Joint Impact of Physical Activity and Family History on Development of Diabetes among Urban Adults in Mainland China: A Pooled Analysis of Community-based Prospective Cohort Studies

ABSTRACT

To examine the joint influences of physical activity (PA) and family diabetic history (FH) on subsequent type 2 diabetes (T2D), we pooled and analyzed data from two community-based urban adult prospective cohort studies in 2011 in Nanjing China. Among 4550 urban participants, the three-year cumulative incidence of T2D was 5.1%. After adjustment for potential confounders, compared to those with FH+ and insufficient PA, the adjusted odds ratio (95%CI) of developing T2D was 0.42 (0.18, 0.98) for participants with sufficient PA and FH+, 0.32 (0.22, 0.46) for participants with insufficient PA and FH-, and 0.15 (0.08, 0.28) for participants with sufficient PA and FH-. Such significant graduated associations between PA/FH and risk of developing T2D were also identified in either men or women, separately. Sufficient PA and negative FH may jointly reduce the risk of developing T2D in urban Chinese adults.

Keywords

Cohort study; family history of diabetes; physical activity; type 2 diabetes; China

INTRODUCTION

Type 2 Diabetes (T2D) is a disabling chronic condition with significant human, social and economic costs, and is a major public health problem worldwide, including within China.[1-4] T2D develops through an interaction of genetic predisposition with behavioral and environmental risk factors.[5] Physical inactivity is one of the main modifiable behavioral risk factors for T2D and other chronic diseases. Strong beneficial effects of physical activity (PA) in reducing insulin resistance and glucose intolerance have been demonstrated in both observational studies and intervention trials.[6-13] Typical public health guidelines on regular physical activity emphasize participation in moderate-intensity physical activity (MPA) for at least 30 minutes on at least 5 days/week, and/or vigorous physical activity (VPA) for at least 20 minutes on at least 3 days/week.[14] Contrastingly, the frequently observed strong familial aggregation of T2D suggests that family history (FH) may be in the etiology of T2D, mediated by potential genetic predisposition, shared environmental and behavioral risk factors, and/or interactions with genes.[15, 16] Previous epidemiological studies have revealed that family history is a strong and independent risk factor for T2D,[16-24] but none have examined its joint effect with environmental risk factors on developing T2D. Considering the complexity of the factors involved in T2D, we hypothesize that behavioral and lifestyle risk factors, particularly physical activity, may exert different influences on the risk of developing T2D for people with and without family history of T2D. In this report, we examine the joint effect of physical activity and parental family history of diabetes on the risk of developing T2D by pooling data from two community-based cohorts of urban adults living in a large regional city in Mainland China.

METHODS

Study design and sample

We pooled data from two three-year community-based prospective cohort studies conducted in Nanjing, Mainland China. Nanjing City is one of the largest cities in east China. In 2004, Nanjing

city had a registered population of more than 5.9 million with eleven urban districts and two rural counties. One study was undertaken between July 2004 and July 2007, the other between July 2007 and July 2010. Both studies used the same protocols, including sampling approaches, instruments, and questionnaires. A two-stage random sampling method was employed to select participants. In the first study, three urban districts were randomly selected, and then one community from each selected district was randomly chosen. In the second study, two urban districts were randomly selected from the eight remaining districts, and then two communities from each selected district were chosen. Thus a total of seven urban communities were included in this pooled study.

A person was eligible to participate in if he/she was a regular resident of that community, and was aged 35 years or older. Individuals who reported having been previously diagnosed with a cancer or diabetes had their medical records checked to confirm the diagnosis, and were then excluded if verified. All enrolled participants were invited to take part in the three-year follow-up survey. Questionnaires were interviewer-administered at both the baseline and follow-up surveys. These two cohort studies were approved by the academic and ethical committee of Nanjing Municipal Center for Disease Control and Prevention (Nanjing CDC) in accordance with the internationally agreed ethical principles for medical research involving human participants.

