Population attributable risk of excess weight, abdominal obesity and physical inactivity for type 2 diabetes in Chinese men and women

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Background: Given the high prevalence of type 2 diabetes mellitus (T2DM) in the Chinese population, it is necessary to estimate the T2DM incident attributable to obesity and physical inactivity.

Methods: We analyzed the data from the Shanghai Men's and Women's Health Studies, including 56,691 men and 70,849 women aged 40–74. The hazard ratios (HRs) and the population attributable risks (PARs) were calculated by Cox regression model and model-based estimation.

Results: A total of 3,315 male and 5,925 female cases were identified during 519,157 and 981,504 person-years, up to 31 December 2017. Excess weight, abdominal obesity were associated with the increased risks of T2DM both in women and men, while physical inactivity was only associated with an increased risk in men. A large proportion of T2DM incident cases can be attributed to excess body weight (women: 48.6%; men: 41.5%) and abdominal obesity (women: 50.4%; men: 30.3%). Physical activity was negatively associated with the risk of T2DM (P_{trend}<0.01). The PARs adjusted for confounders were 3.6% for physical inactivity in men and 1.7% in women.

Conclusions: Excess weight and abdominal obesity accounted for a large proportion of T2DM incident cases in men and women; a small part of T2DM cases were attributed to physical inactivity in men. Weight control is of great significance in curbing the epidemic of diabetes.

Keywords: Type 2 diabetes; obesity; physical activity; population attributable risk; cohort studies

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Introduction

Diabetes mellitus (DM) has become one of the most prevalent chronic diseases in the world. According to the latest data from the International Diabetes Federation, the global prevalence of diabetes is 9.3% (463 million people) in 2019 and will reach 10.2% (578 million people) in 2030 (1). The burden of diabetes in China is of high prevalence. The estimated standardized prevalence of total diagnosed and undiagnosed diabetes was 10.9% (95% CI: 10.4–11.5%) among the Chinese adult population in 2013 (2).

The prevalence of obesity was also rising rapidly in the past decades worldwide. The prevalence of obesity varies by country and ranges from 3.7% in Japan to 38.2% in the United States (3). A study based on nationally representative data demonstrated that the prevalence of abdominal obesity was 29.1% (28.6% in men and 29.6% in women) in China (4). And urban residents in China lack physical exercise, especially in the middle-aged and elderly population (5). Many studies reported that obesity and physical inactivity are associated with the incidence of T2DM. Obesity and weight gain dramatically increased the risk (6-8), and physical inactivity further increased the risk as well, independently of obesity (9,10).

Although there are many epidemiological studies on the relationship between obesity, physical activity, and diabetes, limited prospective research has been done in China to quantify the PAR of excess weight and physical inactivity on T2DM incidence. Therefore, we analyzed the data from two large prospective cohorts to evaluate the association between excess weight, physical inactivity, and the risk of T2DM and then calculated the proportion of T2DM incident cases attributable to them.

We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/atm-20-6121).

Methods

Study population

The study was based on two ongoing, population-based prospective cohort studies, the Shanghai Men's Health Study (SMHS) and the Shanghai Women's Health Study (SWHS). These two studies recruited 61,469 eligible men aged 40–74 years (January 2002 to September 2006) and 74,940 eligible women aged 40–70 years (December 1996 to May 2000) in Shanghai. Details about studies design, scientific rationale, and demographic characteristics at baseline survey have been published previously (11,12). Participants were interviewed in-person by trained interviewers (retired nurses or physicians) using a structured questionnaire to obtain information on demographic characteristics, lifestyle, dietary habits, medical history, and anthropometric measurements (including weight, height, circumferences of waist and hips). Since the baseline survey, participants have been followed up every 3–4 years through in-person interviews to update their information about health status and lifestyle (SMHS: 2004–2008, 2008–2011, 2012–2017; SWHS: 2000–2002, 2002–2004, 2004–2006, 2007–2010, 2012–2017). Excluding participants with diabetes at baseline, missing data on BMI, waist circumference, physical activity and lifestyle factors, a total of 56,691 men and 70,849 women were included in the analysis. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). All participants provided written informed consent. This study was approved by the Renji Hospital Ethics Committee of Shanghai Jiao Tong University School of Medicine (No. KY2019-196).

