Television Time and Continuous Metabolic Risk in Physically Active Adults

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ABSTRACT

HEALY, G. N., D. W. DUNSTAN, J. SALMON, J. E. SHAW, P. Z. ZIMMET, and N. OWEN. Television Time and Continuous Metabolic Risk in Physically Active Adults. *Med. Sci. Sports Exerc.*, Vol. 40, No. 4, pp. 639–645, 2008. **Purpose:** Among Australian adults who met the public health guideline for the minimum health-enhancing levels of physical activity, we examined the dose–response associations of television-viewing time with continuous metabolic risk variables. **Methods:** Data were analyzed on 2031 men and 2033 women aged $\geq$ 25 yr from the 1999–2000 Australian Diabetes, Obesity and Lifestyle study without clinically diagnosed diabetes or heart disease, who reported at least 2.5 $h{\cdot}wk^{-1}$ of moderate- to vigorous-intensity physical activity. Waist circumference, resting blood pressure, and fasting and 2-h plasma glucose, triglycerides, and high-density-lipoprotein cholesterol (HDL-C) were measured. The cross-sectional associations of these metabolic variables with quartiles and hours per day of self-reported television-viewing time were examined separately for men and for women. Analyses were adjusted for age, education, income, smoking, diet quality, alcohol intake, parental history of diabetes, and total physical activity time, as well as menopausal status and current use of postmenopausal hormones for women. **Results:** Significant, detrimental dose–response associations of television-viewing time were observed with waist circumference, systolic blood pressure, and 2-h plasma glucose in men and women, and with fasting plasma glucose, triglycerides, and HDL-C in women. The associations were stronger in women than in men, with significant gender interactions observed for triglycerides and HDL-C. Though waist circumference attenuated the associations, they remained statistically significant for 2-h plasma glucose in men and women, and for triglycerides and HDL-C in women. **Conclusions:** In a population of healthy Australian adults who met the public health guideline for physical activity, television-viewing time was positively associated with a number of metabolic risk variables. These findings support the case for a concurrent sedentary behavior and health guideline for adults, which is in addition to the public health guideline on physical activity. **Key Words:** SEDENTARY BEHAVIOR, EXERCISE, WAIST CIRCUMFERENCE, LIPIDS, BLOOD PRESSURE, BLOOD GLUCOSE

For more than a decade, physical activity guidelines have emphasized the importance of achieving at least 30 min of physical activity on most days (34). The scientific basis for this guideline (often interpreted as 2.5 $h{\cdot}wk^{-1}$ of moderate- to vigorous-intensity activity) comes from considerable evidence showing that this represents the minimum level of physical activity necessary to lower risk for several adverse health outcomes, including all-cause premature mortality, cardiovascular disease, and type 2 diabetes (30). Consequently, this recommendation has been widely disseminated and incorporated into national physical activity guidelines (14).

In addition to the promotion of regular moderate- to vigorous-intensity physical activity, there is emerging evidence to suggest that sedentary time, involving prolonged sitting time and absence of whole-body movement, is an independent risk factor for several health outcomes. These include abnormal glucose tolerance, the metabolic syndrome, type 2 diabetes, and cardiovascular risk factors, particularly obesity, 2-h plasma glucose, and lipids (15–17,21,27,29). Importantly, the associations of sedentary behavior with these adverse metabolic outcomes have been shown to be independent of moderate- to vigorous-intensity physical activity. This suggests that sedentary time should be considered a unique class of behavior, and not simply the lack of moderate-to-vigorous physical activity (7,33,37). Consequently, the need to promote the reduction of sedentary behavior, in addition to promoting regular physical activity participation, is now being recognized (33). However, there has been limited research on the association of sedentary behavior with metabolic risk among those who already meet the minimum physical activity guideline of 2.5 $h{\cdot}wk^{-1}$ of moderate- to vigorous-intensity activity.