Outcome Variables

The outcome variable, T2D, was defined using diagnostic approaches according to the 1999 World Health Organization (WHO) criteria.[25] Participants were classified as having newly identified T2D if they had been diagnosed as having T2D by registered physicians based on fasting venous blood glucose concentration and clinical symptoms at a hospital during the three-year follow-up period.

Exposure Variables

Participants self-reported their frequency and duration of physical activity during the previous week using the validated Chinese short-version of International Physical Activity Questionnaire (IPAQ-CHN), which has demonstrated to be both valid and reliable. [26, 27] Total PA time for the previous week was calculated as the sum of the time spent performing moderate-intensity physical activity (MPA) plus double the time spent in vigorous-intensity physical activity (VPA). Participants whose total PA time was equal to or greater than 150 minutes/week were classified as having sufficient PA, and those whose total PA time was less than 150 minutes/week were classified as having insufficient PA.[14]

A participant with positive family history (FH+) refers to having at least one parent who had been diagnosed with T2D. Participants who were not with FH+ were categorized as having a negative family history (FH-). Family history was reported by the participant. All participants were classified into four categories to estimate the joint influence of physical activity and family history of diabetes on subsequent T2D: (1) insufficient PA and FH+ (reference group, 'the highest risk group'), (2) sufficient PA and FH+, (3) insufficient PA and FH-, and (4) sufficient PA and FH- ('the lowest risk group').

At baseline and study completion, body weight and height were recorded, respectively. Participants, wearing light indoor clothing and without shoes, had their weight measured to the nearest 0.1 kilograms using a beam balance scale, and height measured to the nearest 0.01 meter using a stadiometer (Wuxi Weight Factory, Wuxi, Jiangsu, China). We calculated BMI [weight (kg)/height (m^2)] for each participant. According to the Chinese recommended BMI cut points, overweight was defined as BMI between 24 and 28, and obesity as BMI equal to or greater than 28. [28] A participant was diagnosed, by a registered hospital physician, as having high blood pressure if either the systolic blood pressure exceeded 140 mmHg or the diastolic blood pressure

exceeded 90mmHg, or both, together with clinical symptoms before the baseline survey or during the period of follow-up. In China, blood pressure was measured with a standardized procedure according to Korotkoff sounds using a calibrated sphygmomanometer, the standard instrument used to measure blood pressure in hospitals. Height, weight and blood pressure were each measured twice at each visit, and the mean of the two readings were used in our analysis.

Participants were classified as young (35-49 years), middle-aged (50-64 years) or elderly (65 years or older). Educational attainment was classified according to years of schooling completed: 0-6, 7-12, or greater than 13. Participants were categorized as 'smokers' (those who smoked at least one cigarette per day continuously for at least one year, or smoked at least eighteen packs in total each year) or 'non-smokers' (those who previously smoked but subsequently quit smoking up to now or never smoked cigarettes), while people were classified as ‘drinkers’ (those who drank alcohol two or more times per week on average, for at least 1 year) or ‘non- drinkers’ (those who drank alcohol but did not meet the criterion of regular drinkers). Participants reported their weekly TV viewing time in the past week. To determine the aspects of dietary intake, we focused on some selected food groups such as vegetables and meats. Participants were asked to report their weekly consumption frequency and typical intake amount of each serve, and then their average consumption amount over the past week was calculated.

Pooled data

In this report, we analyzed the pooled data from two community-based cohorts. We thought it was highly appropriate to pool data from the two cohorts, because: (1) The same research team designed and conducted the two cohort studies; (2) The same protocols, including sampling approaches, instruments, and questionnaires, were used in the two cohort studies; (3) Participants were limited to regular urban residents in order to guarantee their socio-economic status at the similar level; (4) Only three-year interval between two studies could yield little difference in

participants' lifestyle and behavioral pattern; and (5) Actually, the characteristic of participants from the 2004-07 and 2007-10 cohorts were similar in terms of age (51.7[11.3] years *vs.* 51.9 [10.3] years) and sex (42.7% male *vs.*43.0% male).

