

Physical activity and sedentary leisure time and their associations with BMI, waist circumference, and percentage body fat in 0.5 million adults: the China Kadoorie Biobank study^{1–3}

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ABSTRACT

Background: Few large studies in China have investigated total physical activity and sedentary leisure time and their associations with adiposity.

Objective: We investigated determinants of physical activity and sedentary leisure time and their associations with adiposity in China.

Design: A total of 466,605 generally healthy participants (age: 30–79 y, 60% female) in the China Kadoorie Biobank were included in this cross-sectional analysis. Self-reported information on a range of activities was collected by interviewer-administered questionnaire. Physical activity was calculated as metabolic equivalent task hours per day (MET-h/d) spent on work, transportation, housework, and nonsedentary recreation. Sedentary leisure time was quantified as hours per day. Adiposity measures included BMI, waist circumference, and percentage body fat (by bioimpedance analysis). Associations were estimated by linear and logistic regression.

Results: The mean physical activity was 22 MET-h/d, and the mean sedentary leisure time was 3.0 h/d. For each sex, physical activity was about one-third lower among professionals/administrators than among factory workers, with intermediate levels for other occupational categories. A 1-SD (14 MET-h/d) greater physical activity was associated with a 0.15-unit (95% CI: 0.14, 0.16) lower BMI (in kg/m²), a 0.58-cm (95% CI: 0.55, 0.61) smaller waist circumference, and 0.48 (95% CI: 0.45, 0.50) percentage points less body fat. In contrast, a 1-SD (1.5 h/d) greater sedentary leisure time was associated with a 0.19-unit higher BMI (95% CI: 0.18, 0.20), a 0.57-cm larger waist circumference (95% CI: 0.54, 0.59), and 0.44 (95% CI: 0.42, 0.46) percentage points more body fat. For any given physical activity level, greater sedentary leisure time was associated with a greater prevalence of increased BMI, as was lower physical activity for any given sedentary leisure time.

Conclusions: In adult Chinese, physical activity varies substantially by occupation, and lack of physical activity and excess sedentary leisure time are independently and jointly associated with greater adiposity. *Am J Clin Nutr* 2013;97:487–96.

INTRODUCTION

The diverse range of waking activities carried out by humans expends energy at greatly differing rates (1). For example, activities performed during work, transportation, housework, and leisure-time exercise (collectively termed here as “physical activity”) generally expend more energy per unit time than sedentary

recreational activities, such as television watching (1). There is evidence, mainly from studies in Western countries, that greater physical activity is associated with lower BMI (2), blood pressure (3), and risks of several chronic diseases and premature death (4, 5) and that, by contrast, more time spent on sedentary activities is associated with increases in BMI (6, 7) and an adverse metabolic profile (8, 9). However, relatively little is currently known about levels of either overall physical activity or sedentary leisure time in China (10), a country in which obesity is rapidly increasing (11), including how these levels vary by characteristics such as age, sex, geographical location, and socioeconomic factors and how strongly they are associated with measures of adiposity. Such associations could differ from those reported in Western countries (12–14), because the nature of both physical activity and sedentary leisure may generally be quite different in China than in the West. Furthermore, there appears to be

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a lack of information not only for China, but generally on the joint associations of physical activity and sedentary leisure time with excess adiposity.

To help fill these gaps, we analyzed baseline survey data in the China Kadoorie Biobank (CKB)—a prospective observational study of >0.5 million adults recruited from 10 diverse areas of China (15, 16). The aims of this study were to describe 1) the sex-specific levels of self-reported physical activity and sedentary leisure time in different age, regional, and socioeconomic groups; 2) the direction and strength of the associations of physical activity and sedentary leisure time with measures of general and central adiposity; and 3) the joint associations of physical activity and sedentary leisure time with the prevalence of increased BMI.

SUBJECTS AND METHODS

Participants

Detailed information about the CKB study rationale, design, survey methods, and participant characteristics was reported previously (15, 16). In brief, all men and women aged 35–74 y residing in 10 geographically defined areas (5 urban and 5 rural) of China, identified through public registry records, were eligible to take part in the study. The areas were selected to cover a wide spectra of risk exposures and disease patterns and for logistical convenience. The study population was not intended to be representative of China as a whole. Recruitment began in June 2004 and ended in July 2008. Invitation letters and study information leaflets were delivered door-to-door by local community leaders or health workers after extensive publicity campaigns. About 1 in 3 of the residents in the target age range (33% in rural areas, 27% in urban areas) agreed to participate. To encourage participation, we did not turn away those few individuals aged 30–34 or 75–79 y (16). In total, we recruited 512,891 participants (210,222 men and 302,669 women). For the current analyses, we excluded those who had a history of heart disease ($n = 15,472$), stroke ($n = 8884$), tuberculosis ($n = 7660$), chronic obstructive pulmonary disease ($n = 13,289$), and/or cancer ($n = 2577$); those who had both physical activity and sedentary leisure time equal to zero ($n = 81$); those who reported spending more than 20 h daily on all waking activities ($n = 813$); and those who gave implausible or conflicting answers to occupational and commuting-related questions (eg, reported not working but had nonzero commuting-related physical activity) ($n = 1418$). After these exclusions, 466,605 participants remained in the analyses.

The study was approved by the ethics committees of the University of Oxford and the Chinese Center for Disease Control and Prevention. In addition, ethical approval was obtained from the institutional research board at the local Center for Disease Control and Prevention in each of the 10 areas. Written informed consent was obtained from all participants.

Data collection

At the baseline survey, data collection was performed in temporary assessment clinics especially set up in the local communities for this study. An interviewer-administered electronic questionnaire was used to collect information on sociodemographic factors, lifestyle, and medical history.