Television-viewing time is a highly prevalent sedentary behavior that is frequently studied within epidemiological research as a key indicator of overall sedentary behavior (36). Studies among adults in Australia, France, and the United States have reported increased television time to be

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Submitted for publication September 2007.
Accepted for publication October 2007.

0195-9131/08/4004-0639/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0b013e3181607421

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associated with increased prevalence of the metabolic syndrome, even among those who met the physical activity guidelines (5,16,20). Similarly, a study of Australian adults has shown that those who watched more than 4 h of television per day had a significantly higher body mass index, even if they were physically active (35). These associations were generally stronger and more consistent in women (5,16,20). Most previous studies have used categorically defined outcomes to examine the association of television-viewing time with metabolic risk among those who meet the physical activity guidelines. This may underestimate the importance of these relationships, given that recent meta-analyses have reported that the associations of waist circumference, triglycerides, and 2-h plasma glucose with risk for cardiovascular disease and premature mortality are progressive, with no apparent threshold of increased risk (11–13,26,31).

We examined the dose–response associations of television-viewing time with continuous metabolic risk variables in a large, population-based sample of physically active Australian adults. We also examined the extent to which central obesity mediated the associations of television-viewing time with the other metabolic risk variables. Findings are reported separately for men and for women, because we have previously observed stronger associations of television viewing with metabolic outcomes for women than men in this population (15–17).

METHODS

The national, cross-sectional Australian Diabetes, Obesity and Lifestyle (AusDiab) study was initially conducted in 1999–2000 to estimate the prevalence of diabetes and its precursors in the Australian adult population $\geq$ 25 yr of age. The methods, response rates, indications of representativeness, and main outcomes of this study have been reported elsewhere in detail (18,19). Ethics approval was obtained from the International Diabetes Institute; all subjects provided written informed consent.

Measures and data management. After an overnight fast (minimum of 10 h), participants attended a local survey center, where an oral glucose-tolerance test was performed using World Health Organization specifications (40). Fasting and 2-h plasma glucose levels, fasting serum triglycerides, and high-density-lipoprotein cholesterol (HDL-C) levels were obtained by enzymatic methods, measured on an Olympus AU600 analyzer (Olympus Optical, Tokyo, Japan). Duplicate waist circumference and triplicate resting blood pressure measurements were conducted by trained personnel; interviewer-administered questionnaires assessed demographic and behavioral attributes. Diet quality was assessed using the Diet Quality Index–Revised dietary assessment tool (22,32), modified for Australian dietary recommendations. Diet variables were derived from the self-administered, validated Anti-Cancer Council of Victoria food frequency questionnaire (28), and the diet quality scale was reported on a scale of 1–100 (with 100 being high diet quality). Under- and overreporters (39) were excluded from the analysis.

Self-reported television-viewing time, calculated as the total time spent watching television or videos in the previous week (36), was reported as both average hours per day, and also as gender-specific quartiles of television-viewing time. To account for zero values and skewness in the variable of television-viewing hours per day, a constant (1) was added; the variable was then logarithmically transformed and standardized so that one unit change was equivalent to one standard deviation.

Physical activity was measured by the Active Australia questionnaire, which asks respondents about their participation in predominantly leisure-time physical activities (including walking for transport) during the previous week (4). Total physical activity time ($h \cdot wk^{-1}$) was calculated as the sum of the time spent walking (if continuous and for 10 min or more) or performing moderate-intensity physical activity, plus double the time spent in vigorous-intensity physical activity (3). This method accounts for the higher volume of energy expenditure per unit of time that is associated with vigorous activities (3). Participants were categorized as being sufficiently physically active for health benefits if they participated in a minimum of 2.5 $h \cdot wk^{-1}$ of moderate- to vigorous-intensity activity (14). Only those AusDiab participants who met this criterion were included in the analysis.