Lifestyle factors assessment and definition

At baseline recruitment, we applied a validated food frequency questionnaire (FFQ) and physical activity questionnaire (PAQ) to collect information on dietary habits and physical activity (13-16). Energy expenditure in standard metabolic equivalent values (METs) was used to estimate the intensity of each type of physical activity (17). Exercise/sports-related energy expenditure was estimated by the weighted average of energy expended in all activities reported during the 5 years preceding the interview. Individual non-exercise-related activities were estimated using the following standard METs: housework, 2.0 METs; walking, 3.3 METs; stair climbing, 9.0 METs; bicycling, 4.0 METs (17). We calculated total physical activity (MET-hours/week) by combining energy expenditure from all types of physical activity. Physical inactivity was defined as METs below the first quartile. Total energy intake was estimated based on dietary information from the food frequency questionnaire (13,14).

Bodyweight and height were measured twice during the baseline survey by a trained interviewer following a standard protocol. Overweight and obesity were defined according to the recommendation of previous studies for Chinese people as a BMI of 24.0 to 27.9 kg/m^2 and a BMI of ≥28.0 kg/m^2 (18,19). Abdominal obesity was defined as WC ≥90 cm in men and ≥80 cm in women using criteria recommended by the International Diabetes Federation (IDF) for Chinese adults (20). Excess body weight was defined as BMI ≥24.

Diabetes ascertainment

We conducted a follow-up survey every 3–4 years to record the occurrence of T2DM. Information collected includes the diagnosis of diabetes by a physician, fasting blood glucose level, postprandial blood glucose level, diabetes symptoms, and medical treatment (hypoglycemic agent or insulin). In this study, the participant was considered as an incident case of T2DM if he/she was been diagnosed by a physician and met at least one of the following criteria: (I) fasting glucose level ≥7 mmol/L; (II) blood glucose 2 hours after meal ≥11.1 mmol/L; (III) use of insulin or hypoglycemic agents; and (IV) had symptoms of diabetes. Self-reported diabetes in our two cohorts was proved sufficiently valid (21).

Statistical analysis

Differences in demographic characteristics between diabetes and non-diabetes groups were assessed using a t-test for continuous variables and the Chi-square test or rank-sum test (Wilcoxon) for categorical variables. The person-year was determined by calculating the interval between the baseline time and the date of diagnosis of T2DM, death, or latest follow-up, whichever came first. We utilized the Cox proportional hazards regression model to estimate the risk of T2DM with lifestyle factors, in age-adjusted (model 1) and multivariate-adjusted (model 2) models. Relevant variables that might have confounded the relationship to the risk of T2DM in model 2 included age (continuous), education (category), income (category), occupation (category), BMI (category), physical activity (quartiles, MET-h/week), family history of diabetes (yes/no), energy intake (quartiles), history of cigarette smoking (never, past, current), history of alcohol drinking (never, past, current), hypertension (yes/no), menopausal status (for women; yes/no). The proportional hazards assumption for the Cox model was checked using Schoenfeld residuals, and no violation was found. Considering the multicollinearity of the variables, we fitted the data linearly, and the variance inflation factor was 1.4. Considering the interaction between obesity and physical activity, we stratified the analysis according to BMI.

The PAR refers to the proportion of incident cases in a particular population that can be reduced after selected risk factors are eliminated within a certain period (22). T2DM is a multifactorial chronic disease so the PAR must be calculated while the distribution of other relevant factors is unchanged. To quantify the public health impact of lifestyle factors, we performed a model-based estimation of PAR as proposed by Dahlquist and Zetterqvist (23) with adjustment of the potential confounders. The time node of PAR was from baseline to the latest date of follow-up. PAR analysis was conducted in (R version 3.6.1); another analysis was performed using SAS software (version 9.2 SAS Institute, Inc., Cary, North Carolina). All tests of statistical significance were based on P values of 0.05 (two-sided) probabilities.