Statistical analysis

We calculated descriptive statistics, and compared demographic and clinical characteristics of participants who did, and did not, complete the follow-up survey. We calculated unadjusted three-year cumulative incidence rates of T2D. A logistic regression model was used to compute the odds ratio (OR) and 95% confidence intervals of achieving an outcome event (T2D) in each of the three comparison groups (sufficient PA and FH+, insufficient PA and FH-, sufficient PA and FH-) compared to the reference group (insufficient PA and FH+), with adjustment for year of study (2004-07 or 2007-10) and for clustering by administrative unit. We computed an unadjusted univariate model, and a multivariate model adjusted for age, gender (not adjusted for in gender-specific analysis), educational attainment, BMI category, status of blood pressure, cigarette smoking, alcohol drinking, TV viewing, vegetable intake and meat consumption. Data analyses were conducted using SPSS 13.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

The total number of individuals eligible to enroll in the constituent studies of this pooled analysis was 6,309, of whom 5,659 (participation percentage = 89.7%) agreed to participate, and 4,550 (follow-up percentage = 80.4%) completed the three-year follow-up survey. The corresponding participation and follow-up percentages for the 2004-07 and 2007-10 cohorts were 91.8% (2677/2915) and 81.3% (2177/2677), and 87.9% (2982/3394) and 79.6% (2373/2982) respectively. Overall, participants who were followed-up were similar to those who were not in terms of age (mean [SD] =51.8[10.6] years *vs.* 51.1 [10.2] years) and sex (42.9% male *vs.* 43.2% male).

Table 1 shows selected baseline characteristics of study participants by gender and PA/FH group. Participants' mean [SD] age was 51.8[10.6] (Men *vs.* women: 51.8[10.8] *vs.* 51.8[10.5]; p=0.94), while mean BMI was 24.3±7.9 (Men *vs.* women: 24.3±5.6 *vs.* 24.3±9.2; p=0.85). There was no significant difference in the percentage of men and women who had family history of diabetes (Women *vs.* men: 9.7% *vs.* 9.0%, p=0.47) or who engaged in sufficient physical activity (Women *vs.* men: 15.7% *vs.* 17.7%, p=0.07).

INSERT TABLES 1 AND 2 ABOUT HERE

The three-year cumulative incidence of T2D was 5.1% (95%CI=4.48, 5.80). Individuals newly diagnosed with T2D were less likely to consume vegetables relative to their counterparts who were not diagnosed with T2D during the follow-up period, but there was no statistical difference in meat intake between them (Table 2).

Table 3 presents the separate influence of PA and FH on the risk of subsequent diabetes. As expected, the odds of a participant with sufficient physical activity being newly diagnosed with T2D were approximately half the odds of a participant with insufficient physical activity being newly diagnosed (OR=0.45, 95%CI=0.31, 0.77), while people with negative family history were significantly less likely to have subsequent T2D (OR=0.39; 95%CI=0.28, 0.55). Adjustment for potential confounders did not materially change such association of physical activity and family history of diabetes with subsequent diabetes, separately.

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Table 4 shows the joint influence of PA and FH on the risk of developing T2D in the three-year

follow-up period. After adjustment for potential confounding variables, compared to those who had FH+ and insufficient PA, participants who had FH+ and sufficient PA were at lower risk of developing T2D (OR=0.42, 95%CI=0.18, 0.98), and participants with FH- and insufficient PA were even less likely to develop T2D (OR=0.32, 95%CI=0.22, 0.46), while those with FH- and sufficient PA were the group least likely to develop T2D (OR=0.15, 95%CI=0. 08, 0.28). Such significant graduated associations between PA/FH and the risk of developing T2D were also identified in both men and women separately, where the observed effect estimates were remarkably similar (Table 5).

