Physical Activity and Television Viewing in Relation to Risk of Undiagnosed Abnormal Glucose Metabolism in Adults

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OBJECTIVE — The goal of this study was to assess the associations of physical activity time and television (TV) time with risk of "undiagnosed" abnormal glucose metabolism in Australian adults.

RESEARCH DESIGN AND METHODS — This population-based cross-sectional study using a stratified cluster design involving 42 randomly selected Census Collector Districts across Australia included 8,299 adults aged 25 years or older who were free from new type 2 diabetes and self-reported ischemic disease and did not take lipid-lowering or antihypertensive drugs. Abnormal glucose metabolism (impaired fasting glycemia [IFG], impaired glucose tolerance [IGT], or new type 2 diabetes) was based on an oral glucose tolerance test. Self-reported physical activity time and TV time (previous week) were assessed using interviewer-administered questionnaires.

RESULTS — After adjustment for known confounders and TV time, the odds ratio (OR) of having abnormal glucose metabolism was 0.62 (95% CI 0.41–0.96) in men and 0.71 (0.50–1.00) in women for those engaged in physical activity ≥2.5 h/week compared with those who were sedentary (0 h/week). The ORs of having abnormal glucose metabolism were 1.16 (0.79–1.70) in men and 1.49 (1.12–1.99) in women who watched TV >14 h/week compared with those who watched ≤7.0 h/week. Higher TV viewing (>14 h/week) was also associated with an increased risk of new type 2 diabetes in men and women and IGT in women compared with those watching <14 h/week. Total physical activity of ≥2.5 h/week was associated with a reduced risk of IFG, IGT, and new type 2 diabetes in both sexes; however, only the association with IGT in women was statistically significant.

CONCLUSIONS — These findings suggest a protective effect of physical activity and a deleterious effect of TV time on the risk of abnormal glucose metabolism in adults. Population strategies to reduce risk of abnormal glucose metabolism should focus on reducing sedentary behaviors such as TV time, as well as increasing physical activity.

Diabetes Care 27:2603–2609, 2004

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In Australia and elsewhere, increases in obesity (1) and declines in adult participation in physical activity have been reported (2,3). Physical activities and sedentary behaviors are two broad classes of behavior that may be clearly distinguished from each other and that have different patterns of determinants (4,5). They may also have independent effects on total energy expenditure, on weight gain, and on underlying metabolic parameters (6,7). In recent times, the importance of regular physical activity has been highlighted in public health guidelines adopted by several health agencies (8), whereby adults should engage in moderate-intensity physical activity for at least 30 min on ≥5 days/week or engage in vigorous physical activity ≥3 days/week for ≥20 min/occasion.

Prospective studies have consistently shown that physical activity reduces the risk of diabetes, with a recent meta-analysis of 23 studies showing that sedentary individuals have a 1.31–1.45 increase in risk compared with active individuals (9). Some population-based cross-sectional studies have also demonstrated an inverse association between physical activity and risk of impaired glucose tolerance (IGT) (10,11). However, most of this evidence has come from non-white populations (10–12). More recent studies in white populations have been limited to middle-aged or elderly subjects (13,14). Information on the associations of physical activity with categories of abnormal glucose metabolism (impaired fasting glycemia [IFG], IGT, and undiagnosed new type 2 diabetes) is needed from larger population-based studies.

Sedentary behaviors, as represented by television (TV) watching, have been linked to obesity and cardiovascular disease risk factors in children (15,16) and adults (17,18). Two longitudinal studies conducted in the U.S. (6,7) have reported an inverse relationship between risk of type 2 diabetes and physical activity and a positive association with TV time. In those studies, type 2 diabetes was, how-

ever, self-reported. There have been no large population-based studies that have simultaneously assessed the relationships between physical activity, TV time, and objectively measured precursors of type 2 diabetes (IFG, IGT, and new type 2 diabetes).

The recent Australian Diabetes, Obesity, and Lifestyle Study (AusDiab) included oral glucose tolerance tests (OGTTs), and this analysis evaluates the cross-sectional associations of physical activity and TV time with the presence of objectively determined indexes of abnormal glucose metabolism (IFG, IGT, new type 2 diabetes).

