Increased Cardiometabolic Risk Is Associated with Increased TV Viewing Time

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ABSTRACT

WIJNDAELE, K., G. N. HEALY, D. W. DUNSTAN, A. G. BARNETT, J. SALMON, J. E. SHAW, P. Z. ZIMMET, and N. OWEN. Increased Cardiometabolic Risk Is Associated with Increased TV Viewing Time. *Med. Sci. Sports Exerc.*, Vol. 42, No. 8, pp. 1511–1518, 2010. **Purpose**: Television viewing time, independent of leisure time physical activity, has cross-sectional relationships with the metabolic syndrome and its individual components. We examined whether baseline and 5-yr changes in self-reported television viewing time are associated with changes in continuous biomarkers of cardiometabolic risk (waist circumference, triglycerides, HDL-cholesterol, systolic and diastolic blood pressure, fasting plasma glucose, and a clustered cardiometabolic risk score) in Australian adults. **Methods**: The Australian Diabetes, Obesity and Lifestyle Study (AusDiab) is a prospective, population-based cohort study with biological, behavioral, and demographic measures collected in 1999–2000 and 2004–2005. Noninstitutionalized adults aged ≥25 yr were measured at baseline (11,247; 55% of those completing an initial household interview); 6400 took part in the 5-yr follow-up biomedical examination, and 3846 met the inclusion criteria for this analysis. Multiple linear regression analysis was used, and unstandardized *B* coefficients (95% confidence intervals (CI)) are provided. **Results**: Baseline television viewing time (10 h·wk^{-1} unit) was not significantly associated with change in any of the biomarkers of cardiometabolic risk. Increases in television viewing time over 5 yr (10 h·wk^{-1} unit) were associated with increases in waist circumference (men: 0.43 cm, 95% CI = 0.08–0.78 cm, $P = 0.02$; women: 0.68 cm, 95% CI = 0.30–1.05, $P < 0.001$), diastolic blood pressure (women: 0.47 mm Hg, 95% CI = 0.02–0.92 mm Hg, $P = 0.04$), and the clustered cardiometabolic risk score (women: 0.03, 95% CI = 0.01–0.05, $P = 0.007$). These associations were independent of baseline television viewing time and baseline and change in physical activity and other potential confounders. **Conclusions**: These findings indicate that an increase in television viewing time is associated with adverse cardiometabolic biomarker changes. Further prospective studies using objective measures of several sedentary behaviors are required to confirm causality of the associations found. **Key Words:** TELEVISION, METABOLIC SYNDROME, WAIST CIRCUMFERENCE, BLOOD PRESSURE, TRIGLYCERIDES, HDL

BASIC SCIENCES

Sedentary behaviors, involving prolonged sitting, have become a prevalent feature of everyday living. Television (TV) viewing time is the most frequently reported leisure time sedentary behavior in adults from Australia, the United States, and Great Britain (2,24,25). Cross-sectionally, TV viewing time has been positively associated with the presence of the metabolic syndrome and its components using both categorical (5,9,12) and continuous (11,16,17,30) measurements. These associations were independent of leisure time physical activity and have also been found in physically active adults (16). Prospectively, TV viewing time and nonoccupational sedentary behavior have been associated with self-reported weight change (6), obesity (19), and type II diabetes (18,19). However, to date, no prospective studies have examined the associations of TV viewing time with objectively measured metabolic syndrome components in adults.

The Australian Diabetes, Obesity and Lifestyle Study (AusDiab) is a prospective population-based cohort study of the etiology of diabetes mellitus and related disorders, with baseline measurements taken in 1999–2000 and follow-up measurements taken 5 yr later (2004–2005). This longitudinal study design allowed us to examine the effects of both baseline TV viewing and (simultaneous) change in TV viewing time on changes in cardiometabolic risk. On the basis of previous cross-sectional results showing stronger

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associations in women compared with men (5,9,12,16,30), we studied these associations by gender.