The questions on physical activity and sedentary leisure time were adapted from validated questionnaires used in several other studies, including the European Prospective Investigation into Cancer and Nutrition (17) and the Shanghai Women's Health Study (18), with some additional modifications after a CKB pilot study. However, no separate validation of these questions was undertaken. Participants were asked about their usual type and duration of activities related to work, commuting, household chores, and leisure-time exercise during the past year (see Supplemental Material S1 under "Supplemental data" in the online issue for an English-language version of the questionnaire; the Chinese-language version is available on request). Time spent sleeping and on leisure-time sedentary ("sitting-down") activities—such as television watching, reading, playing cards or mahjong, and using a computer outside of work—was also requested. There were 2 sets of work- and commuting-related questions: 1 for farmers and 1 for nonfarmers. For a few questions related to weekly hours spent, some simple mental arithmetic was needed, and this was assisted, if necessary, by the interviewers.

To quantify the amount of physical activity, metabolic equivalent tasks (METs) from the 2011 update (1) of a major compendium of physical activities were used. The MET value for a particular type of physical activity represents the ratio of the energy expended per kilogram of body weight per hour during that activity to that expended when sitting quietly. Thus, 1 MET is equivalent to sitting quietly for 1 h. The number of hours spent per day participating in each activity was multiplied by the MET score for that activity, and the daily amount of physical activity was obtained by summing the MET-hours for activities related to occupation, commuting, housework, and nonsedentary leisure-time activities (see Supplemental Table S2 under "Supplemental data" in the online issue). For generic activities (eg, ball games), mean MET scores of specific activities under that genre were used. If an activity listed in the compendium is not widely performed in China (eg, paddleball), it was excluded from the calculation. To avoid overrepresentation of specific activities that happen to have multiple entries, mean MET scores were weighted by the reciprocal of the number of entries representing the same activity. For example, both codes 05030 ("cleaning, house or cabin, general, moderate effort") and code 05040 ["cleaning, general (straightening up, changing linen, carrying out trash, light effort)"] represented cleaning; thus, 50% weight was given to each of the 2 MET values represented by 05030 and 05040 when the mean MET score for household activity was calculated. Sedentary leisure time, which is not included in the physical activity calculation, was quantified as hours/d. Adjustment of physical activity and sedentary leisure time of every individual participant, either upward or downward to make up a daily self-reported activity time (including sleeping) of 24 h (13, 19), did not materially change any of the main results.

Body weight, standing height, waist circumference, and percentage body fat were measured by trained technicians while participants were wearing light clothes and no shoes. Standing height was measured to the nearest 0.1 cm by using a stadiometer, and waist circumference was measured with a soft nonstretchable tape midway between the lowest rib and the iliac crest, also to the nearest 0.1 cm. Weight and percentage body fat were measured by using a bioelectrical impedance device (TANITA-TBF-300GS; Tanita Corp). BMI was calculated as weight (in kg) divided by the square of standing height (in m).

Statistical analyses

Multiple linear regression models were used to estimate the mean levels of physical activity and sedentary leisure time after adjustment for age (in 5-y intervals), sex, and study area, where appropriate. *P* values for heterogeneity or for the linear trend of these adjusted means by sociodemographic factors were calculated by using a chi-square test.

Differences in, and 95% CIs for, BMI, waist circumference, and percentage body fat per 1-SD greater physical activity or sedentary leisure time were estimated by using multiple linear regression models. The analyses were stratified by sex and rural/urban residence, adjusting for age (in 5-y intervals), study area, education (4 categories: no formal education, primary school, middle or high school, or college or university), and annual household income (4 categories: <10,000, 10,000–19,999, 20,000–34,999, or ≥35,000 yuan). Physical activity and sedentary leisure time were included in the models simultaneously. The pooled overall associations were estimated by using inverse-variance weighting. Heterogeneity was assessed by chi-square statistics, *P* values from Cochran *Q* tests, and *I*² statistics (ie, the variation in pooled estimates accounted for by heterogeneity rather than by chance). Weighted least-squares regression was used to assess whether the assumption of linearity of adjusted mean values of anthropometric measurements (dependent variable) by fifths of physical activity or sedentary leisure time (independent variable) was reasonably met. The weights used were the inverse variances of the adjusted means, and the goodness-of-fit *R*² statistics are reported.

To investigate the joint associations of physical activity and sedentary leisure time with excess adiposity, participants were classified into 3 groups by sex-specific tertiles of physical activity and 5 groups according to sedentary leisure time (<1.5, 1.5–2.4, 2.5–3.4, 3.5–4.4, or ≥4.5 h/d). The adjusted prevalence of BMI (in kg/m²) ≥28, a cutoff point often used to define obesity in China (20–22), for each of these 15 groups was calculated by using logistic regression, with adjustment for age, study area, education, and annual household income. SAS 9.2 (SAS Institute Inc) was used for all the statistical analyses.