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DISCUSSION

This pooled analysis of two prospective community-based cohorts with three-year follow-up contained 4,550 urban Chinese men and women, and revealed that sufficient PA and negative FH could independently reduce the risk of developing T2D. Furthermore, a graduated relationship exists between the insufficient-PA/FH+, sufficient-PA/FH+, and insufficient-PA/FH- to sufficient-PA/FH- subgroups. Sufficient PA reduced by 55% (OR=0.45, 95%CI=0.28, 0.72) the odds of developing T2D relative to insufficient PA, and negative family history of diabetes reduced by 68% (OR=0.32; 95%CI=0.23, 0.46) the odds of subsequent T2D compared to positive family history among this sample population, while sufficient PA and negative family history of diabetes together reduced the odds of developing T2D by 85% in the same population (OR=0.15, 95%CI=0. 08, 0.28), which suggests sufficient physical activity and negative family history of diabetes may jointly produce additional benefit on reducing risk of developing T2D. When the data were analyzed in men and women separately, we found similar graduated associations within each gender.

In addition to evidence in epidemiological studies, [6-13] there is an extensive biological base demonstrating that physical activity can exert beneficial effect on developing T2D. Skeletal muscle is the predominant site for insulin resistance[29] and physical activity has been shown to improve insulin sensitivity in these tissues[30] via increased oxidative enzymes, glucose transporters (GLUT4), and capillarity in muscle, as well as by reducing abdominal fat. [31]

While physical activity reduced the risk of developing T2D through complex biomedical mechanisms, a positive family history of T2D has been suggested to reflect potential genetic predisposition or/and shared environmental and behavioral risk factors and their interactions with genes,[15, 16] and to be a strong and independent risk factor for T2D. [16-24] Thus, the impact of physical activity on T2D might be different in populations with different familial tendency of diabetes, which has been supported by evidence from this study.

To our knowledge, this is the first community-based prospective study to estimate the joint influence of physical activity and family history of diabetes on the risk of developing T2D among urban adults. The findings have particular implications for communities in Mainland China, emphasizing the need to initiate physical activity promotion campaigns against T2D in different targeted populations, particularly, in those people with a positive family history, where obesity and some related chronic diseases such as T2D and metabolic syndrome have been increasing at remarkable rates over the past two decades.[4] Given the rapidly increasing prevalence of T2D, there is a need to identify predictors of T2D that can be relatively easily recorded and widely accepted by the general population – clearly questions on physical activity and family history fit this criterion.

Our study has several important strengths including its large community-based sample, prospective study design, excellent recruitment and follow-up proportions, reliable assessment

and measurement of, and adjustment for, potential confounders. This study also has some limitations. First, three years of follow-up is relatively short when investigating a chronic condition such as T2D. Next, physical activity was self-reported, although the instrument, Chinese version IPAQ questionnaire, has been shown to be valid and reliable in epidemiological studies.[26, 27] Third, family history of diabetes was also self-reported by participants, which might yield potential misclassification errors. In addition, very few participants (n=7) with FH+ and sufficient PA developed T2D during the follow-up period, especially after stratification by gender (3 men and 4 women diabetic patients identified), which might result in imprecise effect estimates. Future longer-term community-based prospective studies are needed to better understand the joint impact of physical activity and family history of diabetes on the subsequent risk of diabetes in different ethnic populations.

This study provides good evidence that physical activity, in combination with family history of diabetes, may jointly influence the risk of developing subsequent T2D. Given that familial diabetic history is an independent risk factor for diabetes and is not modifiable, it is clearly extremely important for people with positive familial diabetic history to undertake sufficient physical activity for preventing T2D, relative to their counterparts with negative family history of diabetes. Future public health campaigns against T2D should be focused on individualizing physical activity promotion and greater efforts shall be put on adults with positive diabetic family history.