RESEARCH DESIGN AND METHODS — AusDiab was conducted during 1999–2000 and studied a representative national sample of adults aged 25 years and older from the six states of Australia and the Northern Territory. The methods and major findings have been reported (1,19,20). The sample of 11,247 adults represented 55% of those completing the initial household interview. The present analyses use data from the 8,299 adults who were not pregnant and did not have health conditions that may affect physical activity habits, including those with clinically diagnosed type 2 diabetes and those taking prescribed medication for hypertension or dyslipidemia. Those who reported a history of angina, stroke, or myocardial infarction were also excluded.

Measures and data management
Participants attended the local survey center after an overnight fast (minimum of 8 h). An OGTT was performed and interpreted using World Health Organization specifications (21). Blood specimens were centrifuged and transported daily to the central laboratory. Plasma glucose levels were determined using an Olympus AU600 automated analyzer. Abnormal glucose metabolism was defined as having IFG, IGT, or new type 2 diabetes.

Waist circumference was measured using a steel measuring tape, with duplicate measurements made halfway between the lower border of the ribs and the iliac crest on a horizontal plane. The mean of these measures was used in the analyses. Obesity was defined as a waist circumference of $\geq$102.0 cm in men and $\geq$88.0 cm in women (22). Height without shoes was measured to the nearest 0.5 cm

using a stadiometer. Weight was measured with the subject wearing light clothes on a mechanical beam balance and was recorded to the nearest 0.1 kg. BMI was calculated as weight (kilograms)/ height (meters squared). Those with a BMI of 25.0–29.9 kg/m^2 were classified as overweight, whereas those with a BMI of $\geq$30.0 kg/m^2 were classified as obese (22).

Demographic attributes, physical activity, and TV time were assessed using an interviewer-administered questionnaire. Participants reported their age, family history of diabetes (mother/father), current cigarette smoking status, and level of educational attainment (categorized as primary/never attended, some secondary, completed secondary, and university/ further education).

Participants self-reported their frequency and duration of physical activity during the previous week using the Active Australia Survey questionnaire (23). Physical activity consisted of walking for recreation or transport, "other" moderate activity, and vigorous activity. These questions have been found to provide reliable and valid estimates of adult physical activity (23). Total physical activity time for the previous week was calculated as the sum of the time spent walking (if continuous and $\geq$10 min) or performing moderate physical activity plus double the time spent in vigorous physical activity. Australian public health guidelines (24) recommend a total physical activity time of at least 150 min/week. Because vigorous-intensity activity is commonly considered to contribute additional health benefits, we analyzed associations between abnormal glucose metabolism and walking plus moderate physical activity time (excluding those who reported any vigorous activity), and total physical activity time (including those who reported >0 min of vigorous activity) was assessed. Total physical activity categories were created to reflect current recommendations—those meeting the public health physical activity guidelines ($\geq$2.5 h/week), those engaged in some physical activity but not meeting the public health guidelines (>0–2.49 h/week), and those reporting no activity (sedentary; 0 h/week). Walking plus moderate physical activity only was categorized according to those meeting the public health guidelines ($\geq$2.5 h/week) and those not meeting the guidelines.

Participants also self-reported the total time they spent watching TV or videos in the previous week. This measure provides a reliable and valid estimate of TV time among adults (5). The average hours watching TV per week was used to create three categories of TV viewing (0–7, 7.01–14, and >14 h/week).

A self-administered validated food frequency questionnaire developed by the Anti-Cancer Council of Victoria (25) was used to assess nutrient intakes. Calculation of nutrient intake was achieved by multiplying the frequency of food consumption by standard portion weights to obtain weight of food consumed per day. These were then converted to nutrient intakes based on the NUTTAB95 nutrient composition data (26).

Statistical analysis
All analyses were conducted using Stata Statistical Software Release 8.0 (27) survey commands for analyzing complex survey data. Sample weights based on the 1998 estimated residential Australian were used to account for clustering and stratification in the survey design and for nonresponse. Odds ratios (ORs) (with 95% CI) for binary outcomes were estimated using forced entry logistic regression models. Regression models included the TV and physical activity categories and were adjusted for age, education level, cigarette smoking, parental history of diabetes, dietary covariates, and waist circumference. Associations of both total physical activity and TV viewing with IFG, IGT, and new type 2 diabetes were determined using separate models with the ORs calculated for the highest category of total physical activity ($\geq$2.5 h/week) and TV viewing (>14 h/week).

