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ENERGY BALANCE AND TYPE 2 DIABETES: A REPORT FROM THE SHANGHAI WOMEN'S HEALTH STUDY

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Abstract

Background and aims—The combined effect of the components of energy balance (energy intake and physical activity) and the development of type 2 diabetes (T2D) has not been adequately investigated. The aim of this study was to examine the components of energy balance and the incidence of type 2 diabetes (T2D) in a cohort of middle-aged women.

Methods and Results—Population-based prospective study of 64,191 middle-aged Chinese women who had no prior history of diabetes or chronic disease at study recruitment. Participants completed in-person interviews at baseline and follow-up surveys that collected information on diabetes risk factors including dietary and physical activity habits and disease occurrence information. Anthropometric measurements were taken by trained interviewers at recruitment. Average follow-up time was 4.6 years. During 297,755 person-years of follow-up, 1,608 new cases of T2D were documented. Body mass index (BMI) and weight gain (since age 20) were strongly associated with T2D incidence. Energy intake (EI) was associated with modestly increased risk, while physical activity (PA) was associated with decreased risk of T2D. Less active women with higher EI had higher risk of T2D (RR=1.96; 95% CI: 1.44, 2.67) than active women with lower EI ($P_{interaction}$ = 0.02). The EI to PA (EI:PA) ratio was positively associated with T2D risk; the association was more evident among overweight and obese women (BMI>=23 kg/m^2).

Conclusion—These data suggest that energy balance plays an important role in the development of T2D, and this effect may be modified by BMI.

Keywords

energy balance; type 2 diabetes; middle-aged women

INTRODUCTION

High body mass index and weight gain (1–3), reflecting a positive energy balance, are associated with a higher risk of type 2 diabetes (T2D). However, the joint effects of the

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components on the other side of the energy balance equation (energy intake (EI) and physical activity (PA)) in association with the incidence of T2D have not been adequately investigated.

The modernization of urban areas of China, such as Shanghai, has resulted in changes in lifestyle and increases in the prevalence of non-communicable diseases, including T2D (4–7). In this report, we evaluated the hypothesis that a behavioral pattern indicating greater energy availability (high EI and low PA) is associated with increased T2D risk using data from an ongoing, population-based cohort study in urban Shanghai, the Shanghai Women's Health Study (SWHS).

RESEARCH METHODS AND PROCEDURES

Study Population

The SWHS is a population-based, prospective cohort study conducted in seven urban communities in Shanghai, China. The cohort includes 74,943 women aged 40–70 years who were recruited into the study (response rate: 92.7%). All study participants completed an in-person interview for assessment of dietary intake, PA, and measurement of anthropometrics and other lifestyle factors. Details of the SWHS methodology have been reported elsewhere (8,9). Biannual, in-person follow-ups for all living cohort members were conducted from 2000 to 2002 and from 2002 to 2004 with response rates of 99.8% and 98.7%, respectively. Only 934 participants were lost to follow-up. The institutional review boards for all institutions involved in the study approved the study protocols, and written informed consent was obtained from all participants prior to interview.

Dietary Energy Intake

Usual dietary intake was assessed at baseline and at the first follow-up through an in-person interview using a validated food frequency questionnaire (FFQ) (8). The Chinese Food Composition Tables (10) were used to estimate intake of nutrients and total energy intake (kcals/day). The reproducibility and validity of the FFQ was assessed in a random sample of 200 participants who completed 24-hour dietary recalls twice a month during a 12-month period and 2 FFQs that were administered 2 years apart. To improve the measurement of long-term dietary intake, the average EI from the baseline and follow-up FFQs, taken approximately 2 years apart, were used in the analyses except for women who developed T2D, cancer, or cardiovascular disease between the baseline and the follow-up FFQs. Because diagnosis of these conditions could result in dramatic changes in dietary intake, for subjects reporting these conditions only the baseline dietary information was used in the analysis. We conducted analyses using baseline dietary information alone and found that high caloric intake was associated with a non-significantly elevated risk of T2D (data not shown). Such an observation is consistent with the notion that non-differential exposure misclassification biases results towards the null.