Result

After removing all participants with diabetes at the baseline survey, 70,849 females and 56,691 males were included in the current analysis. During 13.9 years (981,504 person-years) and 9.2 years (519,157 person-years) of follow-up, 5,925 female and 3,315 male incident cases of T2DM were identified in two cohorts. Corresponding density incidence rates of women and men were 6.0/1,000 person-years and 6.4/1,000 person-years.

The demographic characteristics of participants by T2DM status are shown in *Table 1*. The prevalence of overweight and obesity was 34.26% and 11.76% in women, and 37.32% and 7.96% in men. The proportions of women and men with abdominal obesity were 39.55% and 29.05%. The smoking rate was very high (60%) among men. Both in men and women, participants with T2DM were older, more likely to have lower levels of education, higher waist circumference, and higher BMI than participants without T2DM. In addition, participants with a family history of diabetes were also more likely to develop T2DM during subsequent follow-up. For women, participants with T2DM were more likely to be manual workers and have lower income than those without T2DM, but these associations were not seen in male participants.

Table 2 shows the relationships between BMI, waist circumference, physical activity and T2DM. The BMI and waist circumferences were positively correlated with the risk of T2DM (P_{trend}<0.01). The HR of T2DM was 3.06 (95% CI: 2.87, 3.25) for excess weight women and was 2.61 (95% CI: 2.42, 2.82) for men, compared with participants with BMI less than 24. The risks of T2DM were 4.58 (95% CI: 4.25, 4.93) and 4.09 (95% CI: 3.69, 4.54) times as high in women and men with BMI ≥24 as those with BMI <28. Compared with subjects with normal waist circumference, the HR of T2DM in abdominally obese women was 3.58 (95% CI: 3.36, 3.81) and that in men was 2.53 (95% CI: 2.35, 2.72). After adjustment for confounders, as physical activity levels increased, the risk of T2DM decreased in both women and men (P_{trend}<0.01). The HRs across quartile of total physical activity were 1.00, 0.93, 0.84, 0.84 in men and 1.00, 0.99, 0.92, 0.88 in women, respectively.

Analysis stratified according to BMI was shown in *Table 3*. Among overweight women, physical activity was associated with a decreased risk of T2DM ($HR_{Q4|Q1}$ =0.87, 95% CI:

Table1 Demographic characteristic of study participants by T2DM incidence status (SWHS 1996–2017, and SMHS 2002–2017)

	Non-T2DM	T2DM	P value
Women			
N	64,924	5,925	
Age[a] (years)	52.01±8.96	55.11±8.72	<0.01
Waist Circumference[a] (cm)	77.00±8.44	84.51±8.66	<0.01
Total physical activity[a] (MET-hours/week)	106.91±45.31	105.93±43.87	<0.01
BMI[b] (kg/m^2)			<0.01
<24	56.63%	24.07%	
24–27.9	33.25%	45.74%	
≥28	10.12%	30.19%	
Education[b]			<0.01
None/Elementary	19.12%	31.07%	
Middle school	37.67%	36.71%	
High school	29.03%	22.21%	
College and above	14.18%	10.01%	
Family Income (yuan/year)[b]			<0.01
<10,000	15.59%	17.34%	
10,000–19,999	38.06%	39.44%	
20,000–29,999	28.53%	26.63%	
≥30,000	17.82%	16.60%	
Occupation[b]			<0.01
Housewife	0.33%	0.56%	
Professional	29.32%	24.39%	
Clerical	20.70%	20.46%	
Manual laborers	49.65%	54.60%	
DM family history[b]	4,993 uncertain		<0.01
Yes	14.76%	26.98%	
No	85.24%	73.02%	
Smoking[b]			<0.01
Never	97.42%	96.34%	
Ex-smoker	0.36%	0.71%	
Current smoker	2.22%	2.95%	
Alcohol drinking[b]			0.46
Never	97.73%	97.84%	
Ex-drinker	0.28%	0.34%	
Current drinker	1.99%	1.82%	

Table 1 (*continued*)

Table 1 (*continued*)

