exercise: effect of glycemic index. *Int J Sports Med* 12 : 180-186

Williamson DF, Madans J, Anda RF (1993) : Recreational physical activity and ten-year weight change in a US national cohort. *Inter J Obes* 17 : 279-286

Wu Xianzhen (1999) : Obesity status investigation and risk factors analysis of primary and high school student of Xicheng district, Beijing. *Chin Sch Health* 20 : 8-9

Yao M, McCrory MA, Ma G (2003) : Relative influence of diet and physical activity on body composition in urban Chinese adults. *Am J Clin Nutr* 77:1409-1416