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CONFLICT OF INTEREST

All the authors declare that they have no competing interests.

REFERENCE

1. World Health Organization. Reducing Risks, Promoting Healthy Life. The World Health Report 2002.Geneva: World Health Organization, 2002.

2. World Health Organization. Preventing Chronic Diseases: A Vital Investment: WHO Global Report. Geneva: World Health Organization 2005.

3. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. Diabetes Care 2004; 27:1047-53.

4. Wang Y, Mi J, Shan X, Wang QJ, Ge K. Is China facing an obesity epidemic and the consequences? The trends in obesity and chronic disease in China. Int J Obes 2007; 31:177-188.

5. Neel JV. Diabetes mellitus: a "thrifty" genotype rendered detrimental by "progress"? Am J Hum Genet 1962; 14: 353-362.

6. Hu FB, Leitzmann MF, Stampfer MJ, Colditz GA, Willett WC, Rimm EB. Physical activity and television watching in relation to risk for type 2 diabetes mellitus in men. Arch Intern Med 2001; 161: 1542-48.

7. Dunstan DW, Salmon J, Owen N, Armstrong T, Zimmet PZ, Welborn TA, Cameron AJ, Dwyer T, Jolley D, Shaw JE. Physical activity and television viewing in relation to risk of undiagnosed abnormal glucose metabolism in adults. Diabetes Care 2004; 27: 2603-2609.

8. Healy GN, Wijndaele K, Dunstan DW, Shaw JE, Salmon J, Zimmet PZ, Owen N. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). Diabetes Care 2008; 31: 369-371.

9. Manson JE, Nathan DM, Krolewski AS, Stampfer MJ, Willett WC, Hennekens CH. A prospective study of exercise and incidence of diabetes among US male physicians. JAMA 1992; 268: 63-67.

10. Sigal RJ, Kenny GP, Wasserman DH, Castaneda-Sceppa C. Physical activity/exercise and type 2 diabetes. Diabetes Care 2004; 27: 2518-39.

11. Helmrich SP, Ragland DR, Leung RW, Paffenbarger RS Jr. Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus. N Engl J Med 1991; 325: 147-52.

12. Perry IJ, Wannamethee SG, Walker MK, Thomson AG, Whincup PH, Shaper AG. Prospective study of risk factors for development of non-insulin dependent diabetes in middle aged British men. BMJ 1995; 310: 560-64.

13. Ezzati M, Lopez A, Rodgers A, Murray C. Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors. Geneva, World Health Organization 2004; p729.

14. U.S. Department of Health and Human Services. Physical Activity and Health: A Report of the Surgeon General. Washington, DC, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion 1996.

15. Yoon PW, Scheuner MT, Khoury MJ. Research priorities for evaluating family history in the prevention of common chronic diseases. Am J Prev Med 2003; 24: 128-135.

16. Annis AM, Caulder MS, Cook ML, Duquette D. Family history, diabetes, and other demographic and risk factors among participants of the National Health and Nutrition Examination Survey 1999-2002. Prev Chronic Dis 2005; 2: 1-12.

17. O'Rahilly S, Barroso I, Wareham NJ. Genetic factors in type 2 diabetes: the end of the beginning? Science 2005; 307: 370-373.

18. Arslanian SA, Bacha F, Saad R, Gungor N. Family history of type 2 diabetes is associated with decreased insulin sensitivity and an impaired balance between insulin sensitivity and insulin secretion in white youth. Diabetes Care 2005; 28: 15-119.

19. Lyssenko V, Jonsson A, Almgren P, Pulizzi N, Isomaa B, Tuomi T, Berglund G, Altshuler D, Nilsson P, Groop L. Clinical risk factors, DNA variants, and the development of type 2 diabetes. N Engl J Med 2008; 359:2220–2232.