METHODS

Study Participants

The baseline AusDiab study was conducted during 1999–2000. As previously described in greater detail, a stratified cluster sampling method was used (10). Briefly, all eligible adults were recruited within 42 randomly selected urban and nonurban areas on the basis of Census Collector Districts, 6 in each of the Australian states and in the Northern Territory of Australia. In total, 28,033 households were approached in the selected clusters. In the 19,215 households where contact was achieved, 2086 households were considered ineligible. From the 17,129 eligible households, 5178 households refused to participate in the household survey, and the occupants of an additional 472 households were away from the residence during the survey period. As such, the number of eligible adults living in these 5650 households could not be ascertained. From the 11,249 households that participated in the household interview, 20,347 adults (age ≥25 yr) completed the household interview, of whom 11,247 (55.3%) attended a testing site for the biomedical examination. A total of 8798 took part in the 5-yr follow-up survey (2004–2005), of whom 6400 participated in the biomedical examination; 137 attended an external pathology laboratory and 2261 completed a telephone questionnaire only. The present analyses used only those (n = 4953) with complete data for baseline and follow-up cardiometabolic risk variables, TV viewing time, and confounding variables (physical activity time, education, employment status, income, cigarette smoking, alcohol, diet quality, and energy intake (excluding participants (n = 279/6400) overreporting or underreporting their dietary intake [31]); parental history of diabetes; baseline age; and medications for hypertension or dyslipidemia at follow-up). Participants were excluded if they had clinically diagnosed diabetes (n = 152), self-reported angina (n = 208), stroke (n = 74), or myocardial infarction (n = 155) at baseline or if they took medications for hypertension (n = 709) or dyslipidemia at baseline (n = 427; exclusion criteria were not mutually exclusive, so participants could be excluded on the basis of more than one criterion). These exclusions were made on the grounds that their condition might have affected their TV viewing time and their biomarkers of cardiometabolic risk. The analysis included 3846 adults (1703 men and 2143 women). The ethics committee of the International Diabetes Institute approved the AusDiab study design. Written informed consent was obtained from all participants.

Measures

Cardiometabolic risk variables. Data collection procedures at baseline and follow-up were similar, as was follow-up time for all participants (~5 yr). 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 (32). Fasting plasma glucose levels, fasting serum triglycerides, and HDL-cholesterol levels were measured by enzymatic methods using an Olympus AU600 analyzer (Olympus Optical, Co, Ltd., Tokyo, Japan) in 1999–2000 and the Roche Modular (Roche Diagnostics, Indianapolis, IN) in 2004–2005: these methods were comparable across the two surveys (4). Trained personnel conducted duplicate waist circumference and resting blood pressure measurements. A more detailed description of these measurement protocols has previously been published (10). The cardiometabolic risk variables were waist circumference, triglycerides, HDL-cholesterol, systolic blood pressure, diastolic blood pressure, and fasting plasma glucose. A continuous clustered cardiometabolic risk score on the basis of these variables was constructed, similar to previous studies examining determinants of the metabolic syndrome/cardiometabolic risk (e.g., [11]). Briefly, after normalization (log 10), all cardiometabolic variables (average blood pressure was used as an index for systolic and diastolic blood pressure) were standardized, i.e., z-scores were computed (z = (value − mean)/SD). For HDL-cholesterol (protective for cardiometabolic risk), the z-score was multiplied by −1. All z-scores were summed, and the sum was divided by 5 to compile the cardiometabolic risk score with units of SD. Means and SD of the representative 1999–2000 AusDiab baseline sample with complete cardiometabolic data (n = 11,029) were used for standardization in both the 1999–2000 and the 2004–2005 data. The aim of using continuous outcome variables, both for the individual cardiometabolic risk variables as the composite score, was to maximize statistical power (26).

TV viewing time and physical activity time. Participants reported total time spent watching TV or videos in the previous week. This measure has been shown to provide a reliable (intraclass correlation = 0.82, 95% confidence interval (CI) = 0.75–0.87) and valid (criterion validity = 0.3) estimate of TV viewing time among adults (27). Using the Active Australia questionnaire, participants also reported their frequency and duration of moderate- to vigorous-intensity leisure time physical activity during the previous week (1,3). This questionnaire has been shown to provide a reliable (intraclass correlation = 0.59, 95% CI = 0.52–0.65) and valid (criterion validity = 0.3) estimate of physical activity among adults (8,29). Changes in TV viewing time and physical activity were calculated as follow-up minus baseline. Change in TV viewing time was used both as a continuous and a categorical predictor (>1 $h \cdot wk^{-1}$ = decrease; 0 ± 1 $h \cdot wk^{-1}$ = no change; >1 $h \cdot wk^{-1}$ = increase).