RESULTS — Table 1 shows the demographic characteristics according to the mean hours spent in total physical activity time and the mean hours spent watching TV. Participants who spent more time engaged in physical activity were younger, were more likely to have completed university/further education, and were less likely to smoke cigarettes, be overweight, or have abnormal glucose metabolism. Those reporting more physical activity time had a lower intake of total fat and saturated fat and had a higher intake of carbohydrates, sugars, fiber, and alcohol. Participants who spent more time watching TV were older, were less likely to have

Table 1—*Selected characteristics* according to categories of total physical activity time and television time in 8,299 adults aged 25 years or older in the AusDiab study

	Total physical activity (h/week)			Television viewing (h/week)		
	0	0.01–2.49	≥2.5	0–7	7.01–14	>14
n	1,323	2,545	4,431	2,917	2,705	2,677
Men	541	968	2,192	1,106	1,257	1,338
Age (years)	46.0 (44.0–47.9)	44.6 (43.3–45.9)	43.5 (42.2–44.9)†	42.7 (41.5–43.9)	44.3 (42.9–45.7)	46.1 (44.1–48.1)†
Parental history of diabetes	19.5 (245)	19.4 (482)	16.8 (776)	17.3 (525)	17.4 (480)	19.6 (498)
Current smoker	21.6 (285)	16.1 (423)	17.0 (687)†	14.1 (407)	16.7 (404)	22.1 (584)†
University/further education	35.2 (412)	47.1 (1,031)	46.8 (1,955)†	50.8 (1,412)	48.1 (1,147)	35.3 (839)†
BMI (kg/m^2)	27.0 (26.4–27.6)	26.1 (25.7–26.5)	26.0 (25.6–26.3)†	25.4 (25.2–25.7)	26.0 (25.6–26.5)	27.2 (26.8–27.5)†
Waist (cm)	90.5 (88.7–92.3)	87.9 (86.5–89.3)	88.1 (86.9–89.3)†	85.3 (84.5–86.1)	88.6 (87.1–90.1)	91.9 (90.9–93.0)†
Overweight (waist)	58.0 (866)	51.2 (1,460)	48.5 (2,323)†	44.1 (1,439)	50.1 (1,507)	59.6 (1,703)†
Abnormal glucose metabolism	21.7 (308)	18.1 (525)	13.8 (722)†	13.5 (445)	15.8 (496)	20.4 (614)†
IFG	5.8 (75)	4.9 (133)	4.6 (228)	4.4 (137)	5.5 (157)	4.9 (142)
IGT	11.2 (173)	9.9 (307)	7.4 (387)†	7.5 (251)	8.5 (269)	10.5 (347)
New diabetes	4.5 (60)	3.6 (85)	1.8 (107)†	1.5 (57)	1.7 (70)	4.9 (125)†
Dietary intake						
Total fat (energy percentage)	35.3 (34.7–35.9)	34.8 (34.3–35.3)	33.5 (33.1–34.0)†	33.6 (33.2–33.9)	34.3 (33.8–34.8)	34.9 (34.5–35.3)†
Total fat ≥30% energy intake	83.3 (1,048)	82.5 (1,936)	74.6 (3,108)†	73.7 (2,049)	79.4 (2,014)	83.0 (2,029)
Saturated fat (energy percentage)	14.3 (14.0–14.6)	14.2 (13.9–14.5)	13.5 (13.3–13.8)†	13.5 (13.4–13.7)	13.9 (13.6–14.1)	14.3 (14.1–14.5)†
Saturated fat intake ≥10%	92.0 (1,117)	89.7 (2,117)	84.8 (3,511)†	84.4 (2,309)	87.9 (2,216)	90.6 (2,220)
Total carbohydrate (energy percentage)	43.3 (42.5–44.0)	43.2 (42.4–44.0)	43.9 (43.6–44.2)†	44.2 (43.8–44.6)	43.5 (43.1–44.0)	43.0 (42.7–43.3)†
Sugars (energy percentage)	18.4 (17.6–19.2)	18.5 (18.1–18.8)	18.7 (18.4–19.0)†	19.0 (18.6–19.4)	18.5 (18.2–18.8)	18.2 (17.9–18.5)†
Fiber (g)	21.5 (20.7–22.2)	22.2 (21.5–22.9)	24.7 (24.2–25.2)†	23.1 (22.2–24.0)	23.9 (23.2–24.7)	23.3 (22.5–24.1)
Alcohol (g)	11.5 (9.4–13.5)	12.2 (10.3–14.1)	15.4 (13.9–17.0)†	12.8 (11.1–14.6)	14.5 (12.4–16.6)	14.3 (12.8–15.9)
Total energy intake (kcal/day)	2,140 (2,050–2,229)	2,128 (2,047–2,209)	2,245 (2,200–2,291)	2,095 (2,040–2,151)	2,231 (2,160–2,303)	2,261 (2,200–2,337)†
Total physical activity time (h/week)	0	1.14 (1.08–1.19)	8.4 (8.1–8.7)†	4.9 (4.4–5.4)	4.8 (4.4–5.1)	4.7 (4.4–5.1)
Mean TV viewing time (h/week)	13.3 (12.0–14.5)	11.6 (10.8–12.3)	12.0 (11.3–12.6)	3.8 (3.7–4.0)	11.2 (11.1–11.3)	22.9 (22.2–23.5)†