20. Meigs JB, Shrader P, Sullivan LM, McAteer JB, Fox CS, Dupuis J, et al. Genotype score in addition to common risk factors for prediction of type 2 diabetes. N Engl J Med 2008; 359:2208–2219.

21. Cornelis MC, Qi L, Zhang C, Kraft P, Manson J, Cai T, Hunter DJ, Hu FB. Joint effects of common genetic variants on the risk for type 2 diabetes in U.S. men and women of European ancestry. Ann Intern Med 2009;150:541–550.

22. Lyssenko V, Almgren P, Anevski D, Perfekt R, Lahti K, Nissen M, et al. Botnia study group. Predictors of and longitudinal changes in insulin sensitivity and secretion preceding onset of type 2 diabetes. Diabetes 2005; 54: 166–174.

23. Hilding A, Eriksson AK, Agardh EE, Grill V, Ahlbom A, Efendic S, Ostenson CG. The impact of family history of diabetes and lifestyle factors on abnormal glucose regulation in middle-aged Swedish men and women. Diabetologia 2006; 49: 2589– 2598.

24. Hemminki K, Li X, Sundquist K, Sundquist J. Familial risks for type 2 diabetes in Sweden. Diabetes Care 2010; 33: 293–297.

25. World Health Organization. Definition, diagnosis, and classification of diabetes Mellitus and its complications. Geneva: World Health Organization 1999. Report of a WHO Consultation.

26. Qu NN, Li KJ. Study on the reliability and validity of international physical activity questionnaire. Chin J Epidemiol 2004; 25: 265-268.

27. Deng HB, Macfarlane DJ, Thomas GN, Lao XQ, Jiang CQ, Cheng KK, Lam TH. Reliability and Validity of the IPAQ–Chinese: The Guangzhou Biobank Cohort Study. Med. Sci. Sports Exerc. 2008; 40: 303-307.

28. Cooperative Meta-analysis Group of China Obesity Task Force. Predictive values of body mass index and waist circumference to risk factors of related disease in Chinese adult population. Chin J Epidemiol 2002; 23: 5-10.

29. DeFronzo RA, Bonadonna RC, Ferrannini E. Pathogenesis of NIDDM. A balanced overview. Diabetes Care 1992; 15: 318-68.

30. Spelberg A MJE. Towards prevention of non-insulin dependent diabetes mellitus. In: Leslie RDG (ed). Causes of Diabetes. Chichester: John Wiley & Sons, 1993, pp. 319-45

31. Chisholm DJ, Campbell LV, Kraegen EW. Pathogenesis of the insulin resistance syndrome (syndrome X). Clin Exp Pharmacol Physiol 1997; 24: 782-84.

Table 1. Selected baseline characteristics by gender and PA/FH category among urban participants in Nanjjng City, China †

Characteristics	Total	Men	Women	PA/FH categories			
				insufficient PA and FH+	sufficient PA and FH+	insufficient PA and FH-	sufficient PA and FH-
No. of participants	4550	1950	2600	300	127	3497	626
Mean age (SD)	51.8 (10.6)	51.8 (10.8)	51.8 (10.5)	50.4 (9.4)	48.7 (9.1)	51.8 (10.7)	53.0 (10.7) #
Educational level (13+yrs) (%)	12.4	16.5	9.2 #	11.0	18.9	12.3	12.0 #
Sufficient Physical Activity (≥150m/wk) (%)	16.5	17.7	15.7	N/A	N/A	N/A	N/A
Positive Family history of diabetes (%)	9.4	9.0	9.7	N/A	N/A	N/A	N/A
Viewing TV time≥3 hr/day (%)	31.0	31.4	30.7	35.0	30.7	30.6	31.3
Current smoker (%)	24.4	53.4	2.7 #	22.7	30.7	24.2	25.2
Alcohol drinker (%)	12.8	28.0	1.4 #	8.3	16.5	12.6	15.5 *
Vegetables intake (g/day)	332.4±218.6	333.0±214.1	331.9±222.0	337.1±172.6	361.4±275.2	318.9±173.9	399.9±378.8 #
Meat intake (g/day)	65.8±54.0	73.6±59.3	60.0±48.8 #	68.1±75.1	66.4±50.6	66.6±52.6	60.5±49.6
BMI ≥28 (kg/m^2) (%)	10.9	10.0	11.6 #	13.0	11.8	10.4	12.8
High blood pressure (%)	21.4	22.7	20.5	26.3	19.7	20.3	25.7 #

† Continuous variables were presented as Means ± SD, while categorical variables, percentages.