Physical Activity

A detailed assessment of PA was obtained using a validated questionnaire (11) at the baseline survey. The validity of the questionnaire was evaluated by comparing Spearman correlations (r) for the questionnaire with two criterion measures administered over a period of 12 months (four 7-day PA logs and up to 28 7-day PA questionnaires). Significant correlations between the PA questionnaire and criterion measures for exercise (PA log, r=0.74; 7-day PA questionnaire, r=0.80) and between the PA questionnaire lifestyle activities and the 7-day questionnaire were also observed (r= 0.30– 0.88). The reproducibility of the questionnaire (2-year test-retest) was evaluated using kappa statistics and intraclass correlation coefficients (kappa=0.64; intraclass correlations coefficients were between 0.14 and 0.54) (11).

The questionnaire evaluated regular exercise and sports participation during the 5 years preceding the interview and daily activity such as walking, stair climbing, cycling, household activities, and daily commuting (walking and cycling on the journey to and from work). PA energy expenditure was estimated using standard metabolic equivalent values (MET) (12). One MET-h/d is roughly equivalent to 1 kcal/kg/d or about 15 minutes of participation in moderate intensity (4 MET) activity for an adult weighing about 60 kg (12). We combined each of the exercise and lifestyle activity indices to derive a quantitative estimate of overall non-occupational PA (MET-hr/day). Because only 3% of the study population reported having a job requiring high PA and because occupational PA was not related to T2D in this population, we focused on non-occupational PA in the current report.

Body Size and Weight History

Anthropometric measurements (weight, height, and waist and hip circumferences) were taken according to a standard protocol at baseline recruitment by trained interviewers who were retired medical professionals (9). All measurements were taken twice and if the difference between the first two measurements was larger than 1 cm for circumferences or 1 kg for weight, a third measurement was taken. The average of the two closest measurements was applied in the present study. From these measurements, the following variables were created: BMI, weight in kg divided by the square of height in meters and WHR, waist circumference divided by hip circumference. Self-reported body weight history was obtained for age 20 years. Standardized weight change was calculated as the difference between measured weight at baseline and weight at the age of 20 years divided by the interval between study recruitment and age 20 (kg/yr).

Endpoint Ascertainment

Incident T2D was identified through follow-up surveys. After an average of 297,755 person years of follow-up for subjects who were free of T2D and/or glycosuria and other chronic diseases (coronary heart disease, stroke, and cancer) at baseline, 1,608 study participants reported having been diagnosed with T2D since baseline. For the current study we considered a case of T2D to be confirmed if the participant reported having been diagnosed with T2D and met at least one of the following criteria: fasting glucose level greater or equal to 7 mmol/l on at least two occasions or an oral glucose tolerance test (OGTT) (conducted at their doctor's office) with a value greater than or equal to 11.1 mmol/L and/or use of hypoglycaemic medication (i.e., insulin or oral hypoglycaemic drugs). Of the self-reported cases a total of 896 participants (56%) met the study outcome criteria and are referred to as 'confirmed' cases of type 2 DM in this report; the remaining 712 cases (44%) were considered 'probable' cases. Nearly half of the self-reported cases did not meet the confirmation criteria because we did not collect information on the number of abnormal fasting glucose tests or OGTT results.in the first follow-up survey. Therefore, according the study criteria, such cases identified in the first follow-up survey could not be considered 'confirmed'. We performed analyses with both confirmed cases and probable cases of T2D and found similar trends. Thus, in this paper we present the results of analyses that included all self-reported cases of T2D.

Statistical Analysis

From the total number of participants that were free of T2D and other chronic diseases at baseline (N=64,227), we excluded participants who had extreme values for total energy intake (<500 or > 3500 kcals/day; N=36) (13), leaving 64,191 participants for the analysis of whom 1,605 developed T2D.

Person-years for each participant were calculated as the interval between the date of baseline recruitment and the date of diagnosis of T2D, censored at death or completion of the second follow-up. The Cox proportional hazards model was used to assess the effect of physical activity, energy intake, weight gain, and BMI on the incidence of T2D with adjustment for potential confounders such as age, WHR, (entered as continuous variables), level of education (none, elementary school, middle/high school, college), family income in yuan/year (<10,000, 10,000–19,999, 20,000–29,999, >30,000), occupation (professional, clerical, farmers/others, housewife/retired), current smoking, and alcohol consumption habits (ever drank beer, wine or spirits at least 3 times per week).