RESULTS

Of the 466,605 participants (mean age: 50.8 y) included in the analyses, 265,904 (57%) lived in rural areas, 365,269 (78%) were aged 40–69 y at survey, and 277,958 (60%) were women (**Table 1**). For both sexes, the distribution of physical activity level was somewhat right-skewed. In women, the median (IQR) was 17.4 (11.2–28.9) MET-h/d, and the mean ± SD was 20.9 ± 12.8, divided between 10.9 ± 12.5 for occupational activities and 10.0 ± 4.6 for nonoccupational activities. In men, the median (IQR) was 19.9 (10.8–33.2), and the mean ± SD was 22.8 ± 15.1, representing the sum of 17.3 ± 14.9 for occupational activities and 5.5 ± 4.1 for other activities. There was a higher proportion of men than women in both the least active (<8 MET-h/d; 17.7% compared with 9.5%) and most active (≥40 MET-h/d; 14.4% compared with 9.7%) groups. In both men and women, the distribution of sedentary leisure time was roughly normal, although with strong digit preference for integer values. About 70% of both sexes had between 1.0 and 4.0 h of sedentary leisure time per day, but the mean was slightly higher in men than in women (3.1 compared with 2.9 h/d). Although women had a much higher

TABLE 1

Main characteristics of 466,605 participants with no history of major disease¹

Characteristics	Men (n = 188,647)	Women (n = 277,958)
Age (%)		
30–39 y	15.2	16.9
40–49 y	30.0	32.2
50–59 y	30.6	30.8
60–69 y	17.8	15.2
70–79 y	6.5	4.8
Age (y)	51.5 ± 10.7 ²	50.3 ± 10.3
Residence (%)		
Urban	42.6	43.3
Rural	57.4	56.7
Physical activity (%) ³		
<8 MET-h/d	17.7	9.5
8–15.9 MET-h/d	22.4	35.8
16–23.9 MET-h/d	17.4	20.6
24–31.9 MET-h/d	15.3	14.0
32–39.9 MET-h/d	12.9	10.3
≥40 MET-h/d	14.4	9.7
Physical activity (MET-h/d) ³	22.8 ± 15.1	20.9 ± 12.8
Sedentary leisure time (%) ³		
<1.5 h/d	12.9	17.1
1.5–2.4 h/d	23.2	24.1
2.5–3.4 h/d	30.6	27.0
3.5–4.4 h/d	18.6	17.6
≥4.5 h/d	14.7	14.1
Sedentary leisure time (h/d) ³	3.1 ± 1.5	2.9 ± 1.5
Adiposity measurements		
BMI (kg/m ²)	23.4 ± 3.2	23.8 ± 3.4
Waist circumference (cm)	81.9 ± 9.7	78.8 ± 9.4
Body fat (%)	22.0 ± 6.2	32.0 ± 7.1

¹ MET-h, metabolic equivalent task hours.

² Mean ± SD (all such values).

³ Self-reported.

mean estimated percentage body fat (32.0% compared with 22.0%) and a slightly higher mean BMI (23.8 compared with 23.4) than did men, their mean waist circumference was lower (78.8 compared with 81.9 cm) (Table 1).

Physical activity and sedentary leisure time were inversely related to each other in both sexes (*see* Supplemental Figure S3 under “Supplemental data” in the online issue). On average, each extra 1 h/d of sedentary leisure time corresponded to 2.0 MET-h/d less physical activity in men and 1.6 MET-h/d less physical activity in women.

Across the full age range and in both sexes, mean physical activity was lower at older ages, and it was less than half as great at 70–79 y as at 30–39 y (**Table 2**). In men, mean physical activity in those aged 60–69 y (15.6 MET-h/d) was more than one-third lower than that in those aged 50–59 y (23.4 MET-h/d). In women, there was also a particularly large difference between those aged 50–59 y (19.1 MET-h/d) and those aged 40–49 y (24.6 MET-h/d). In contrast, mean sedentary leisure time differed little by age.

As compared with the urban residents, those who lived in the rural areas on average had ~20% greater physical activity and ~5% less sedentary leisure time (Table 2). In both sexes, the average physical activity was at least twice as great in the most active area (Zhejiang, a midlatitude coastal rural area) as in the least active area (Haikou, a southern coastal urban area) (*see*

TABLE 2Self-reported physical activity and sedentary leisure time by sociodemographic variables among 466,605 participants with no history of major disease¹

Sociodemographic variable	Men			Women		
	No.	Physical activity	Sedentary leisure time	No.	Physical activity	Sedentary leisure time
		MET-h/d	h/d		MET-h/d	h/d
Age						
30–39 y	28,694	27.2 ± 13.3 ²	3.1 ± 1.4	47,033	25.0 ± 10.8	3.0 ± 1.4
40–49 y	56,513	26.8 ± 13.3	3.1 ± 1.4	89,625	24.6 ± 10.8	2.9 ± 1.4
50–59 y	57,721	23.4 ± 13.3	3.0 ± 1.4	85,692	19.1 ± 10.8	2.9 ± 1.4
60–69 y	33,512	15.6 ± 13.3	3.1 ± 1.4	42,206	15.0 ± 10.8	2.9 ± 1.4
70–79 y	12,207	11.3 ± 13.3	3.2 ± 1.4	13,402	11.6 ± 10.8	2.9 ± 1.4
Residence						
Rural	108,347	24.7 ± 14.0	3.0 ± 1.5	157,557	22.5 ± 11.8	2.9 ± 1.5
Urban	80,300	20.3 ± 14.0	3.2 ± 1.5	120,401	18.7 ± 11.8	3.0 ± 1.5
Occupation						
Farmer	84,124	24.3 ± 15.9	2.9 ± 1.8	116,776	24.0 ± 11.5	2.7 ± 1.8
Factory worker	38,389	30.0 ± 14.6	2.9 ± 1.7	31,190	31.3 ± 10.3	2.5 ± 1.6
Sales, self-employed, and other occupations	19,450	25.4 ± 13.0	3.1 ± 1.5	24,826	28.5 ± 9.7	2.7 ± 1.5
Professional and administrator	13,839	19.8 ± 12.9	3.1 ± 1.5	11,304	21.1 ± 9.5	2.7 ± 1.4
Not in paid employment	32,845	10.3 ± 14.9	3.8 ± 1.7	93,862	11.5 ± 10.8	3.5 ± 1.7
Retired	23,286	12.3 ± 15.2	3.8 ± 1.7	44,378	13.1 ± 11.6	3.7 ± 1.8
Homemakers	4,379	7.9 ± 12.6	3.6 ± 1.4	42,145	10.8 ± 9.7	3.2 ± 1.5
Unemployed	5,180	6.0 ± 12.6	4.0 ± 1.4	7,339	9.7 ± 9.5	3.7 ± 1.4
Education						
No formal education	16,387	24.7 ± 14.6	2.8 ± 1.6	70,147	21.6 ± 13.0	2.6 ± 1.7
Primary school or lower	62,101	24.0 ± 14.4	3.0 ± 1.5	87,196	21.4 ± 11.2	2.9 ± 1.5
Middle or high school	95,869	22.3 ± 14.2	3.2 ± 1.5	108,625	20.2 ± 12.2	3.2 ± 1.6
College or university	14,290	19.2 ± 14.2	3.1 ± 1.5	11,990	19.3 ± 11.5	3.0 ± 1.5
Annual household income						
<10,000 yuan	48,718	23.0 ± 15.4	2.9 ± 1.6	82,776	20.4 ± 12.4	2.8 ± 1.6
10,000–19,999 yuan	53,248	23.3 ± 13.5	3.1 ± 1.4	81,908	21.0 ± 10.9	3.0 ± 1.4
20,000–34,999 yuan	48,151	23.4 ± 14.0	3.1 ± 1.5	67,527	21.7 ± 11.4	3.0 ± 1.5
≥35,000 yuan	38,530	21.2 ± 14.4	3.2 ± 1.5	45,747	20.4 ± 11.6	3.1 ± 1.5