Data are means (95% CI) or % (n). *Data (unadjusted means and percentages) are weighted to the Australian population. †$P < 0.05$ for trend, adjusted for age and sex.

Table 2—Adjusted* ORs for the presence of abnormal glucose metabolism according to categories of physical activity

	n		Age-adjusted		Multivariate		Additional adjustment for waist circumference	
	Men	Women	Men	Women	Men	Women	Men	Women
Total physical activity								
0 h/week	541	782	1.00	1.00	1.00	1.00	1.00	1.00
0.01–2.49 h/week	968	1,577	0.68 (0.51–0.91)	1.00 (0.76–1.34)	0.73 (0.53–1.03)	1.09 (0.78–1.53)	0.82 (0.57–1.17)	1.18 (0.84–1.68)
≥2.5 h/week	2,192	2,239	0.59 (0.41–0.86)	0.60 (0.42–0.85)	0.62 (0.41–0.96)	0.71 (0.50–1.00)	0.70 (0.45–1.08)	0.85 (0.61–1.17)
P for trend			0.01	0.002	0.05	0.02	0.11	0.12
Walking + moderate physical activity only								
<2.5 h/week	1,369	2,182	1.00	1.00	1.00	1.00	1.00	1.00
≥2.5 h/week	933	1,102	0.98 (0.72–1.32)	0.58 (0.42–0.80)	0.96 (0.68–1.35)	0.66 (0.47–0.92)	0.96 (0.66–1.40)	0.73 (0.53–1.01)
P			0.89	0.001	0.81	0.02	0.82	0.06

Data are OR (95% CI). *Adjusted for age, sex, education, family history of diabetes, cigarette smoking, dietary covariates (total energy, total fat, total saturated fat, total carbohydrates, total sugars, fiber, and alcohol), and TV time.

completed university/further education, and were more likely to smoke cigarettes, be overweight, and have abnormal glucose metabolism. These participants also had a higher intake of total energy, total and saturated fats, total carbohydrates, and total sugars. However, there were no significant differences with respect to total physical activity. The correlation between TV watching and physical activity levels was negligible ($r = -0.04$).

The risk of abnormal glucose metabolism was inversely associated with total physical activity in men and women (Table 2). The associations remained significant after further adjustment for education, family history of diabetes, smoking, dietary covariates, and TV time, but were no longer significant after adjustment for waist circumference. Women who engaged in ≥2.5 h/week of walking plus moderate activity only (excluding those who reported >0 min vigorous activity) were less likely to have abnormal glucose metabolism compared with those not achieving the public health recommendations. No significant associ-

ations for walking plus moderate activity only were observed in men.

After adjusting for age, higher levels of TV time were positively associated with an increased risk of having abnormal glucose metabolism in women, but not in men (Table 3). Further adjustment for education, family history, smoking, dietary covariates, and physical activity did not appreciably alter the ORs. However, the inclusion of waist circumference into the model led to a larger attenuation in the association in both sexes.

Separate logistic regression models (adjusted for the various confounders, except waist circumference) were applied to provide an estimate of the influence of each 1-h increment in daily TV viewing time and each 30-min/day increase in physical activity on the risk of abnormal glucose metabolism. For each 1-h/day increase in time spent watching TV, there was a 7% (95% CI −4 to 19%; *P* = 0.21) and 18% (9–29%; *P* = 0.001) increase in the risk of abnormal glucose metabolism in men and women, respectively. In contrast, each 30-min/day increase in physi-

cal activity was associated with an 11% (3–19%; *P* = 0.01) and 10% (−2 to 10%; *P* = 0.10) decrease in risk of abnormal glucose metabolism in men and women, respectively.