The present analysis uses data from the 2031 men and 2033 women who were categorized as sufficiently physically active, who took part in the biomedical examination, were not pregnant, did not have clinically diagnosed diabetes or a history of angina, stroke, or myocardial infarction, were not on hypertensive or lipid-lowering medication, and had complete data for all variables.

Statistical analysis. Pearson chi-square analysis and Student's *t*-tests were used to compare gender differences for sociodemographic and behavioral variables. Forced-entry regression models examined the associations of television viewing with metabolic risk variables: waist circumference, systolic and diastolic blood pressure, fasting and 2-h post-load plasma glucose, triglycerides, and HDL-C. To account for skewness, fasting plasma glucose, 2-h plasma glucose, and plasma triglycerides were logarithmically transformed. Both unstandardized (b) and standardized (β) regression coefficients are reported. As the data are expressed in their original units (e.g., mean difference in waist circumference is reported in centimeters); unstandardized b coefficients enable clinical interpretation of the results. In contrast, standardized regression coefficients express both the independent (television-viewing time) and the dependent (metabolic risk) variables, using the same unit (standard deviations). Therefore, with standardized regression coefficients, it is possible to directly compare the magnitude of the association of television-viewing time for the different risk variables.

Model 1 adjusted for the potential confounders of age (yr), parental history of diabetes, cigarette smoking (current or ex-/nonsmoker), alcohol intake (self-reported as none, light, or moderate-to-heavy), income (household income ≥ \$1500 per week: yes/no), education (attended university or further education: yes/no), and diet quality (Diet Quality Index–Revised). Although all participants met the minimum physical activity guideline of 150 min of moderate- to vigorous-intensity physical activity per week, there was a wide variation in physical activity time above this minimum (range, 2.5–28 $h \cdot wk^{-1}$). Therefore, total physical activity time ($h \cdot wk^{-1}$) was also included in the analysis. The models for women additionally adjusted for menopausal status (going or gone through menopause) and current use of postmenopausal hormones (estrogen pills or hormone therapy, N = 306). Model 2 adjusted for the model 1 variables, with additional adjustment for waist circumference. Gender differences were tested for by interactions within the regression models. Significance was set at $P <$ 0.05. Analyses were conducted using SPSS version 13 (SPSS, Inc., Chicago, IL).

RESULTS

According to the International Diabetes Federation metabolic syndrome criteria (1), more than half the sample had elevated waist circumferences (54% men, 51% women), whereas the majority of participants had values in the normal range for blood pressure (56% men, 75% women), fasting plasma glucose (64% men, 85% women), triglycerides (69% men, 82% women), and HDL-C (83% men, 80% women). A total of 53% of women had gone through, or were going through, menopause.

Gender-specific behavioral, sociodemographic, and metabolic characteristics of the participants are shown in Table 1. Significant gender differences were observed for all variables, with the exception of age. In general, women had a more favorable metabolic profile compared with men (lower waist circumference, blood pressure, fasting plasma glucose, and triglycerides, and higher HDL-C), although women had a higher average 2-h plasma glucose than men. On average, men watched more television per day, but they also had a higher mean physical activity time compared with women. Women had significantly higher diet quality compared with men. The correlation between television-viewing time and physical activity time was low both for men (Pearson $r = -0.002$) and for women (Pearson $r = -0.09$), reinforcing the argument that these are separate domains and, hence, separate risk factors.

TABLE 1. Selected characteristics of men and women who met the physical activity guideline of at least 2.5 $h \cdot wk^{-1}$ of moderate- to vigorous-intensity physical activity.