Exposures of interest were categorized by quintile distribution with the lowest quintile serving as the reference. We also looked at BMI categories for obesity according to WHO recommendations (14) and those suggested for Asian populations (15). Tests for trend were performed by entering the categorical variables as continuous parameters in the models. We investigated joint associations of categories of EI and PA (lower quartile, second and third quartiles combined, and upper quartile) with the risk of T2D. The log-likelihood ratio test was used to test the interaction effect of activity levels and energy intake on T2D risk. All analyses were performed using SAS (version 9.1) and tests of statistical significance were based on two-sided probability.

RESULTS

During the average 4.6 years of follow-up (297,755 person-years at risk), 1,608 SWHS participants reported having developed T2D, (incidence: 5.4 per 1,000 person-years). The age-standardized population characteristics by quintile of BMI are presented in Table 1. Participants with a higher BMI were more likely to be older, less educated, have lower income, and not be employed at the time of the survey. Women in the lower BMI quintile had a prevalence of hypertension of 7.3% as compared to a prevalence of 22.4% in women in the upper BMI quintile.

BMI and standardized weight gain were associated with a higher risk of T2D (Table 2). The fully-adjusted relative risks (RR) for T2D across BMI quintiles were 1.00, 1.91, 2.39, 3.22, and 5.66 (P_{trend} <0.001) in analysis adjusted for age, kcal/day, WHR, PA, smoking, alcohol consumption, income level, education level, occupation, and hypertension. The RR were 1.00, 2.13, and 3.45 (P_{trend}<0.001) for WHO obesity categories (data not shown in Table 2) and 1.00, 2.06, and 3.88 (P_{trend}<0.001) for Asian obesity categories. Compared to participants that either lost weight or had stable weight, the fully-adjusted RR increased from 2.21 (95 %CI: 1.65, 2.95) for weight gain of up to 0.25 kg/y to 12.67 (95 %CI: 9.36, 17.16) for weight gain of 0.75 kg/yr or higher.

EI was associated with a modest increase in risk of T2D, while PA was associated with a decrease in T2D risk (Table 3). EI:PA ratio was positively associated with risk of T2D. The adjusted RR for T2D for quintiles of the EI:PA ratio were 1.00, 1.04, 1.10, 1.25, and 1.43 (P_{trend}<0.001). In analyses conducted after exclusion of participants with a BMI>=27.5 kg/m^2 but a low EI:PA ratio (lowest quartile) and those with a BMI<23 kg/m^2 but a high EI:PA ratio (highest quartile), the RR for quintiles of EI:PA ratio were 1.00, 1.09, 1.17, 1.36, and 1.66 (P_{trend}<0.001). Participants in this group (85.6%) were representative of the population in terms of age, income level, education and occupation status, while participants with low EI:PA ratio/high BMI were older, less educated, less likely to be employed at baseline, and had lower income, and those with high EI:PA ratio/low BMI were younger, had higher income and education, and were more likely to be employed at the time of the survey.

Because BMI is a very strong risk factor for the development of T2D, we present associations between components of energy balance (EI, PA, and EI:PA ratio) stratified by BMI categories in Table 5. The association between the components of energy balance and T2D was accentuated in participants with higher BMI but tests for multiplicative interaction were not significant.

DISCUSSION

In this large cohort study of middle-aged Chinese women, high BMI and weight gain in adulthood, indicating a positive energy balance, were associated with a higher risk of T2D. We also found that the components of energy balance, EI and PA, have an interactive effect on the incidence of T2D.

Participants with the lowest BMI were the least active, while the most obese were among the most active. Reasons for this association could be genetic, reverse causation, or the fact that more active people consume more kcal/day.

BMI was positively associated with the incidence of T2D, which is in agreement with many previous observations (1,16–19). Weight gain, reflecting a positive energy balance, was also positively associated with T2D in this study, which has also been witnessed in other studies (2,3,17,20–22). A number of specific mechanisms, such as a reduced number of insulin receptors, high fat oxidation, and fat glucose substrate competition in skeletal muscle have been suggested as the mechanisms behind the obesity and T2D association (23). Efforts to control weight gain, involving either reduction of EI, increase of energy expenditure, or both (24), should receive priority in T2D prevention.