Potential confounding variables. The following demographic attributes were assessed using an interviewer-administered questionnaire: education (university or further education; yes/no), employment status (full-time or part-time job; yes/no), total household income (≥A\$1500·wk^{-1};

yes/no), cigarette smoking status (current heavy (≥20 cigarettes per day), current light (<20 cigarettes per day), ex, non), alcohol intake (classified as nondrinker, light drinker, or moderate to heavy drinker), and parental history of diabetes (yes/no). Dietary intake (usual eating habits during the past 12 months) was assessed using a self-administered validated food frequency questionnaire developed by the Anti-Cancer Council of Victoria (20), with total energy intake and a diet quality index score (Diet Quality Index—Revised, 0–100 with 100 representing high diet quality [23]) included in the analysis.

Changes during the 5 yr for employment status, income, smoking, and alcohol were categorized as decreased, no change, or increased; change for education was categorized as no change or increased.

Statistical Analysis

Multiple linear regression was used to examine the association of baseline and change in TV viewing with change in cardiometabolic risk. Results provided are unstandardized *B* coefficients. For every regression model, the following five checks were made: 1) standardized residuals and Cook's distance for outliers and influential cases, 2) normality of standardized residuals, 3) homoscedasticity of standardized residuals, 4) the Durbin–Watson statistic to test the independence of residuals, and 5) the variance inflation factor to test multicolinearity. Analyses were conducted using SPSS 14.0 (SPSS, Inc., Chicago, IL) and STATA 10.0 (StataCorp LP, College Station, TX). Statistical significance was set at $P < 0.05$.

Regression models for baseline TV viewing time ($h \cdot wk^{-1}$). Change in the clustered cardiometabolic risk score and the individual cardiometabolic risk variables was regressed against: baseline TV viewing time, baseline age, and cardiometabolic risk variable under study; baseline education, employment status, income, cigarette smoking, alcohol, diet quality, energy intake, and parental history of diabetes; and hypertension or lipid medication use at follow-up (model A). Adding baseline physical activity time gave the effect of baseline TV viewing time independent of physical activity (model B). Adding baseline waist circumference examined if central obesity attenuated the association of baseline TV viewing time with change in the following cardiometabolic risk variables: triglycerides, HDL-cholesterol, systolic and diastolic blood pressure, and fasting plasma glucose (model C). In the regression models for baseline TV viewing, TV viewing precedes change in cardiometabolic risk, which allows inference about the causality of any effects found.

Regression models for change in TV viewing time ($h \cdot wk^{-1}$). Change in the clustered cardiometabolic risk score and the individual cardiometabolic risk variables was regressed against: change in TV viewing time; baseline TV viewing time; baseline age and cardiometabolic risk; baseline and change in education, employment status, income, cigarette smoking, alcohol, diet quality, and energy intake; any parental history of diabetes at follow-up; and follow-up hypertension or lipid medication use (model A). Adding baseline and change in physical activity gave the effect of a change in TV viewing time, independent of physical activity (model B). In addition, adjusting for baseline and change in waist circumference examined if central obesity attenuated the association of change in TV viewing time with change in the following cardiometabolic risk variables: triglycerides, HDL-cholesterol, systolic and diastolic blood pressure, and fasting plasma glucose (model C).

In the multiple linear regression models including change in TV viewing time as a categorical variable, participants showing no change (0 ± 1 $h \cdot wk^{-1}$) and participants increasing (>1 $h \cdot wk^{-1}$ increase) their TV viewing time were compared with the reference group of participants decreasing

TABLE 1. Demographic, behavioral, and cardiometabolic characteristics of participants, AusDiab 1999–2000 and 2004–2005.