	Men (N = 2031)	Women (N = 2033)	P Value
Age (yr)	47.3 (13.1)	46.7 (12.5)	0.101
Parental history of diabetes (%)	15.8	19.2	0.002
Current smoker (%)	17.2	13.9	0.002
University/further education (%)	49.0	39.9	< 0.001
Household income ≥ \$1500 per week (%)	23.5	19.8	0.003
Moderate-to-heavy alcohol intake (%)	40.2	21.1	< 0.001
Diet Quality Index–Revised (scale of 1–100)	63.3 (12.9)	69.8 (12.8)	< 0.001
Total physical activity time ($h \cdot wk^{-1}$)	9.08 (6.30)	7.39 (5.14)	< 0.001
Television-viewing time ($h \cdot d^{-1}$)	1.85 (1.35)	1.60 (1.23)	< 0.001
Waist circumference (cm)	95.5 (10.5)	81.7 (11.7)	< 0.001
Systolic blood pressure (mm Hg)	129 (15)	121 (16)	< 0.001
Diastolic blood pressure (mm Hg)	73.1 (10.4)	65.3 (10.5)	< 0.001
Log fasting plasma glucose (mM)	0.74 (0.05)	0.71 (0.04)	< 0.001
Log 2-h plasma glucose (mM)	0.74 (0.13)	0.75 (0.12)	0.011
Log triglycerides (mM)	0.12 (0.24)	0.02 (0.22)	< 0.001
HDL cholesterol (mM)	1.30 (0.31)	1.62 (0.39)	< 0.001

Data are reported as percentages or as means (SD).

Table 2 shows the adjusted unstandardized regression coefficients for increasing quartiles of television viewing with metabolic risk variables for men and for women. Significant dose–response associations were observed for waist circumference, systolic blood pressure, and 2-h plasma glucose in men and women, and also for fasting plasma glucose, triglycerides, and HDL-C in women. Gender differences were observed in the dose–response threshold of metabolic risk for television viewing, with the threshold substantially lower in women than in men. For women, each quartile increase in television-viewing time was associated with a significant mean change from the reference category for waist circumference, fasting plasma glucose, 2-h plasma glucose, and triglycerides. For men, the associations were less pronounced, with significant differences from the reference category only observed in quartiles 3 and 4 for waist circumference, quartile 2 for systolic blood pressure, and quartile 4 for 2-h plasma glucose. Clinically, these results are significant. For example, women who watched more than 2.16 h of television per day had, on average, a 4.2-cm-higher waist circumference compared with those who watched less than 0.7 h.

To characterize the potential mediating effect of central obesity on the associations, Figure 1 shows the standardized regression coefficients of television-viewing time with metabolic variables, with and without adjustment for waist circumference. As the coefficients for HDL-C were inverted, the results can be interpreted as the higher the standardized regression coefficient, the stronger the association of television-viewing time on the metabolic outcome. Only those metabolic variables that were significantly associated with television time in the model unadjusted for waist circumference are shown. For all metabolic variables, the associations for television-viewing time were stronger in women than in men. In the model not adjusted for waist circumference, the largest effect sizes were observed for waist circumference and 2-h plasma glucose for men, and waist circumference and triglycerides for women. In this model, significant gender–television-hours interactions were observed for triglycerides ($P < 0.001$) and HDL-C (P = 0.003). When waist circumference was included in the model, although attenuated, the significant association with television-viewing time persisted for 2-h plasma glucose for men and women, and for lipids for women.

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TABLE 2. Cross-sectional associations of gender-specific quartiles of television viewing with metabolic risk variables in men and women who were physically active (≥ 2.5 h·wk^{-1} of moderate- to vigorous-intensity activity).