‡ Diabetes was diagnosed based on venous blood glucose test plus clinical symptoms by registered physicians according to the 1999 WHO diagnostic criterion.

* p <0.05, # p < 0.01, the difference between men and women, and between participants with different PA/FH categories was significant.

N/A: Not applicable

Table 2. Selected baseline characteristics according to diabetic status by the end of three -years follow-up in urban Chinese adults in Nanjing City, China †

Characteristics	Total	Diabetic status at 3-year follow-up ‡	
		Diabetes	Normal (ref.)
No. of participants	4550	232	4318
Mean age(SD)	51.8 (10.6)	55.4 (9.4) #	51.6 (10.6)
Educational level (13+yrs) (%)	12.4	6.9 *	12.6
Sufficient Physical Activity (≥150m/wk) (%)	16.5	9.1 #	17.0
Positive Family history of diabetes (%)	9.4	19.8 #	8.8
Viewing TV time≥3 hr/day (%)	31.0	23.7 *	31.4
Current smoker (%)	24.4	26.3	24.3
Alcohol drinker (%)	12.8	12.9	12.8
Vegetables intake (g/day)	332.4±218.6	299.4±164.0 *	334.2±221.1
Meat intake (g/day)	65.8±54.0	64.8±45.0	65.9±54.4
BMI ≥28 (kg/m^2) (%)	10.9	11.6	10.9
High blood pressure (%)	21.4	28.0 #	21.1

† Continuous variables were presented as Means ± SD, while categorical variables, percentages.

‡ Diabetes was diagnosed based on venous blood glucose test plus clinical symptoms by registered physicians according to the 1999 WHO diagnostic criterion.

* $p < 0.05$, # $p < 0.01$, the difference between men and women, and between participants with and without diabetes was significant.

Table 3. The separate influence of moderate physical activity and family history of diabetes on subsequent diabetes at 3-year follow-up among overall sample population in urban areas of Nanjing, China *

Exposure variables	N of participants	Participants who developed diabetes [a]		
		% (n)	OR (95%CI)	
			Model 1[b]	Model 2[c]
Physical Activity[†]				
Insufficient	3797	5.6 (211)	1.00	1.00
Sufficient	753	2.8 (21)	0.45 (0.31, 0.77)	0.45 (0. 28, 0.72)
Family History of diabetes[‡]				
Positive	427	10.8 (46)	1.00	1.00
Negative	4123	4.5 (186)	0.39 (0.28, 0.55)	0.32 (0.23, 0.46)

* Odds ratio (OR) and 95% CIs were used to present the influence of baseline moderate physical activity and family history of diabetes on subsequent diabetes, separately, among overall sample population.

a Diabetes was diagnosed based on venous blood glucose test plus clinical symptoms by registered physicians according to the 1999 WHO diagnostic criterion. Participants with normal blood glucose values were treated as the reference.

b Model 1: univariate logistic regression model.

c Model 2: multivariate logistic regression model with adjustment for age, gender, educational attainment, FH/PA， body weight status, cigarette smoking, alcohol drinking, TV viewing, vegetables intake, meat intake, and diagnosed hypertension.

† Physical activity was categorized into 'Sufficient' and 'Insufficient' based on the recommendation (at least 150 minutes per week) for adults'

‡ Family history of diabetes was classified into 'positive' and 'negative' based on parental history of diabetes.