¹ MET-h, metabolic equivalent task hours.² Mean ± SD (all such values). Adjusted means were calculated by using general linear regression models with adjustment for age (in 5-y intervals) and study area, where appropriate. SEs for each mean value in this table can be calculated as SD/\sqrt{n} , where n is the number of participants in that group. All P -heterogeneity and P -trend across subgroups <0.0001.

Supplemental Figure S4 under “Supplemental data” in the online issue). There was, similarly, at least 2-fold variation in sedentary leisure time across the 10 areas for each sex, with the lowest average levels in Zhejiang and the highest in Sichuan (a midlatitude inland rural area).

Factory workers had the highest average level of physical activity (men: 30.0 MET-h/d; women: 31.3 MET-h/d), which in both sexes was ~50% greater than that for professionals and administrators, whereas farmers and other workers had intermediate levels (Table 2). However, for those not in paid employment (eg, retired, homemaker, or unemployed), average physical activity levels (10.3 MET-h/d in men and 11.5 MET-h/d in women) were only half as great as those for professionals and administrators and only one-third as much as for factory workers. For both sexes, the mean (±SD) physical activity level (in MET-h/d) was higher among those who were retired (men: 12.3 ± 15.2; women: 13.1 ± 11.6) than in homemakers (men: 7.9 ± 12.6; women: 10.8 ± 9.7) or in those who were unemployed (men: 6.0 ± 12.6; women: 9.7 ± 9.5). In contrast, those not in paid employment reported on average nearly 1 extra hour per day of sedentary leisure time than did those in paid occupations. The mean sedentary leisure time (in h/d) was somewhat less in those who were homemakers

(men: 3.6 ± 1.4; women: 3.2 ± 1.5) than in those who were retired (men: 3.8 ± 1.7; women: 3.7 ± 1.8) or unemployed (men: 4.0 ± 1.4; women: 3.7 ± 1.4).

In both sexes, there was a tendency toward lower levels of physical activity at higher education levels (P -trend < 0.0001): in men, for example, the mean MET-h/d was nearly 30% higher in those with no formal education than in those with a college or university education (Table 2). However, no clear evidence of trend with educational level for sedentary leisure time was observed, although those with no formal education on average generally had ~10–20% less sedentary leisure time than did those in the other groups (P -heterogeneity < 0.0001). In contrast, sedentary leisure time was positively (though only weakly) associated with annual household income level (P -trend < 0.0001), but physical activity appeared to be slightly higher at moderate income levels.

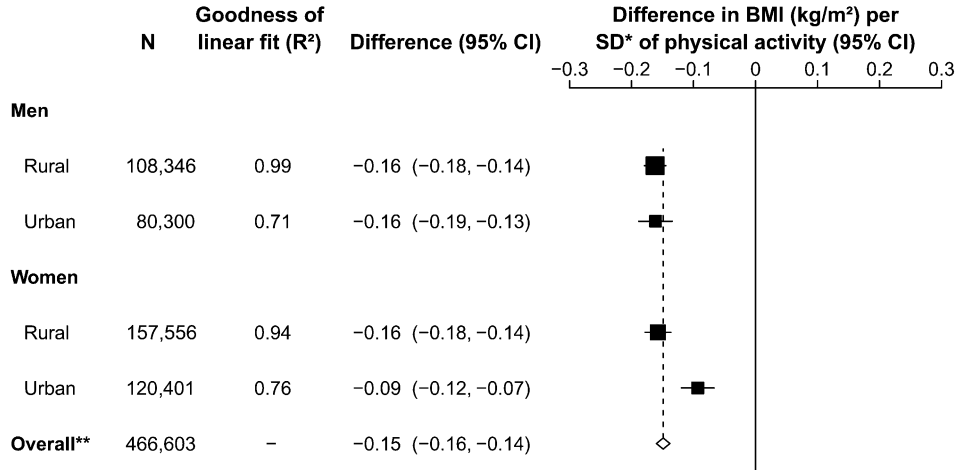
In urban and rural men and women, BMI, waist circumference, and percentage body fat were each associated inversely with physical activity level but positively with sedentary leisure time (Figures 1–3). All of the underlying associations were either moderately or highly linear (goodness-of-linear-fit R^2 between 0.71 and 1.00). Overall, 1-SD extra physical activity (14 MET-h/d)