The effect of EI on the risk of T2D has been addressed in a few studies, and results were not consistent. EI was positively associated with the risk of T2D in Pima Indian women (25), but only a weak and non-significant association between EI and T2D was found in the Nurses' Health Study (26,27). No association was found between EI and incidence of T2D in the Health Professionals Follow-up Study (28), while an inverse association between EI and glucose intolerance was found in the Hoorn Study (29). Reasons for little or no association between total EI and T2D might be related to underreporting of EI by overweight and obese subjects (30–32), who are at higher risk of developing T2D. In our population, the prevalence of obesity is low, which minimized the influence of body weight on the dietary assessment. Another reason for the lack of association between EI and T2D could be the inherent challenge in quantifying EI in population-based studies. In addition, metabolic efficiency, an important determinant of EI, cannot be measured in epidemiological studies (32). Because the human basal metabolic rate is supposed to account for up to 70% of total EI (32), we attempted to investigate associations between estimated available energy and the risk of T2D. We used an equation to derive the basal metabolic rate that has been proposed and validated for Asian populations (33,34). Available energy was then estimated by subtracting the basal metabolic rate from total dietary EI. Estimated available energy was positively associated with the risk of T2D in a manner similar to that of total EI. The fully adjusted RR of T2D for quintiles of available energy were 1.00, 0.99, 1.06, 1.15, and 1.41 (P_{trend} <0.01; data not shown in tables).

We found an inverse association between PA and incidence of T2D, consistent with the findings of previous studies (35–39). Skeletal muscle is the predominant site for insulin resistance (40) and exercise training has been shown to improve insulin sensitivity in these tissues (23). Thus, it is biologically plausible that PA may reduce the risk of T2D (23).

EI and PA interacted with each other in the development of T2D and this interactive effect appeared to be more evident in women with a higher BMI. To our knowledge there are no other reports investigating interactions of the components of energy balance and T2D. The mechanisms underlying these interactions are unknown. We speculate that the EI:PA ratio was only associated with T2D among women with high BMI because the underlying insulin resistance related to obesity makes individuals more vulnerable to a positive energy balance.

In the Women's Health Initiative Study, lower fasting insulin levels were found in participants with lower EI and higher PA compared to participants with higher EI and lower PA (8.74 micromol/L vs 18.08 micromol/L) (41).

Findings from diabetes prevention trials suggest that changes in energy balance decrease the risk of T2D. In the Finnish Diabetes Prevention Study, the mean (+/−SD) amount of weight lost between baseline and one year later was 4.2+/−5.1 kg in the intervention group and 0.8+/−3.7 kg in the control group and the risk of developing diabetes was reduced by 58% in the intervention group (42). A similar reduction in T2D incidence was reported in the US Diabetes Prevention Program (DPP) in the lifestyle intervention group (58%) as compared to the placebo group (43). In a recent report of the DPP, the relative risk of diabetes for a 5 kg weight loss was 0.42 (95%CI: 0.35–0.51). An increase in physical activity helped to sustain weight loss and independently reduced T2D by 44% among those who did not lose weight. The authors concluded that interventions to reduce the risk of T2D should primarily target weight reduction (44).

Our study has several strengths. This population-based study represents women from a wide range of socioeconomic backgrounds. The study has a low lost-to-follow-up rate. Detailed information on socioeconomic status and other lifestyle factors allowed for a comprehensive adjustment for these factors. The repeated dietary measurements in the study improved the quality of the dietary information. The PA assessment instrument was specifically designed to assess a wide range of activities and was validated in the study population (11). The high quality of data and the large sample size allowed us to comprehensively evaluate individual components and interactions of components of energy balance in the etiology of T2D.

However, we acknowledge important limitations of the study. Reliance on self-reports of T2D is an important factor to consider when interpreting these results. A recent report suggested that the prevalence of diabetes was under-diagnosed in Shanghai and that as many as two in five diabetes cases may be undiagnosed (45). We are not aware of any program for systematic screening for diabetes in our study area. At baseline recruitment, we conducted a urinary glucose test for all cohort members who donated a urine sample (88.2% of participants). We found that 1% who reported never having been diagnosed by a physician as having diabetes had a positive urinary glucose test. These subjects were excluded from the current analysis. However, it is possible that there were still some T2D cases that remained undiagnosed in our study. Random misclassification of T2D could weaken the association between EI and PA and the risk of T2D. However, if high weight/BMI, energy intake and low levels of PA were associated with diagnosis of T2D, an over-estimation of the association could also occur. Misclassification in the dietary assessment would most likely be non-differential and thus attenuate the true associations. The PA variable may also be subject to measurement error.