	Men (*n* = 1703)		Women (*n* = 2143)	
Characteristic	**Baseline**	**Follow-up**	**Baseline**	**Follow-up**
Age (yr)	48.61 (48.06 to 49.16)	53.60 (53.05 to 54.15)	47.64 (47.17 to 48.11)	52.64 (52.17 to 53.11)
University/further education, *n* (%)	859 (50.4)	859 (50.4)	894 (41.7)	929 (43.3)
Employed, *n* (%)	1384 (81.3)	1287 (75.6)	1409 (65.7)	1425 (66.5)
Income ≥A$1500·wk^{-1}, *n* (%)	432 (25.4)	653 (38.3)	443 (20.7)	626 (29.2)
Current heavy smoker, *n* (%)	125 (7.3)	91 (5.3)	105 (4.9)	67 (3.1)
Moderate to heavy drinker, *n* (%)	658 (38.6)	716 (42.0)	384 (17.9)	497 (23.2)
Diet quality, 1–100	60.26 (59.66 to 60.86)	61.31 (60.72 to 61.90)	66.12 (65.58 to 66.65)	66.34 (65.82 to 66.85)
Total energy intake (kJ·d^{-1})	9882.09 (9756.24 to 10,007.93)	9269.76 (9142.60 to 9396.92)	7315.28 (7223.10 to 7407.45)	6912.58 (6824.43 to 7000.72)
Parental history of diabetes, *n* (%)	297 (17.4)	395 (23.2)	415 (19.4)	573 (26.7)
TV viewing time (h·wk^{-1})	12.71 (12.29 to 13.13)	13.59 (13.16 to 14.02)	11.03 (10.66 to 11.39)	12.14 (11.75 to 12.52)
Physical activity (h·wk^{-1})	5.47 (5.18 to 5.75)	5.34 (5.06 to 5.62)	4.07 (3.86 to 4.27)	4.75 (4.53 to 4.98)
Cardiometabolic risk variables				
Waist circumference (cm)	95.92 (95.42 to 96.42)	97.59 (97.06 to 98.13)	82.78 (82.26 to 83.30)	85.57 (85.03 to 86.10)
Triglycerides (mmol·L^{-1})	1.65 (1.60 to 1.71)	1.56 (1.52 to 1.61)	1.21 (1.18 to 1.24)	1.23 (1.20 to 1.25)
HDL-cholesterol (mmol·L^{-1})	1.28 (1.26 to 1.29)	1.28 (1.26 to 1.29)	1.59 (1.58 to 1.61)	1.60 (1.58 to 1.62)
Systolic BP (mm Hg)	129.36 (128.66 to 130.07)	125.54 (124.76 to 126.32)	121.37 (120.71 to 122.02)	116.63 (115.85 to 117.42)
Diastolic BP (mm Hg)	74.06 (73.57 to 74.56)	72.78 (72.35 to 73.22)	65.46 (65.02 to 65.91)	65.13 (64.73 to 65.53)
Fasting plasma glucose (mmol·L^{-1})	5.57 (5.54 to 5.60)	5.49 (5.46 to 5.53)	5.22 (5.19 to 5.24)	5.20 (5.18 to 5.23)
Clustered cardiometabolic risk	−0.12 (−0.14 to −0.09)	−0.15 (−0.18 to −0.12)	−0.19 (−0.22 to −0.17)	−0.17 (−0.20 to −0.15)

Data are means (95% CI), unless otherwise indicated.
BP, blood pressure.

TABLE 2. Change in TV viewing time, physical activity, and cardiometabolic risk from baseline to follow-up.

Characteristic	Men (n = 1703)	Women (n = 2143)
TV viewing time (h·wk^{-1})	0.88 (0.47 to 1.28)	1.11 (0.74 to 1.47)
TV viewing time, categorical		
Increased, n (%)	784 (46.0)	971 (45.3)
Same, n (%)	292 (17.1)	475 (22.2)
Decreased, n (%)	627 (36.8)	697 (32.5)
Physical activity (h·wk^{-1})	−0.12 (−0.45 to 0.20)	0.68 (0.45 to 0.92)
Cardiometabolic risk		
Waist circumference (cm)	1.67 (1.40 to 1.94)	2.79 (2.49 to 3.08)
Triglycerides (mmol·L^{-1})	−0.09 (−0.13 to −0.04)	0.01 (−0.01 to 0.04)
HDL-cholesterol (mmol·L^{-1})	−0.004 (−0.01 to 0.01)	0.003 (−0.01 to 0.01)
Systolic blood pressure (mm Hg)	−3.82 (−4.49 to −3.15)	−4.74 (−5.34 to −4.13)
Diastolic blood pressure (mm Hg)	−1.28 (−1.73 to −0.83)	−0.33 (−0.74 to 0.07)
Fasting plasma glucose (mmol·L^{-1})	−0.08 (−0.11 to −0.04)	−0.01 (−0.04 to 0.01)
Clustered cardiometabolic risk	−0.03 (−0.05 to −0.01)	0.02 (0.01 to 0.04)

Data are means (95% CI), unless otherwise indicated.
Change, follow-up minus baseline.