was associated with a 0.15-unit (95% CI: 0.14, 0.16) lower BMI, a 0.58-cm (0.55, 0.61) smaller waist circumference, and 0.48 (0.45, 0.50) percentage points less body fat. In contrast, each additional 1 SD of sedentary leisure time (1.5 h/d) was associated with a 0.19-unit (0.18, 0.20) higher BMI, a 0.57-cm (0.54, 0.59) larger waist circumference, and 0.44 (0.42, 0.46) percentage points more body fat. The associations across the different sex and rural/urban groups showed a qualitatively similar pattern, but they were quantitatively heterogeneous (chi-square between 20.8 and 137.8, I^2 between 85.6% and 97.8%, all P -heterogeneity < 0.0001),

although the patterns of heterogeneity were not entirely consistent. For example, the association of physical activity with BMI was relatively weak in urban women, and the association with waist circumference was relatively strong in urban men. For sedentary leisure time, however, its associations with BMI and percentage body fat were somewhat weaker in urban men than in the other 3 groups, but its association with waist circumference was rather consistent among rural and urban men and women.

The joint associations of physical activity and sedentary leisure time with prevalence of BMI ≥ 28 are shown in **Figure 4**.

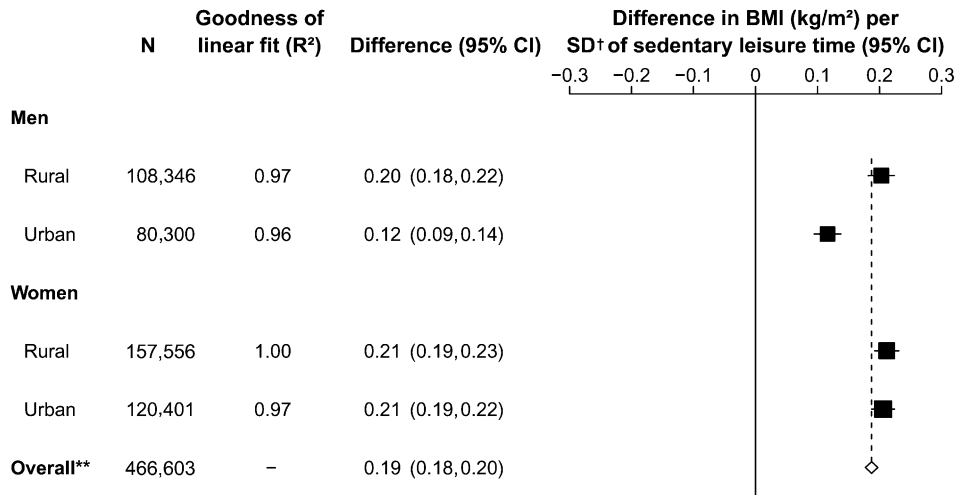
A Physical activity



$I^2 = 85.6\%$, $\chi^2 = 20.8$ (d.f.= 3), P for heterogeneity < 0.0001

*SD of physical activity = 14 MET-hrs/day

B Sedentary leisure time

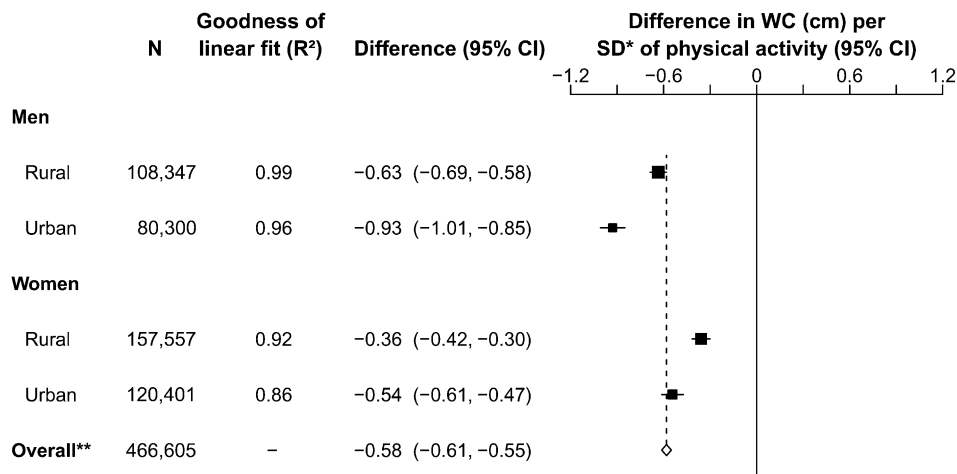


$I^2 = 94.5\%$, $\chi^2 = 54.1$ (d.f.= 3), P for heterogeneity < 0.0001

†SD of sedentary leisure time = 1.5 hrs/day

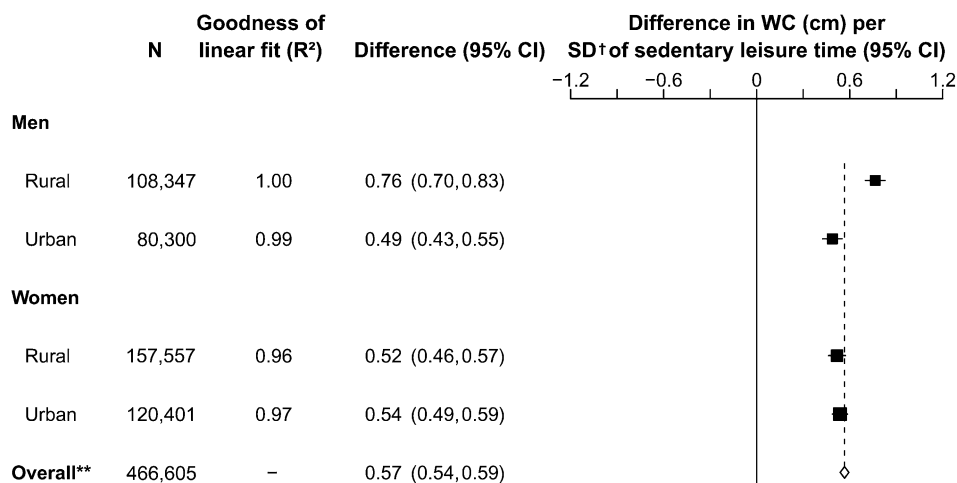
** Inverse-variance-weighted average

FIGURE 1. Differences in BMI associated with a 1-SD greater self-reported physical activity (A) or sedentary leisure time (B) among 466,605 participants with no history of major disease (excluding 2 participants with missing values on BMI). Each closed square represents the point estimate of the regression coefficient, and the horizontal bar represents its 95% CI, which was estimated by using multiple linear