	Non-T2DM	T2DM	P value
Men			
N	53,376	3,315	
Age[a] (years)	54.93±9.65	55.53±9.32	<0.01
Waist Circumference[a] (cm)	84.54±8.56	90.44±8.22	<0.01
Total physical activity[a] (MET-hours/week)	59.63±34.10	58.06±34.57	<0.01
BMI[b] (kg/m^2)			<0.01
<24	56.36%	29.20%	
24-27.9	36.50%	50.23%	
≥28	7.14%	20.57%	
Education[b]			<0.01
None/Elementary	6.28%	7.17%	
Middle school	33.36%	37.34%	
High school	36.69%	34.98%	
College and above	23.66%	20.52%	
Person Income (yuan/month)[b]			0.19
<500	12.57%	13.20%	
500–999	42.43%	42.89%	
1,000–1,999	35.07%	35.28%	
≥2,000	9.75%	8.64%	
Occupation[b]			0.75
Professional	26.18%	25.57%	
Clerical	21.92%	22.13%	
Manual laborers	51.90%	52.30%	
DM family history[b]	66 cases uncertain		<0.01
Yes	20.81%	39.01%	
No	79.19%	60.99%	
Smoking[b]			0.01
Never	29.89%	28.17%	
Ex-smoker	10.43%	11.83%	
Current smoker	59.68%	60.00%	
Alcohol drinking[x`]			<0.01
Never	66.07%	65.40%	
Ex-drinker	4.08%	5.52%	
Current drinker	29.85%	29.08%	

[a], analysis of *t*-test for continuous variables. Data are shown as mean ± SD. [b], analysis of Chi-square test or rank-sum test (Wilcoxon) for categorical variables. Data are shown as a percentage (%). T2DM, type 2 diabetes mellitus; MET, metabolic equivalent value; BMI, body mass index; SWHS, Shanghai Women's Health Study; SMHS, Shanghai Men's Health Study.

Table 2 Associations between excess weight, abdominal obesity, physical activity and risk of T2DM incidence in women and men (SWHS 1996–2017, and SMHS 2002–2017)

	Person-years	Cases	HR† (95% CI)	HR‡ (95% CI)
Women				
BMI (kg/m^2)				
<24	544,279	1,426	1.00	1.00
≥24	437,225	4,499	3.57 (3.36, 3.80)	3.06 (2.87, 3.25)
Subgroup				
<24	544,279	1,426	1.00	1.00
24–27.9	331,795	2,710	2.92 (2.74, 3.11)	2.61 (2.44, 2.78)
≥28	105,431	1,789	5.70 (5.31, 6.12)	4.58 (4.25, 4.93)
			P_{trend}<0.01	P_{trend}<0.01
Waist circumference (cm)				
<80	613,556	1,588	1.00	1.00
≥80	367,949	4,337	4.15 (3.90, 4.41)	3.58 (3.36, 3.81)
Subgroup				
80–84	183,098	1,514	3.08 (2.86, 3.31)	2.78 (2.59, 3.00)
85–89	101,088	1,240	4.45 (4.12, 4.81)	3.87 (3.58, 4.19)
≥90	83,763	1,583	6.53 (6.05, 7.04)	5.38 (4.98, 5.82)
			P_{trend}<0.01	P_{trend}<0.01
Total physical activity (MET_hours/week)				
Q1 (<75)	242,705	1,439	1.00	1.00
Q2 (75–100)	245,934	1,530	1.02 (0.95, 1.09)	0.99 (0.92, 1.07)
Q3 (101–131)	246,399	1,506	0.98 (0.91, 1.06)	0.92 (0.85, 0.98)
Q4 (≥132)	246,466	1,450	0.96 (0.90, 1.04)	0.88 (0.82, 0.95)
			P_{trend}=0.20	P_{trend}<0.01
Men				
BMI (kg/m^2)				
<24	287,914	968	1.00	1.00
≥24	231,243	2,347	3.00 (2.79, 3.24)	2.61 (2.42, 2.82)
Subgroup				
<24	287,914	968	1.00	1.00
24–27.9	191,994	1,665	2.57 (2.37, 2.78)	2.31 (2.13, 2.51)
≥28	39,249	682	5.14 (4.66, 5.67)	4.09 (3.69, 4.54)
			P_{trend}<0.01	P_{trend}<0.01
Waist circumference (cm)				
<90	373,128	1,542	1.00	1.00
≥90	146,028	1,773	2.93 (2.73, 3.13)	2.53 (2.35, 2.72)