(>1 h·wk^{-1} decrease) their TV viewing time. Also, a linear trend for more unfavorable changes in cardiometabolic risk across the three TV viewing time categories was examined.

In the regression models for change in TV viewing, the changes for TV viewing and cardiometabolic risk occur during the same period of 5 yr, which does not allow inference about the causality of any effects found.

Data imputation and sensitivity analysis. As a sensitivity analysis of the effect of missing data, we imputed the missing data for all participants of the baseline AusDiab measurement phase (n = 11,247) and reran the regression models for both baseline and change in TV viewing on 8078 subjects after applying the original exclusion criteria (21). We created 10 data sets with stochastically imputed values and then combined the parameter estimates using PROC MIANALYZE in SAS 9.1 (SAS Institute, Inc., Cary, NC). We imputed values for the continuous variables by assuming they had a multivariate normal distribution. We estimated the variance–covariance matrix using WinBUGS 1.4 (MRC Biostatistics Unit, Cambridge, UK) and also used this software to impute values using a Markov chain Monte Carlo simulation. For missing variables that were binary or ordinal, we used regression models to estimate the missing values. These models and imputed values were also estimated using WinBUGS.

RESULTS

Descriptive Characteristics of the Sample

Demographic characteristics of participants and changes in TV viewing time, physical activity, and cardiometabolic risk are shown in Tables 1 and 2. TV viewing time

TABLE 3. Unstandardized B coefficients (95% CI) relating baseline TV viewing time and 5-yr change in TV viewing time to changes in cardiometabolic risk from baseline to 5 yr (unit for TV viewing time is 10 h·wk^{-1}).