regression models. Adjustment was made for age (in 5-y intervals), study area, education, and annual household income. The size of the square is proportional to the inverse variance. The overall point estimates, calculated by using inverse-variance weighting, are represented by dotted lines and open diamonds; the width of the diamonds indicates the 95% CI. MET, metabolic equivalent task.

A Physical activity

$I^2 = 97.8\%$, $\chi^2 = 137.8$ (d.f.= 3), P for heterogeneity < 0.0001

*SD of physical activity = 14 MET-hrs/day

B Sedentary leisure time

$I^2 = 93.7\%$, $\chi^2 = 47.9$ (d.f.= 3), P for heterogeneity < 0.0001

†SD of sedentary leisure time = 1.5 hrs/day

** Inverse-variance-weighted average

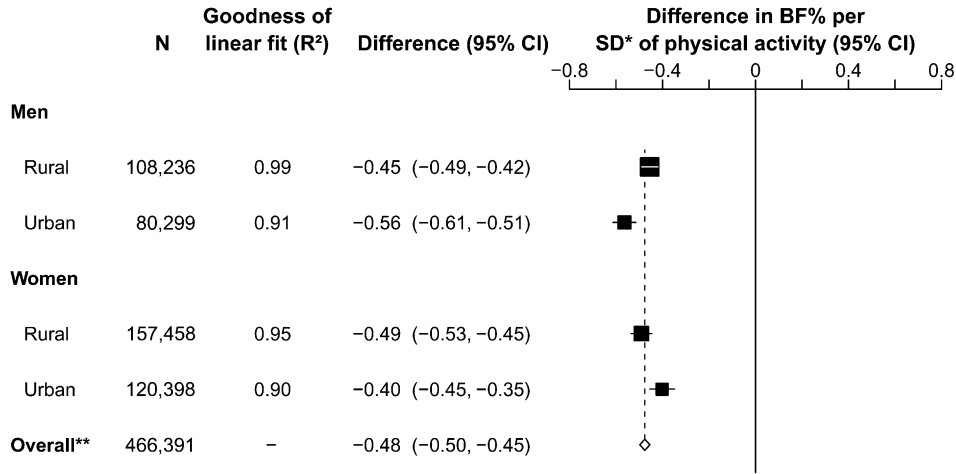
FIGURE 2. Difference in waist circumference associated with a 1-SD greater self-reported physical activity (A) or sedentary leisure time (B) among 466,605 participants with no history of major disease. Each closed square represents the point estimate of the regression coefficient, and the horizontal bar represents its 95% CI, which was estimated by using multiple linear regression models. Adjustment was made for age (in 5-y intervals), study area, education, and annual household income. The size of the square is proportional to the inverse variance. The overall point estimates, calculated by using inverse-variance weighting, are represented by dotted lines and open diamonds; the width of the diamonds indicates the 95% CI. MET, metabolic equivalent task; WC, waist circumference.

For both sexes, the prevalence was positively associated with sedentary leisure time in each stratum of physical activity; similarly, at any given level of sedentary leisure time, the prevalence was higher in those who were less physically active. In men, 6.0% of those who had a high level of physical activity (>28.8 MET-h/d) and little sedentary leisure time (<1.5 h/d) had a BMI ≥ 28 , in contrast with 12.1% of those who had a low level of physical activity (<17.8 MET-h/d) and much sedentary leisure time (>4.5 h/d). In women, the corresponding prevalence rates were 8.9% and 15.2%.