TV Viewing (h·d^{-1})	*N*	Waist (cm)	Systolic Blood Pressure (mm Hg)	Diastolic Blood Pressure (mm Hg)	Log Fasting Plasma Glucose (mM)	Log 2-h Plasma Glucose (mM)	Log Triglycerides (log) (mM)	HDL Cholesterol (mM)
Men								
< 0.93	518	Reference	Reference	Reference	Reference	Reference	Reference	Reference
0.94–1.71	551	0.63 (−0.59, 1.84)	1.56 (−0.07, 3.19)	0.15 (−1.05, 1.36)	0.000 (−0.005, 0.006)	0.014 (−0.002, 0.03)	−0.02 (−0.05, 0.01)	−0.003 (−0.04, 0.03)
1.72–2.57	445	1.62 (0.32, 2.91)*	2.28 (0.54, 4.02)*	0.81 (−0.47, 2.09)	0.004 (−0.002, 0.010)	0.014 (−0.002, 0.03)	0.001 (−0.03, 0.03)	−0.02 (−0.06, 0.02)
> 2.57	517	2.62 (1.35, 3.88)*	0.18 (−1.52, 1.87)	−0.08 (−1.33, 1.18)	0.005 (−0.001, 0.011)	0.035 (0.02, 0.05)*	−0.001 (−0.03, 0.03)	−0.03 (−0.07, 0.01)
P for trend		< 0.001	0.023	0.519	0.179	< 0.001	0.511	0.477
Women								
< 0.71	591	Reference	Reference	Reference	Reference	Reference	Reference	Reference
0.71–1.43	497	1.65 (0.29, 3.01)*	0.88 (−0.82, 2.58)	0.14 (−1.65, 0.96)	0.005 (0.001, 0.010)*	0.014 (0.001, 0.03)*	0.03 (0.003, 0.05)*	−0.04 (−0.08, 0.004)
1.44–2.14	446	1.83 (0.42, 3.24)*	0.61 (−1.16, 2.37)	−0.18 (−1.48, 1.13)	0.008 (0.003, 0.013)*	0.019 (0.004, 0.03)*	0.03 (0.004, 0.06)*	−0.07 (−0.11, −0.02)*
> 2.14	499	4.22 (2.81, 5.63)*	2.53 (0.77, 4.30)*	−0.35 (−1.12, 1.39)	0.007 (0.002, 0.011)*	0.035 (0.02, 0.05)*	0.06 (0.04, 0.09)*	−0.12 (−0.16, −0.07)*
P for trend		< 0.001	0.039	0.906	0.011	< 0.001	< 0.001	< 0.001

Data are unstandardized regression coefficients (95% CI) showing mean difference (units) in metabolic measures for increasing quartiles of television watching relative to the reference category. Models are adjusted for age, education, parental history of diabetes, smoking, income, alcohol intake, diet quality, menopausal status (women only), current use of postmenopausal hormones (women only), and physical activity time. Fasting and 2-h plasma glucose and serum triglycerides were logarithmically transformed before inclusion in the model; coefficients and 95% CI reflect transformed values. * $P < 0.05$ compared with reference group.

DISCUSSION

Among healthy Australian adults who met the public health guideline of 2.5 h·wk^{-1} of moderate- to vigorous-intensity physical activity, television-viewing time was positively associated with a number of metabolic risk variables. Significant dose–response associations were observed for waist circumference, systolic blood pressure, and 2-h plasma glucose in men and women, and for fasting plasma glucose, triglycerides, and HDL-C in women. These findings, using continuous metabolic risk measures, build on previous work that we have done within the AusDiab population, showing detrimental associations of sedentary behavior with categorically defined metabolic risk, independent of physical activity participation (16). The data provide further support to the case for having a specific sedentary behavior and health guideline for adults, in addition to the currently accepted physical activity and health guideline.

In addition to meeting the physical activity guidelines, the majority of participants also had metabolic values in the normal range (1) and would, therefore, be generally considered at low risk for metabolic complications. However, the recent meta-analyses showing progressive associations of waist circumference, triglycerides, and 2-h plasma glucose with risk for cardiovascular disease and premature mortality across the continuum from normal to diseased state suggest that even small changes in these metabolic parameters may be clinically significant (11–13,26,31).