		Men (n = 1703)				Women (n = 2143)			
		Baseline TV Viewing Time		Change in TV Viewing Time		Baseline TV Viewing Time		Change in TV Viewing Time	
Cardiometabolic Outcome	Model	B (95% CI)	P	B (95% CI)	P	B (95% CI)	P	B (95% CI)	P
Clustered cardiometabolic risk[a,b]	Model A	−0.01 (−0.03 to 0.01)	0.47	0.02 (−0.003 to 0.04)	0.09	−0.01 (−0.02 to 0.01)	0.54	**0.03 (0.01 to 0.05)**	**0.004**
	Model B	−0.01 (−0.03 to 0.01)	0.45	0.02 (−0.003 to 0.04)	0.08	−0.01 (−0.02 to 0.01)	0.51	**0.03 (0.01 to 0.05)**	**0.007**
Waist circumference (cm)	Model A	−0.24 (−0.56 to 0.07)	0.13	**0.42 (0.07 to 0.77)**	**0.02**	0.05 (−0.30 to 0.40)	0.78	**0.71 (0.33 to 1.09)**	**<0.001**
	Model B	−0.25 (−0.56 to 0.06)	0.12	**0.43 (0.08 to 0.78)**	**0.02**	0.04 (−0.31 to 0.39)	0.83	**0.68 (0.30 to 1.05)**	**<0.001**
Triglycerides[a] (mmol·L^{-1})	Model A	0.00 (−0.05 to 0.03)	0.66	0.03 (−0.02 to 0.08)	0.24	0.00 (−0.02 to 0.02)	0.98	0.02 (−0.01 to 0.05)	0.07
	Model B	0.00 (−0.04 to 0.09)	0.65	0.03 (−0.02 to 0.08)	0.24	0.00 (−0.03 to 0.02)	0.95	0.02 (−0.03 to 0.05)	0.09
	Model C	−0.02 (−0.06 to 0.03)	0.45	0.02 (−0.03 to 0.07)	0.35	0.00 (−0.03 to 0.02)	0.86	0.01 (−0.01 to 0.04)	0.39
HDL-cholesterol[a] (mmol·L^{-1})	Model A	0.00 (−0.01 to 0.01)	0.55	0.00 (−0.02 to 0.01)	0.54	0.00 (−0.01 to 0.01)	0.93	−0.01 (−0.02 to 0.003)	0.13
	Model B	0.00 (−0.01 to 0.01)	0.50	0.00 (−0.02 to 0.01)	0.47	0.00 (−0.01 to 0.01)	0.97	0.00 (−0.02 to 0.004)	0.18
	Model C	0.00 (−0.01 to 0.01)	0.44	0.00 (−0.01 to 0.01)	0.82	0.00 (−0.01 to 0.01)	0.88	0.00 (−0.02 to 0.01)	0.54
Systolic blood pressure[b] (mm Hg)	Model A	0.43 (−0.30 to 1.15)	0.25	−0.38 (−1.20 to 0.45)	0.37	0.00 (−0.70 to 0.70)	0.99	0.63 (−0.14 to 1.40)	0.11
	Model B	0.43 (−0.30 to 1.15)	0.25	−0.38 (−1.21 to 0.45)	0.37	−0.02 (−0.72 to 0.68)	0.95	0.61 (−0.16 to 1.39)	0.12
	Model C	0.28 (−0.45 to 1.01)	0.45	−0.53 (−1.34 to 0.28)	0.20	−0.17 (−0.86 to 0.52)	0.63	0.37 (−0.39 to 1.12)	0.35
Diastolic blood pressure[b] (mm Hg)	Model A	0.37 (−0.05 to 0.80)	0.08	0.38 (−0.10 to 0.86)	0.12	0.34 (−0.06 to 0.74)	0.10	**0.48 (0.03 to 0.92)**	**0.04**
	Model B	0.38 (−0.05 to 0.80)	0.08	0.37 (−0.11 to 0.86)	0.13	0.34 (−0.07 to 0.74)	0.10	**0.47 (0.02 to 0.92)**	**0.04**
	Model C	0.29 (−0.14 to 0.71)	0.19	0.30 (−0.18 to 0.77)	0.22	0.25 (−0.15 to 0.65)	0.22	0.33 (−0.11 to 0.77)	0.15
Fasting plasma glucose (mmol·L^{-1})	Model A	0.01 (−0.03 to 0.04)	0.67	−0.02 (−0.05 to 0.02)	0.43	0.01 (−0.02 to 0.03)	0.70	0.01 (−0.02 to 0.04)	0.62
	Model B	0.01 (−0.03 to 0.04)	0.66	−0.02 (−0.06 to 0.02)	0.38	0.00 (−0.02 to 0.03)	0.77	0.01 (−0.02 to 0.03)	0.67
	Model C	0.00 (−0.04 to 0.03)	0.87	−0.02 (−0.06 to 0.02)	0.32	0.00 (−0.03 to 0.02)	0.68	0.00 (−0.03 to 0.03)	0.79

Baseline TV viewing: model A was adjusted for baseline age and cardiometabolic risk variable under study; follow-up medication for dyslipidemia[a]/hypertension[b]; and baseline education, employment status, income, cigarette smoking, alcohol, diet quality, total energy intake, and parental history of diabetes; model B was adjusted for all covariates in model A plus baseline physical activity; and model C was adjusted for all covariates in model B plus baseline waist circumference.
Change in TV viewing: model A was adjusted for baseline age, TV viewing time, and cardiometabolic risk variable under study; follow-up medication for dyslipidemia[a]/hypertension[b]; baseline and change in: education, employment status, income, cigarette smoking, alcohol, diet quality, and total energy intake; and follow-up parental history of diabetes; model B was adjusted for all covariates in model A plus baseline and change in physical activity; and model C was adjusted for all covariates in Model B plus baseline and change in waist circumference.

increased by approximately 1 h·wk^{-1} during the 5 yr in men and women (Table 2).