DISCUSSION

In this first ever large epidemiologic study to simultaneously consider physical activity and sedentary leisure time in China, self-reported physical activity and, to a lesser extent, sedentary leisure time showed marked sociodemographic variations. For example, the average physical activity was 3 times higher in factory workers than in those not in paid employment and was at least twice as high in young as in old adults. Greater physical activity and less sedentary leisure time were each independently associated with less adiposity. On average, 14 MET-h/d extra

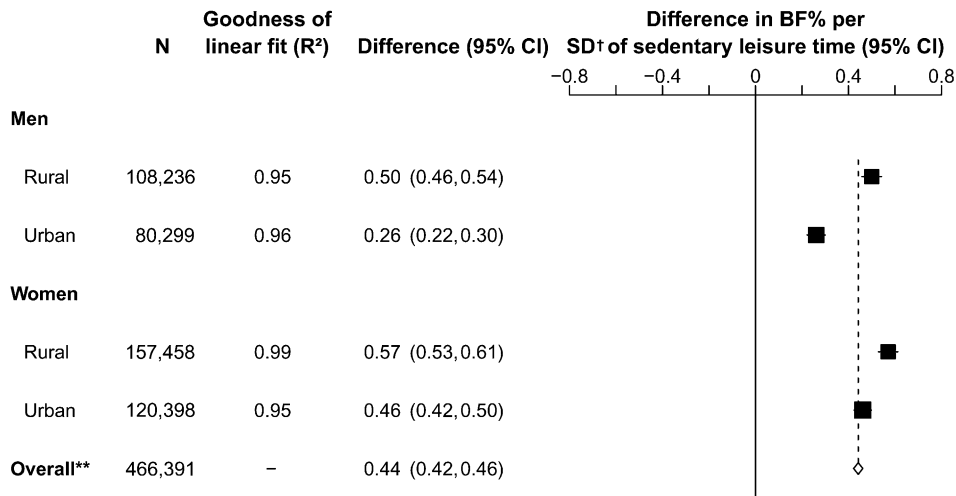
A Physical activity



$I^2 = 86.3\%$, $\chi^2 = 22.0$ (d.f.= 3), P for heterogeneity < 0.0001

*SD of physical activity = 14 MET-hrs/day

B Sedentary leisure time



$I^2 = 97.7\%$, $\chi^2 = 128.8$ (d.f.= 3), P for heterogeneity < 0.0001

†SD of sedentary leisure time = 1.5 hrs/day

** Inverse-variance-weighted average

FIGURE 3. Difference in percentage body fat associated with a 1-SD greater self-reported physical activity (A) or sedentary leisure time (B) among 466,605 participants with no history of major disease (excluding 214 participants with missing values on percentage body fat). Each closed square represents the point estimate of the regression coefficient, and the horizontal bar represents its 95% CI, which was estimated by using multiple linear regression models. Adjustment was made for age (in 5-y intervals), study area, education, and annual household income. The size of the square is proportional to the inverse variance. The overall point estimates, calculated by using inverse-variance weighting, are represented by dotted lines and open diamonds; the width of the diamonds indicates the 95% CI. BF%, body fat percentage; MET, metabolic equivalent task.

physical activity was associated with a 0.15-unit lower BMI, a 0.58-cm smaller waist circumference, and 0.48 percentage points less body fat, whereas 1.5 h/d extra sedentary leisure time was associated with a 0.19-unit higher BMI, a 0.57-cm larger waist circumference, and 0.44 percentage points more body fat.

Accurate assessment of habitual levels of physical and sedentary behaviors is a prerequisite for studies of physical activity and health. However, in very large epidemiologic studies it is impractical to obtain objective measures of usual activity level. In

our study, we used an interviewer-administered electronic questionnaire with a moderately large number of questions about frequency, duration, and type (intensity) of physical activity in several different domains. For farmers, the questions about agriculture-related activities were specifically tailored to the nature of their work. However, measurement error may still exist because of subjective reporting, genuine fluctuations of habitual activity levels with time, omission of some activities from the study questionnaire (in particular, low-intensity activities), and the

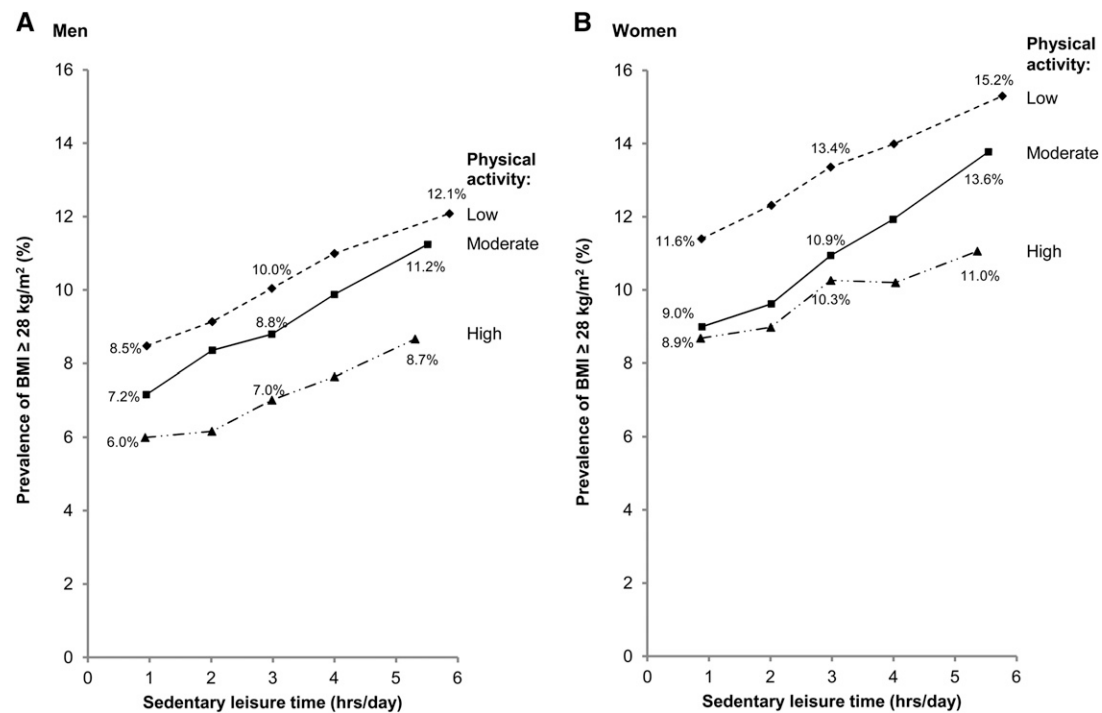


FIGURE 4. Prevalence of BMI (in kg/m²) ≥ 28 by self-reported sedentary leisure time—in low, moderate, and high levels of self-reported physical activity—among 466,605 men (A) and women (B) with no history of major disease. The adjusted prevalence was calculated by using logistic regression models with adjustment for age (in 5-y intervals), study area, education, and annual household income. In men, the cutoff values for defining low, moderate, and high levels of physical activity were 17.8 and 28.8 MET-h/d, whereas in women, the corresponding cutoff values were 12.6 and 24.4 MET-h/d. MET, metabolic equivalent task.