The associations of TV viewing and total physical activity with IFG, IGT, and new type 2 diabetes are shown in Fig. 1. Compared with those who watched TV 14 h/week or less (reference group), watching TV >14 h/week was associated with a significantly increased risk of having new type 2 diabetes in men (OR 2.4 [95% CI 1.41–4.12]) and women (2.2 [1.32–3.61]). TV viewing >14 h/week was also associated with an increased risk of IGT in women (1.34 [0.99–1.81]). No significant associations were observed between IFG and TV viewing. Women who engaged in ≥2.5 h/week of total physical activity were significantly less likely to have IGT than those who participated in physical activity <2.5 h/week. Reductions in risk for IFG, IGT, and new type 2 diabetes in men and IFG and new type 2 diabetes in women were not statistically significant.

Table 3—Adjusted* ORs for the presence of abnormal glucose metabolism according to categories of TV

	n		Age-adjusted		Multivariate		Additional adjustment for waist circumference	
	Men	Women	Men	Women	Men	Women	Men	Women
Television viewing								
0–7 h/week	1,106	1,811	1.00	1.00	1.00	1.00	1.00	1.00
7.01–14 h/week	1,257	1,448	0.90 (0.65–1.25)	1.24 (0.91–1.69)	0.89 (0.63–1.25)	1.25 (0.92–1.71)	0.81 (0.60–1.09)	1.21 (0.87–1.69)
>14 h/week	1,338	1,339	1.11 (0.82–1.49)	1.54 (1.13–2.11)	1.16 (0.79–1.70)	1.49 (1.12–1.99)	0.97 (0.68–1.39)	1.34 (0.94–1.92)
P for trend			0.46	0.008	0.41	0.008	0.95	0.10

Data are OR (95% CI). *Adjusted for age, education, family history of diabetes, cigarette smoking, dietary covariates (total energy, total fat, total saturated fat, total carbohydrates, total sugar, fiber, and alcohol), and physical activity time.
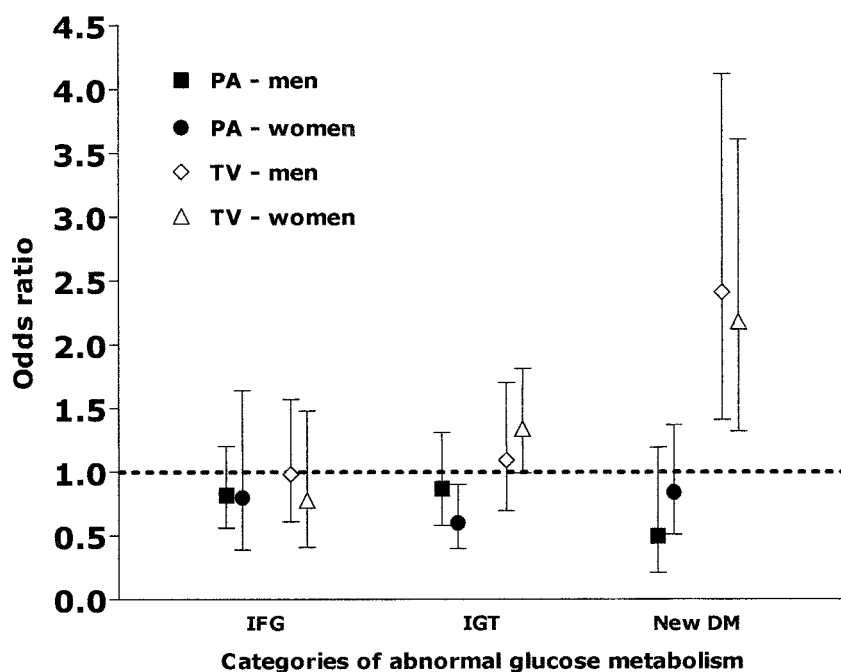
Figure 1—*Adjusted ORs for the presence of IFG, IGT, and undiagnosed (new) type 2 diabetes (new DM) according to TV viewing (≥14 h/week vs. ≤14 h/week) and total physical activity (PA) (≥2.5 h/week vs. <2.5 h/week). ORs were adjusted for age, education, family history of diabetes, cigarette smoking, dietary covariates (total energy, total fat, total saturated fat, total carbohydrates, total sugars, fiber, and alcohol), and TV time/physical activity time.*

CONCLUSIONS — In this large cross-sectional study of Australian adults, compliance with the recommended public health guidelines for physical activity (≥2.5 h/week) was associated with a reduced risk of having abnormal glucose metabolism in men and women. The study also demonstrated that a sedentary lifestyle, characterized by time spent watching TV, was significantly associated with an increased risk for abnormal glucose metabolism in women, independent of the effects of physical activity. Greater TV time was also shown to more than double the risk of having new type 2 diabetes in men and women.