A comparison between participants included in the current analyses (Table 1) and those only taking part in the baseline 1999–2000 AusDiab survey (without any further exclusions) showed that men and women in the current analyses watched less TV at baseline and that women in the current analyses were more physically active at baseline. They also showed a more favorable profile for all of the cardiometabolic risk variables compared with those who took part in the baseline 1999–2000 study phase only, except for diastolic blood pressure in men, which was similar (results not shown).

Regression Models for Baseline TV Viewing Time

Results for the associations of baseline TV viewing time and continuous change in TV viewing time with change in the cardiometabolic risk variables are presented in Table 3. All regression coefficients (95% CI) in this table are expressed using a unit of 10 h·wk^{-1} for TV viewing time. No significant associations were found between baseline TV viewing time and changes in any of the cardiometabolic risk variables (Table 3).

Regression Models for Change in TV Viewing Time

Continuous TV viewing time. Increasing TV viewing time was associated with increasing waist circumference in men and women and, in addition, with increasing clustered cardiometabolic risk and diastolic blood pressure in women (Table 3, model A). These associations were unchanged after additional adjustment for physical activity (model B). Every 10-h increase in TV viewing time was, for example, associated with an average 0.43-cm increase in waist circumference in men and an average 0.68-cm increase in women. The effect of change in TV viewing time on diastolic blood pressure in women was attenuated by additional adjustment for waist circumference (model C). No significant associations were found between change in TV viewing time and change in triglycerides, HDL-cholesterol, systolic blood pressure, or fasting plasma glucose.