The strongest associations with metabolic variables were observed in the highest quartile of television viewing (> 2.57 h·d^{-1} for men; > 2.14 h·d^{-1} for women), although detrimental associations of television viewing were observed in women who viewed as little as 43–86 min, and in men who viewed 1.7–2.6 h, of television per day. However, these data are cross-sectional. Experimental research examining the short-term effects of various dose–response thresholds of television viewing, as well as prospective studies to examine longer-term health effects and possible causal relationships, are required. Unlike physical activity, there are currently no recommendations in adults on the quantity of sedentary behavior likely to confer health risk. In children, the sedentary behavior guideline currently recommends no more than 2 h of screen time per day (2,10). A similar recommendation for adults (i.e., no more than 2 h of leisure-time screen time per day) may be a practical starting point.

The mechanisms through which television time is associated with metabolic risk, even in this healthy subpopulation, are likely to be of both physiological and behavioral origin. Physiologically, there is emerging evidence that sedentary behavior results in unique metabolic outcomes, particularly for triglycerides and HDL-C, which are not simply the inverse of those for physical activity (23). Behaviorally, it has been suggested that sedentary time is associated with health outcomes as it displaces time in

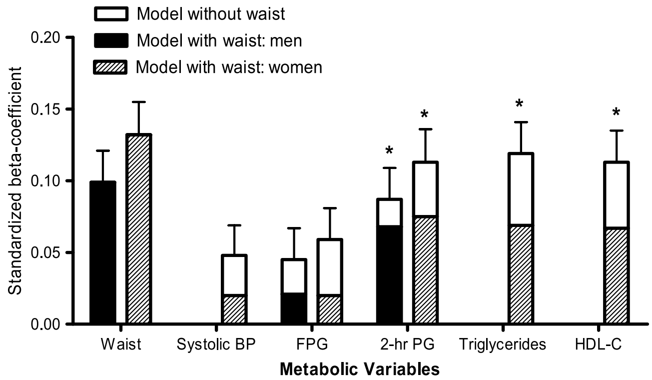

FIGURE 1—Standardized regression coefficients (SE) of television-viewing time with metabolic variables, with and without adjustment for waist circumference in adults who met the minimum physical activity recommendations of 2.5 h·wk^{-1} of moderate- to vigorous-intensity physical activity. Only those variables showing a significant association with television-viewing time in the model unadjusted for waist circumference are shown. All models were adjusted for age, education, parental history of diabetes, smoking, income, alcohol intake, diet quality, and total physical activity time. The models for women were additionally adjusted for menopausal status and current use of postmenopausal hormones. * Coefficients remain significant (P < 0.05) after inclusion of waist circumference to the model. FPG, fasting plasma glucose; 2-h PG, 2-h plasma glucose; HDL-C, high-density-lipoprotein cholesterol. Coefficients for HDL-C are inversed.

moderate- to vigorous-intensity activity (9). However, in line with previous research in this population (17), we found low correlations between television-viewing time and physical activity in both men and women. Additionally, using objective measures of physical activity and sedentary time (accelerometers), we have previously reported that, on average, only 4% of waking hours are spent in moderate- to vigorous-intensity activity, with the majority of waking hours spent either in sedentary or in light-intensity activity (25). Therefore, the detrimental associations of increased television time with metabolic risk may be attributable to television time displacing time spent in light-intensity activity. Light-intensity activity has been beneficially associated with 2-h plasma glucose, independent of time spent in moderate- to vigorous-intensity activity (25). Increased snacking has also been associated with high levels of television viewing and increased body mass index (8). Although we controlled for overall diet quality, we could not specially examine snacking behaviors.

Overall, the findings were stronger for women than for men, with significant gender interactions observed for the associations of television-viewing time with lipid measures. The gender differences observed are consistent with previous research in this and in other adult populations (5,16,20). Possible reasons for this gender difference include a true physiological sex difference in response to television viewing, because sex differences in fuel homeostasis have been observed in response to prolonged sedentary time, such as days and weeks of bed rest (6). There may be gender differences in the potential behavioral mechanisms already mentioned (displacement of light-intensity activity, and more snacking behavior). Finally, only a single leisure-time sedentary behavior was measured. There may be gender differences in the extent to which television time is a broader marker of total sedentary behavior. Sugiyama and colleagues (38) have recently reported that television-viewing time was associated with other sedentary behaviors (and total sedentary behavior) for women, but not for men. Further research, preferably using objective measures, is required to examine the association of various sedentary behaviors with metabolic risk.