Few population-based studies have used an OGTT to determine the association between physical activity and abnormal glucose metabolism (10,11,13,14). Most previous studies that have reported a protective effect of physical activity on the prevalence of undiagnosed diabetes or IGT have followed-up middle-aged/elderly participants (13,14) or have sampled nonwhite populations (10,11). Our study covers a broad age range, and because individuals with IFG, IGT, or new type 2 diabetes were unaware of their condition, biased reporting of physical activity is no more likely in those with or without abnormal glucose metabolism. Although it is well accepted that physical activity reduces the risk of type 2 diabetes (6), our findings have extended this knowledge base by demonstrating an inverse association between physical activity and the presence of asymptomatic diabetes or its precursors.

The findings provide further support for current physical activity recommendations, suggesting that adults who adhere to the minimum physical activity guidelines could reduce their risk of having abnormal glucose metabolism irrespective of TV time and dietary intake. Although our results show that the beneficial effects of physical activity were partly mediated by body fat distribution (waist circumference), it has been argued that adjustment for waist circumference in regression models may constitute statistical overcorrection and lead to an underestimation of the true beneficial effect of physical activity (6). This is because physical activity has beneficial effects on weight loss and weight maintenance; therefore, increased physical activity may reduce body fat content (6).

Our finding of an independent asso-

ciation between TV time and new type 2 diabetes in men and women is consistent with recent cohort studies showing that increased TV time is associated with the incidence of self-reported type 2 diabetes, independent of physical activity (6,7). Our study produced mixed results with respect to other categories of abnormal glucose metabolism in that a positive association was observed between TV time and IGT in women but not in men, with no significant associations observed for IFG in either sex. Although the association between TV time and abnormal glucose metabolism in women was attenuated by the adjustment for waist circumference, the association was more pronounced in women than in men. An earlier population-based sample from the NHLBI (National Heart, Lung and Blood Institute) Family Heart Study showed that blood glucose concentrations were positively correlated with TV watching in both sexes (18). However, analyses included adjustments for occupational physical activity in that study. Sex differences in associations between TV time and abnormal glucose metabolism in the current study may be caused by limitations in the physical activity instrument, which excludes assessment of domestic and occupational physical activity. Furthermore, previous research has demonstrated that higher proportions of women underreport their dietary intake (28), which could also explain stronger associations between TV viewing and abnormal glucose metabolism among women even after adjusting for dietary intake.

The positive association observed between TV time and risk of abnormal glucose metabolism may be explained in a number of ways. It could be that TV viewing displaces physical activity. However, the two variables are poorly related in our own and in other studies (7). TV viewing has also been found to be associated with snacking behavior (29). Although the association between TV time and abnormal glucose metabolism was independent of dietary intake, our investigation shows that adults who watched more TV also had an unhealthy eating pattern, as evidenced by higher reported total energy, fat, and saturated fat intake compared with those watching less TV.

The major strengths of this study include its large sample size across a wide age range, measurement of glucose metabolism through blood collection, and

measurement of several other covariates including body adiposity. Limitations of the study include assessment of just one aspect of sedentary living (TV viewing) and the cross-sectional study design. Therefore, it is difficult to determine the extent to which participants were in lower physical activity or higher TV time categories because of their health status. Longitudinal studies in this population should clarify the temporal associations between TV time, physical activity, and abnormal glucose metabolism. Furthermore, additional work is required to elucidate the potential behavioral and psychophysical mechanisms for the observed associations between physical activity and TV viewing with abnormal glucose tolerance. In particular, there is evidence that depression is associated with TV viewing (16) and type 2 diabetes (30). Future research should also aim to collect biomedical end points (such as an OGTT) when assessing abnormal glucose metabolism, and objective measures of physical activity such as accelerometers and pedometers should also be used.

In conclusion, this study provides further evidence that higher levels of physical activity are associated with a reduced risk of having "undiagnosed" abnormal glucose metabolism in adults. In contrast, prolonged TV watching increases the risk, especially in women. These findings suggest that the promotion of physical activity and encouragement of adults to watch less TV may be important dual public health strategies for the prevention of abnormal glucose metabolism and type 2 diabetes.

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