In summary, this large, population-based study found that energy balance plays an important role in the development of T2D in Chinese women. Interactions between the components of the energy balance equation were suggested. In China the prevalence of overweight and obesity has doubled in females and tripled in males between 1989 and 1997 (46), and the prevalence of T2D has increased from 1.9% to 5.6% between 1993 and 2003. Thus, there is an urgent need to promote an active lifestyle and a healthy diet to maintain weight and control weight gain. This should be one of the highest public health priorities.

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Table 1

Age-standardized characteristics of the population by quintiles of BMI[+]

	BMI				
	Q1	**Q2**	**Q3**	**Q4**	**Q5**
Age	48.9	49.3	50.5	52.0	54.1
Energy Intake	1612.7	1635.5	1650.1	1665.8	1693.9
Ever smoker	1.8	2.0	1.9	2.0	1.8
Alcohol consumption	2.4	1.5	1.5	1.8	2.1
High PA [**]	19.0	20.1	21.2	22.0	22.4
Education					
None	12.0	12.6	14.1	15.9	19.5
Elementary	30.1	30.8	32.5	33.8	36.6
Up to High School	27.1	26.4	24.6	23.2	19.2
College	14.0	13.6	12.0	10.4	7.9
Income Level					
<10,000	12.2	11.9	12.8	12.3	14.5
10,000–19,999	30.9	30.5	30.9	32.5	34.1
20,000–29,999	24.5	24.8	24.2	23.9	22.0
>=30,000	15.6	16.1	15.4	14.6	12.7
Occupation					
Professional	18.2	18.4	17.2	16.2	12.2
Clerical	10.3	10.6	10.8	10.9	11.8
Farmers/others	18.3	18.9	19.6	19.6	19.4
Housewife/Retired	36.5	35.3	35.7	36.6	39.9
Hypertension	7.4	10.9	13.7	18.7	22.4

[+] Data are presented as percentages and are directly standardized in years to the age distribution of the population for all variables except for energy intake and age for which means are presented. Means of energy intake (kcal/day) are adjusted by age using a general linear model.

[*] Upper quartile of METs/day

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Table 2

Associations of T2D with BMI categories and weight gain

	No. events	Person-yr	RR	95% CI	P trend
BMI Categories *					
BMI Quintiles					
<21.0	64	60,440	1.00		<0.001
21.0–22.7	146	59,759	1.91	1.42, 2.55	
>22.7–24.3	215	59,234	2.39	1.81, 3.16	
>24.3–26.4	358	59,729	3.22	2.46, 4.21	
>26.4	817	58,375	5.66	4.35, 7.37	
Asians					
<23	238	129,689	1.00		<0.001
23–27.5	748	129,991	2.06	1.78, 2.40	
>=27.5	614	37,589	3.88	3.30, 4.58	
Standardized Weight Gain **					
<=0 (15.15%)	60	41,233	1.00		<0.001
>0–0.25 (24.03%)	224	65,361	2.21	1.65, 2.95	
>0.25–0.50 (31.58%)	465	85,644	4.18	3.16, 5.53	
>0.50–0.75 (19.10%)	347	51,598	6.80	5.09, 9.10	
>0.75 (10.16%)	272	27,123	12.67	9.36, 17.16	

* Adjusted for age, WHR, kcal/day, physical activity, alcohol consumption, smoking, education level, income level, occupation, and hypertension

** Units kg/year. Adjusted for age, weight at 20 yrs, kcal/day, physical activity, alcohol consumption, smoking, education level, income level, occupation, and hypertension

Table 3

Associations of T2D with components of energy balance

	No. events	Person-yr	RR	95% CI	P trend
Energy Intake (kcals/day)*					
<1376.9	334	59,003.9	1.00		<0.001
1376.9–1550.5	284	59,745.6	0.91	0.78, 1.07	
>1550.5–1713.2	289	59,905.8	0.95	0.81, 1.12	
>1713.2–1925.9	324	59,829.2	1.11	0.95, 1.30	
>1925.9	374	59,294.7	1.26	1.08, 1.46	
PA (METs/day)**					
<10.52	341	60,029.8	1.00		<0.001
10.52–13.6	338	59,623.8	0.92	0.79, 1.07	
>13.6–16.9	369	59,813.5	0.95	0.82, 1.11	
>16.9–21.7	305	59,244.7	0.82	0.70, 0.95	
>21.7	249	59,067.4	0.70	0.60, 0.83	
EI:PA ratio*** (kcal/METS-h)					
<73.3	272	58,597.7	1.00		<0.001
73.3–95.6	300	59,541.8	1.04	0. 89, 1.23	
>95.6–120.7	310	59,644.6	1.10	0.93, 1.29	
>120.7–159.4	340	59,741.1	1.25	1.06, 1.46	
>159.4	379	60,195.9	1.43	1.22, 1.67	