Table 2 (*continued*)

Table 2 (*continued*)

	Person-years	Cases	HR[†] (95% CI)	HR[‡] (95% CI)
Subgroup				
90–94	83,666	815	2.35 (2.16, 2.56)	2.13 (1.95, 2.32)
95–99	39,707	537	3.27 (2.96, 3.60)	2.79 (2.52, 3.08)
≥100	22,656	421	4.49 (4.03, 5.00)	3.54 (3.16, 3.97)
			P_{trend}<0.01	P_{trend}<0.01
Total physical activity (MET_hours/week)				
Q1 (<35)	129,891	906	1.00	1.00
Q2 (35–53)	130,243	846	0.91 (0.83, 1.00)	0.93 (0.85, 1.02)
Q3 (54–78)	129,613	758	0.80 (0.73, 0.89)	0.84 (0.76, 0.92)
Q4 (≥79)	129,410	805	0.83 (0.75, 0.92)	0.84 (0.76, 0.93)
			P_{trend}<0.01	P_{trend}<0.01

‡, adjusted for age, occupation, family history of diabetes, income, educational level, energy intake, physical activity, BMI, smoking, alcohol drinking, hypertension and menopause status (only for women). T2DM (Type 2 Diabetes Mellitus), MET (Metabolic Equivalent value), BMI (Body Mass Index), HR (Hazard Ratio), SWHS (Shanghai Women's Health Study), SMHS (Shanghai Men's Health Study). †adjusted for age.

Table 3 Hazard ratio of type 2 diabetes in physical activity stratified by body mass index

Physical activity	BMI <24, HR (95% CI)	24≤ BMI <28, HR (95% CI)	BMI ≥28, HR (95% CI)
Women[‡]			
Q1 (<75)	1.00	1.00	1.00
Q2 (75–100)	0.95 (0.83, 1.10)	0.97 (0.87, 1.08)	1.06 (0.93, 1.20)
Q3 (101–131)	0.89 (0.77, 1.03)	0.92 (0.83, 1.03)	0.91 (0.80, 1.05)
Q4 (≥132)	0.87 (0.75, 1.01)	0.87 (0.78, 0.97)	0.89 (0.77, 1.01)
P_{trend}	0.06	<0.01	0.02
Men[‡]			
Q1 (<35)	1.00	1.00	1.00
Q2 (35–53)	0.83 (0.70, 0.99)	0.99 (0.87, 1.14)	0.95 (0.77, 1.17)
Q3 (54–78)	0.73 (0.61, 0.88)	0.88 (0.77, 1.02)	0.87 (0.70, 1.08)
Q4 (≥79)	0.66 (0.55, 0.80)	0.87 (0.75, 1.01)	1.06 (0.85, 1.31)
Ptrend	<0.01	0.02	0.89

‡, adjusted for age, occupation, family history of diabetes, income, educational level, energy intake, physical activity, BMI, smoking, alcohol drinking, hypertension and menopause status (for women). T2DM, Type 2 Diabetes Mellitus; MET, Metabolic Equivalent value; BMI, Body Mass Index; HR, Hazard Ratio.

0.78, 0.97, P_{trend}<0.01). Among men with a BMI of less than 24, physical activity was associated with a decreased risk of T2DM ($HR_{Q4|Q1}$=0.66, 95% CI: 0.55, 0.80, P_{trend}<0.01). However, this association was not found in overweight or obese men.