same MET value being assigned to the same activity regardless of between-person differences in intensity of performance. The extent to which our findings could be confounded by the other side of energy balance (ie, total energy intake) is unknown, because total energy intake was not assessed in our study. However, in a supplementary analysis with additional adjustment for dietary patterns, the findings were not materially different. It is possible that different levels of measurement error and uncontrolled confounding contributed to the heterogeneity in the strength of association between areas and between the sexes. Furthermore, the cross-sectional nature of study means that we cannot rule out the possibility that differences in physical activity and sedentary leisure time are consequences, rather than causes, of greater adiposity.

An inverse association of physical activity level with age has also been observed in other, generally Western, populations (23). Previous studies reporting a positive association between educational level and physical activity have largely focused on leisure-time physical activity only (23). In our study, the inverse association between levels of physical activity and level of education was mainly driven by occupational physical activity, presumably because most sedentary jobs require more education. Indeed, in a supplementary analysis with additional adjustment for occupation, the differences in physical activity between people at different educational levels were reduced by more than half (data not shown).

The rural-urban differences in physical activity and sedentary leisure time observed in our study are consistent with the previously noted pattern that urbanization is a major predictor of low physical activity and increased sedentary behaviors in China (24). Moreover, the observed regional variations in physical activity and sedentary leisure time might in part also reflect differences in

the stages of economic development and urbanization as well as the effect of traditional lifestyles. For instance, the average physical activity level among participants in the urban area of Suzhou, which consisted of mainly people from rural communities that were integrated into the urban area only a decade ago, was much higher than in the other 4 more established urban areas and very close to the level among participants from the rural area in neighboring Zhejiang province (*see* Supplemental Figure S4 under “Supplemental data” in the online issue).

A large number of studies, mainly in Western populations, have investigated the association between physical activity and adiposity, but many have assessed leisure-time physical activity only, and relatively few have included physical activity from other domains (25–27). However, information from other domains may be crucial for China in particular because the proportion of adult Chinese participating in leisure-time physical activity, as observed in this and other previous large studies (24, 28), was rather low ($\sim 20\%$), and much lower than that seen in Western populations (typically $\sim 70\%$) (29, 30). Furthermore, China’s obesity epidemic might recently have been driven more by decreasing levels of occupational and commuting-related physical activity than by changes in leisure-time physical activity (11).

Because of methodologic differences, the strength of associations with adiposity observed in our study cannot be compared directly with those previously observed. In a cross-sectional analysis of data on 405,819 participants in the European Prospective Investigation into Cancer and Nutrition–Physical Activity, Nutrition, Alcohol, Cessation of smoking, Eating out of home And obesity study, one-level higher physical activity (such as from inactive to moderately inactive or from moderately active to active) was

associated with a 0.25-unit lower BMI and a 1.0-cm smaller waist circumference (12). In a cohort study of >9000 adult Canadians, each 1000 MET-min/d increase in physical activity was associated with a decrease in BMI of ~0.4 during 5 y of follow-up (13). In a study of ~50,000 US nurses (6), 2 h/d of television viewing was associated with a 23% relative increase in the prevalence of BMI \geq 30. In a cross-sectional study of a few hundred Australians, long periods of sitting time were associated with a >60% higher risk of being overweight (14).

Sedentary leisure time was previously reported to be associated not only with obesity but also with a range of other metabolic disorders, such as diabetes and metabolic syndrome (6, 31, 32), although the mechanisms are not fully understood (33). More time spent on sedentary leisure means less time available for physical activity, but this seems unlikely to explain the positive association between sedentary leisure time and adiposity because, in our analyses, physical activity level was adjusted for (although there may have been some residual confounding by low-intensity physical activity). An increased energy intake might be one of the main underlying reasons for this positive association, because television watching, a major sedentary activity, is often accompanied by snacking (34), and watching television at mealtime might lead to subconscious overconsumption (35). In addition, participants who spend more time watching television might tend to have unhealthy dietary patterns as a consequence of increased exposure to food advertising (6).

The observed associations of physical activity and sedentary leisure time with adiposity were, although highly statistically significant, not large in magnitude. However, if causal, even these moderately weak associations could be relevant to China's public health. For example, if an extra 14 MET-h/d really does lower BMI by an average of 0.15 units, it could be expected that stroke mortality in middle and early old age might consequently be reduced by 1–2% in China (36). Because ~1.6 million people die of stroke each year in China, many in middle and early old age (37), even this small percentage reduction in stroke mortality would represent a significant public health gain.

In conclusion, our data show that lack of overall physical activity and excess sedentary leisure time are both independently and jointly associated with greater adiposity. These cross-sectional associations suggest that studies of the effects of physical activity on health should collect information on a wide range of physical and sedentary activities, and, once collected, associations with physical and sedentary activities should be considered separately and not simply be combined.

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