Table 4. The joint influence of moderate physical activity and family history of diabetes on subsequent diabetes at 3-year follow-up among overall sample population in urban areas of Nanjing, China *

Exposure variables		N of participants	Participants who developed diabetes [a]		
			% (n)	OR (95%CI)	
				Model 1[b]	Model 2[c]
Physical Activity[†]	Family history of diabetes[‡]				
Overall					
Insufficient	Positive	300	13.0 (39)	1.00	1.00
Sufficient	Positive	127	5.5 (7)	0.39 (0.17, 0.90)	o.42 (0.18, 0.98)
Insufficient	Negative	3497	4.9 (172)	0.35 (0.24, 0.50)	0.32 (0.22, 0.46)
Sufficient	Negative	626	2.2 (14)	0.15 (0.08, 0.29)	0.15 (0. 08, 0.28)

* Odds ratio (OR) and 95% CIs were used to present combined influence of baseline moderate physical activity and family history of diabetes on subsequent diabetes.

a Diabetes was diagnosed based on venous blood glucose test plus clinical symptoms by registered physicians according to the 1999 WHO diagnostic criterion. Participants with normal blood glucose values were treated as the reference.

b Model 1: univariate logistic regression model.

c Model 2: multivariate logistic regression model with adjustment for age, gender, educational attainment, body weight status, cigarette smoking, alcohol drinking, TV viewing, vegetables intake, meat intake, and diagnosed hypertension.

† Physical activity was categorized into 'Sufficient' and 'Insufficient' based on the recommendation (at least 150 minutes per week) for adults'

‡ Family history of diabetes was classified into 'positive' and 'negative' based on parental history of diabetes.

Table 5. The joint influence of moderate physical activity and family history of diabetes on subsequent diabetes at 3-year follow-up among urban Chinese men and women, separately, in Nanjing, China *

Exposure variables		N of participants	Participants who developed diabetes [a]		
			% (n)	OR (95%CI)	
				Model 1[b]	Model 2[c]
Physical Activity[†]	Family history of diabetes[‡]				
Men					
Insufficient	Positive	117	13.7 (16)	1.00	1.00
Sufficient	Positive	59	5.1 (3)	0.34 (0.09, 1.21)	0.37 (0.10, 1.36)
Insufficient	Negative	1488	5.7 (85)	0.38 (0.22, 0.68)	0.34 (0.19, 0.62)
Sufficient	Negative	286	2.4 (7)	0.16 (0.06, 0.40)	0.15 (0. 06, 0.39)
Women					
Insufficient	Positive	183	12.6 (23)	1.00	1.00
Sufficient	Positive	68	5.9 (4)	0.44 (0.15, 1.31)	0.47 (0.15, 1.44)
Insufficient	Negative	2009	4.3 (87)	0.32 (019, 0.51)	0.29 (0.17, 0.47)
Sufficient	Negative	340	2.1 (7)	0.15 (0.06, 0.35)	0.15 (0.06, 0.36)

* Odds ratio (OR) and 95% CIs were used to present combined influence of baseline moderate physical activity and family history of diabetes on subsequent diabetes, with the category of insufficient physical activity and positive family history of diabetes as reference group.

a Diabetes was diagnosed based on venous blood glucose test plus clinical symptoms by registered physicians according to the 1999 WHO diagnostic criterion. Participants with normal blood glucose values were treated as the reference.

b Model 1: univariate logistic regression model.

c Model 2: multivariate logistic regression model with adjustment for age, residence area, educational attainment, body weight status, cigarette smoking, alcohol drinking, TV viewing, vegetables intake, meat intake, and diagnosed hypertension.

† Physical activity was categorized into 'Sufficient' and 'Insufficient' based on the recommendation (at least 150 minutes per week) for adults'

‡ Family history of diabetes was classified into 'positive' and 'negative' based on parental history of diabetes.