In men, the estimated proportions of T2DM incident cases attributable to excess weight, abdominal obesity, physical inactivity were 41.5% (95% CI: 38.5%, 44.6%), 30.3% (95% CI: 27.8%, 32.8%), and 3.6% (95% CI: 1.7%, 5.5%) as shown in *Table 4*. In women, the estimated

Table 4 The population attributable risk and hazard ratio of type 2 diabetes in excess weight, abdominal obesity and physical inactivity stratified by age group (95% CI)

Factors	Women‡				Men‡			
	Overall	40–49	50–59	60–70	Overall	40–49	50–59	60–74
Case	5,925	2,044	1,814	2,067	3,315	1,134	1,143	1,038
Excess weight								
HR (95% CI)	3.06 (2.87, 3.25)	3.73 (3.38, 4.11)	2.71 (2.42, 3.03)	2.45 (2.20, 2.74)	2.61 (2.42, 2.82)	2.94 (2.58, 3.36)	2.58 (2.26, 2.95)	2.29 (2.00, 2.63)
PAR% (95% CI)	48.6 (46.3, 50.9)	50.4 (47.1, 53.7)	45.5 (41.1, 49.9)	44.1 (39.5, 48.7)	41.5 (38.5, 44.6)	44.1 (39.2, 49.0)	41.0 (35.4, 46.6)	37.8 (32.1, 43.4)
Abdominal obesity								
HR (95% CI)	3.58 (3.36, 3.81)	4.07 (3.71, 4.46)	3.22 (2.89, 3.59)	2.99 (2.66, 3.37)	2.53 (2.35, 2.72)	2.87 (2.54, 3.24)	2.47 (2.18, 2.78)	2.27 (2.00, 2.57)
PAR% (95% CI)	50.4 (48.3, 52.5)	45.0 (42.1, 48.0)	48.3 (44.4, 52.2)	52.2 (47.7, 56.7)	30.3 (27.8, 32.8)	31.5 (27.5, 35.4)	28.0 (23.6, 32.5)	30.1 (25.4, 34.9)
Physical inactivity								
HR (95% CI)	1.04 (0.98, 1.11)	1.11 (1.01, 1.23)	1.12 (1.01, 1.25)	1.06 (0.96, 1.18)	1.13 (1.04, 1.22)	1.16 (1.03, 1.32)	1.28 (1.12, 1.45)	1.01 (0.84, 1.21)
PAR% (95% CI)	1.7 (0.4, 3.0)	2.4 (0, 4.8)	2.6 (0.2, 5.0)	1.2 (−0.9, 3.2)	3.6 (1.7, 5.5)	4.6 (0.6, 8.5)	6.0 (2.6, 9.3)	0 (−2.3, 2.5)

‡, adjusted for age, occupation, family history of diabetes, income, educational level, energy intake, physical activity, BMI, smoking, alcohol drinking, hypertension and menopause status (for women). T2DM, type 2 diabetes mellitus; MET, metabolic equivalent value; BMI, body mass index; HR, hazard ratio; PAR, population attributable risk.

proportions of T2DM incident cases attributable to excess weight, abdominal obesity and physical inactivity were 48.6% (95% CI: 46.3%, 50.9%), 50.4% (95% CI: 48.3%, 52.5%) and 1.7% (95% CI: 0.4%, 3.0%). Furthermore, we explored the contributions of factors with different age groups. According to their baseline age, age group 40-49 was found to have the highest PARs of excess weight; age group 50-59 was found to have the highest PARs of physical inactivity in both women and men.

Discussion

In these two large prospective cohort studies, we found that excess body weight and abdominal obesity were major risk factors for T2DM incidence among middle-aged Chinese. Besides, we observed that physical activity had a protective effect on the development of T2DM in middle-aged adults. These large observational cohort studies suggested that exposures to unfavorable levels in BMI, waist circumference, physical activity were attributable for 48.6%, 50.4% and 1.7% cases of incident T2DM in women and 41.5%, 30.3% and 3.6% in men.

We found that excess body weight and abdominal obesity were associated with a dramatically increased risk of T2DM among middle-aged Chinese, consistent with previous studies (6-8). It has been reported that obesity was an independent risk factor and a major cause of T2DM (24). A study of 154,989 subjects from Asian, New Zealand, and Australian populations in the Asia-Pacific region found that baseline BMI was positively associated with T2DM risk, with a 27% reduction in diabetes risk for each 2 kg/m^2 reduction in BMI (7). The biological mechanism underlying this effect is that adipocytes secrete signaling molecules that increase insulin resistance and glucose intolerance, and that levels increase in diet-induced obesity as well as in genetic models of obesity and insulin resistance (25). In our study, there was a gender difference in the association between excess body weight, abdominal obesity and risk of T2DM. Women with excess body weight or abdominal obesity had a higher risk of developing T2DM than men. The reason may be related to the menopausal status of female subjects, increased visceral fat deposition among women after menopause may promote increased insulin resistance and elevated incidence of the metabolic syndrome in older women (26,27).