In August 2007, the American College of Sports Medicine and the American Heart Association released the updated recommendation of physical activity and health for adults (24). This updated recommendation included moderate-intensity activity for a minimum of 30 min, 5 d·wk^{-1}, or vigorous-intensity activity for a minimum of 20 min, 3 d·wk^{-1}, plus the addition of strength-training activities at least twice per week (24). Participants in this study were included if they reported a minimum of 2.5 h·wk^{-1} of moderate- to vigorous-intensity activity. Strength training was not reported in the 1999–2000 AusDiab study, and, hence, we are unable to report the association of television viewing with metabolic risk in those who met these updated recommendations.

This study was conducted in a large, representative adult population who were free of clinically diagnosed diabetes and self-reported heart disease. Additional strengths of the study include the continuous measures of metabolic risk and television-viewing time, and the statistical adjustment for several potential confounding factors, including diet quality and total moderate- to vigorous-intensity physical activity time. Limitations of the study include the cross-sectional study design, and the self-reporting of television-viewing time and physical activity. Additionally, only a single sedentary behavior (television viewing) was examined. Future research should incorporate objective measures, such as accelerometers, to assess sedentary time across the day (not just leisure time), and to capture light-intensity activities. Additionally, further research is needed to examine the association of time spent in other common sedentary behaviors, such as computer use, with metabolic risk.

There are significant public health implications that may arise from these findings. Currently, there are no public health guidelines for sedentary behavior among adults. These findings suggest that even in those who meet the physical activity guidelines, detrimental dose–response associations with metabolic risk are observed with increasing television-viewing time. The data support the recommendation for a concurrent sedentary behavior and health guideline, in addition to the physical activity and health guideline in adults.

G.N. Healy is supported by an Australian Postgraduate Award. N. Owen is supported by a Queensland Health Core Research Infrastructure grant and by NHMRC Program Grant funding (#301200). D.W. Dunstan is supported by a Victorian Health Promotion Foundation Public Health Research Fellowship. J. Salmon is supported by a National Heart Foundation and Sanofi-Aventis Career Development Award. The following provided financial support for the AusDiab study: The Commonwealth Department of Health and Aged Care, Abbott Australasia, Alphapharm, Aventis Pharmaceutical, AstraZeneca, Bristol-Myers Squibb Pharmaceuticals, Eli Lilly (Australia), GlaxoSmithKline, Janssen-Cilag (Australia), Merck Lipha, Merck Sharp & Dohme (Australia), Novartis Pharmaceutical (Australia), Novo Nordisk Pharmaceutical, Pharmacia and Upjohn, Pfizer, Roche Diagnostics, Sanofi Synthelabo (Australia), Servier Laboratories (Australia), BioRad Laboratories, HITECH Pathology, the Australian Kidney Foundation, Diabetes Australia, Diabetes Australia (Northern Territory), Queensland Health, South Australian Department of Human Services, Tasmanian Department of Human Services, Victorian Department of Human Services and Health Department of Western Australia. Also, for their invaluable contribution to the setup and field activities of AusDiab, we are enormously grateful to A. Allman, B. Atkins, S. Bennett, S. Chadban, S. Colagiuri, M. de Courten, M. Dalton, M. D'Embden, T. Dwyer, D. Jolley, I. Kemp, P. Magnus, J. Mathews, D. McCarty, A. Meehan, K. O'Dea, P. Phillips, P. Popplewell, C. Reid, A. Stewart, R. Tapp, H. Taylor, T. Welborn, and F. Wilson. The results of the present study do not constitute endorsement by ACSM.

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