* Adjusted for age, WHR, BMI, physical activity, alcohol consumption, smoking, education level, income level, occupation, and hypertension

** Adjusted for age, WHR, BMI, kcal/day, alcohol consumption, smoking, education level, income level, occupation, and hypertension

*** Adjusted for age, WHR, BMI, alcohol consumption, smoking, education level, income level, occupation, and hypertension

Table 4

Associations between the incidence of T2D and components of energy balance by BMI* categories

	BMI<23			BMI>=23		
	RR	**95% CI**	***P trend***	**RR**	**95% CI**	***P Trend***
Energy Intake (kcals/day)*			*0.10*			*<0.001*
<1376.9	1.00			1.00		
1376.9–1550.5	1.29	0.88,1.90		0.87	0.73,1.04	
>1550.5–1713.2	1.06	0.70,1.61		0.96	0.81,1.15	
>1713.2–1925.9	1.09	0.72,1.66		1.14	0.96,1.35	
>1925.9	1.60	1.07,2.38		1.29	1.10,1.52	
P interaction 0.32+						
PA (METs/day)**						
<10.52	1.00		*0.86*	1.00		*<0.001*
10.52–13.6	1.08	0.71,1.63		0.90	0.76,1.06	
>13.6–16.9	1.24	0.83,1.85		0.90	0.76,1.05	
>16.9–21.7	1.17	0.78,1.77		0.74	0.63,0.88	
>21.7	0.98	0.63,1.53		0.64	0.53,0.77	
P interaction 0.15+						
EI:PA ratio*** (kcal/METS-h)				*0.61*		*<0.001*
<73.3	1.00			1.00		
73.3–95.6	1.27	0.85,1.89		1.02	0.85,1.22	
>95.6–120.7	0.97	0.63,1.49		1.15	0.96,1.37	
>120.7–159.4	1.27	0.84,1.91		1.31	1.10,1.56	
>159.4	1.14	0.75,1.74		1.58	1.33,1.88	
P interaction 0.10+						

* Adjusted for age, WHR, physical activity, alcohol consumption, smoking, education level, income level, occupation, and hypertension

** Adjusted for age, WHR, kcal/day, alcohol consumption, smoking, education level, income level, occupation, and hypertension

*** Adjusted for age, WHR,, alcohol consumption, smoking, education level, income level, occupation, and hypertension

+ The log-likelihood ratio test was used to test the interaction effect between BMI categories and the EI:PA ratio categories

Table 5

Joint effect of physical activity and energy intake on T2D risk among all participants and stratified by BMI

	Energy Intake (kcal/day)					
	<1424.7		1424.7–1863.1		>1863.1	
Among all participants						
PA*	**RR**	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
High	1.00		1.20	0.90, 1.60	1.14	0.83, 1.58
Medium	1.51	1.146, 199	1.22	0.93, 1.59	1.75	1.33, 2.31
Low	1.39	1.02, 1.89	1.42	1.07, 1.89	1.96	1.44, 2.67
$P_{interaction}$ *0.02*+						
Among participants with a BMI<23 kg/m^2						
PA**	**RR**	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
High	1.00		1.06	0.52, 2.13	1.69	0.82, 3.47
Medium	1.32	0.68, 2.54	1.17	0.62, 2.18	1.67	0.86, 3.27
Low	1.04	0.50, 2.17	1.04	0.51, 2.09	1.82	0.84, 3.91
$P_{interaction}$ *0.91*+						
Among participants with a BMI>=23 kg/m^2						
PA**	**RR**	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
High	1.00		1.24	0.90, 1.71	1.10	0.77, 1.57
Medium	1.58	1.16, 2.14	1.27	0.95, 1.71	1.93	1.43, 2.61
Low	1.50	1.06, 2.11	1.60	1.17, 2.19	2.15	1.54, 3.01
$P_{interaction}$ *<0.01*+						

* Adjusted for age, WHR, BMI, alcohol consumption, smoking, education level, income level, occupation, and hypertension

** Adjusted for age, WHR, alcohol consumption, smoking, education level, income level, occupation, and hypertension

\+ The log-likelihood ratio test was used to test the interaction effect of the activity levels and energy intake on T2D risk.