In PAR analysis, we found that almost half of T2DM cases could be attributed to excess body weight (women: 48.6%, men: 41.5%). Previous studies also showed a large proportion of T2DM cases attributable to excess body weight. In Tehran, the PARs adjusted for family history of diabetes, age, triglycerides, systolic blood pressure was 23.3% for overweight, and 37.1% for obesity (28). In our study, 50.9% female and 31.2% male T2DM were attributed to abdominal obesity. A cohort study conducted in a sample of 24,996 Chinese adults aged 35–74 years, found that 28.1% incident diabetes among men and 41.2% among women would theoretically not have occurred if all people had no abdominal obesity (29). In Australia, the percentage of diabetes incident cases attributable to obesity (BMI combined waist circumference) was 47% according to the results from the Australian Diabetes, Obesity and Lifestyle Study (30).

Previous epidemiological studies have suggested that physical activity was associated with a reduced risk of T2DM (9,10,31). Our study also found a similar result. Similarly, a sedentary lifestyle was a risk factor for T2DM. Bennet DA conducted a follow-up of 512,000 Chinese for 9 years and found that more physical activity and less leisure time could reduce the risk of T2DM, and sitting an additional hour per day increased the risk of T2DM by 5% (31). Among the middle-aged population in Shanghai, we found that total physical activity in women was higher than men, which may be related to women doing more housework and lack of exercise for both men and women. In men with normal BMI, total physical activity was protective against T2DM but not found in other BMI groups. The possible reason was that obese men need more physical activity than normal-weight men to have protective effects against T2DM.

The PARs of T2DM caused by physical inactivity in men and women were 3.6% and 1.7%. The possible reason was that men have lower levels of physical activity than women and that the criteria for physical inactivity differed between men and women. Furthermore, The HR and PAR of T2DM caused by inadequate physical activity were highest in men aged 50–59 years. Therefore, men aged 50–59 years were priority populations who needed to improve their lifestyle on health intervention. There are few studies on PAR of physical activity on T2DM and the criteria for physical activity are different. Hosein Fallahzadeh (32) estimated PAR of T2DM by Bayesian methods based on the cohort study of chronic diseases in the adults of Yazd city, which showed that 17.92% women and 18.53% men cases were attributable to physical inactivity in Iran. In Finland, PARs for absence of exercise ranged from 3% (95% CI: −11.0, 16.0) in men to 7% (95% CI: −9.0, 20.0) in women (33).

Strength and limitations

Our study was based on two large population-based cohort studies with high quality exposure data and high recruitment and high follow-up rates (>90%), which minimized selection bias. Another advantage is the availability of detailed information including lifestyle factors, and the total energy intake of subjects was estimated according to a food frequency questionnaire, which allowed us for a more comprehensive evaluation of PAR. However, several possible limitations of this study warrant consideration. The main concern for our study is its reliance on self-reported T2DM, misclassification and undiagnosed are likely. Also, our research is based on Chinese adults aged 40–74, thus, more studies are needed to investigate the PAR of excess body weight on T2DM incidence by other groups of age.

Conclusions

In conclusion, our findings from the two prospective cohorts revealed that excess weight and abdominal obesity were associated with a significant increase in the risk of T2DM incidence in Chinese adults. Excess weight and abdominal obesity could explain nearly 50% of T2DM cases. Insufficient physical activity accounted for a small part of T2DM cases. Weight control and promotion of physical activity should be conducted through various ways to reduce the burden of T2DM in China.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Renji Hospital Ethics Committee of Shanghai Jiaotong University School of Medicine (KY2019-196) and informed consent was taken from all individual participants.

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