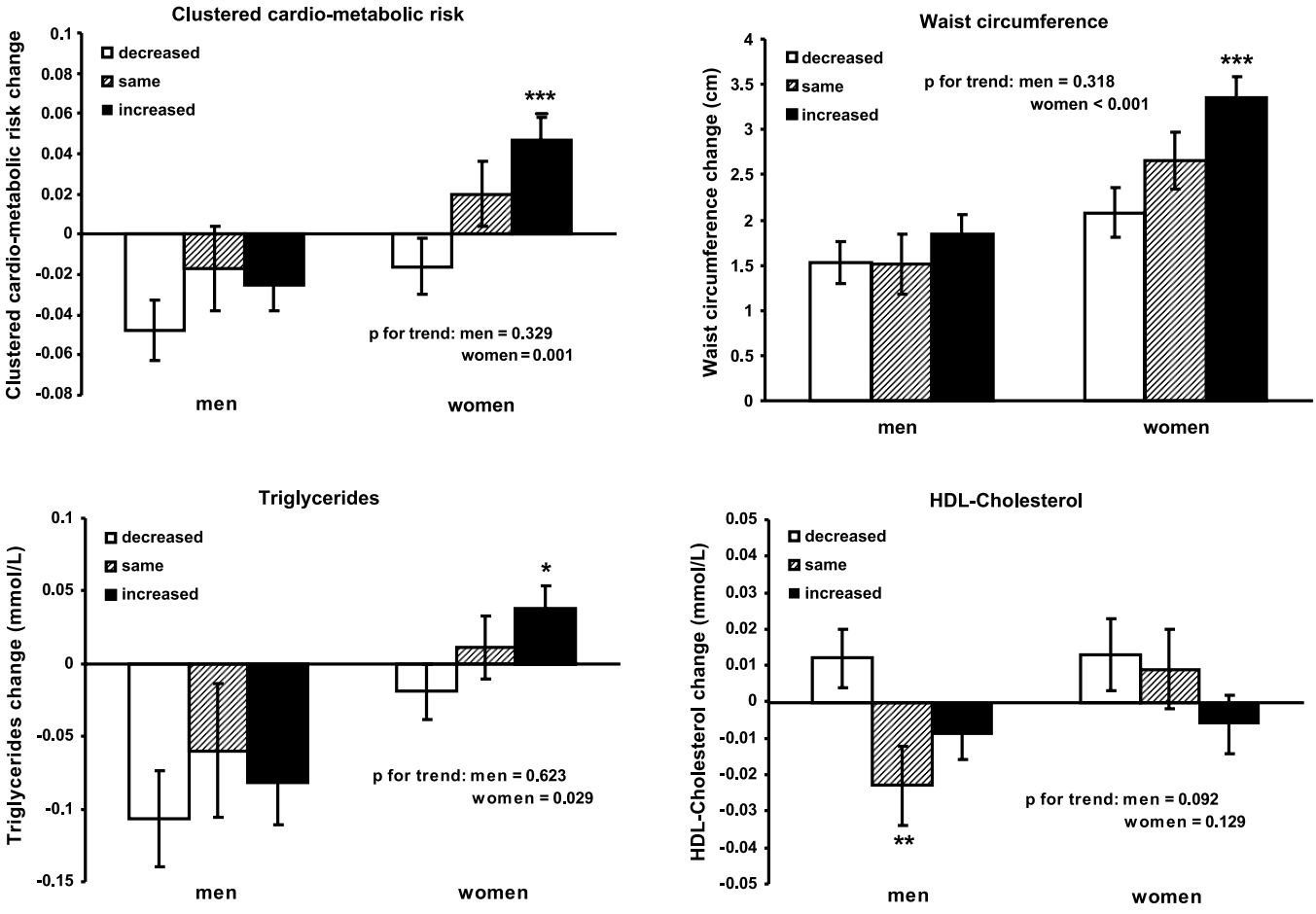

FIGURE 1—Cardiometabolic risk change comparing participants decreasing, staying the same, or increasing their TV viewing time. Participants decreasing their TV viewing time: reference group: >1 h·wk^{-1} less; those staying the same: 0 ± 1 h·wk^{-1}; those increasing their TV viewing time: >1 h·wk^{-1} more. Change is follow-up minus baseline. Data are adjusted means (SE). Models are adjusted for baseline TV viewing time; baseline age and cardiometabolic risk variable under study; baseline and change in education, employment status, income, cigarette smoking, alcohol, diet quality, energy intake, and physical activity; follow-up parental history of diabetes; and follow-up hypertension or lipid medication use (only for clustered cardiometabolic risk, triglycerides, and HDL-cholesterol). *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$.

Categorical TV viewing time. Figure 1 shows the cardiometabolic risk factors that were altered with a change in TV viewing time as a categorical variable (decreased (reference group): >1 $h \cdot wk^{-1}$ less; same: 0 ± 1 $h \cdot wk^{-1}$; increased: >1 $h \cdot wk^{-1}$ more TV viewing time). Results are shown after adjustment for physical activity (model B). Compared with women who decreased their TV viewing time (reference group), women who increased their TV viewing time significantly increased their clustered cardiometabolic risk score, waist circumference, and triglycerides. For example, women increasing their TV viewing time showed an increase in waist circumference, which was, on average, 1.3 cm higher than the increase in waist circumference seen in women decreasing their TV viewing time. The unfavorable changes in clustered cardiometabolic risk, waist circumference, and triglycerides were also evident as a trend across the three TV viewing time categories in women. Compared with men who decreased their TV viewing time, a significant decrease in HDL-cholesterol was found in men who did not change their TV viewing time.

Sensitivity Analysis

After imputing missing data, the coefficients were similar or stronger and more statistically significant compared with the results shown in Table 3 (results not shown).

DISCUSSION

In this prospective population-based cohort of Australian adults, baseline TV viewing time was not associated with subsequent 5-yr change in cardiometabolic risk. However, the change in TV viewing time during a 5-yr period was significantly positively associated with changes in waist circumference in men and women and, in addition, with clustered cardiometabolic risk and diastolic blood pressure in women. These associations were largely independent of several potential confounding factors, including physical activity and diet. The findings for change in TV viewing time are consistent with those of cross-sectional studies that have shown significant associations of sedentary time with continuous measures of these individual cardiometabolic risk variables and clustered cardiometabolic risk (16,17,30). They suggest that significant beneficial cardiometabolic effects could result from reducing time spent in TV viewing time or *vice versa*.

This is the first prospective study to examine the association between TV viewing and objectively assessed biomarkers of cardiometabolic risk. Additional strengths include the large, population-based sample covering a wide age range with similar numbers of men and women. We were also able to adjust for a variety of relevant confounding variables, including diet and physical activity. Other key strengths are the use of continuous outcome measures for the individual cardiometabolic risk variables and clustered cardiometabolic risk (26).

However, our study is not without limitations. Although the outcome measures are objectively assessed biological attributes, our findings rely on self-report indices of TV viewing time and other behavioral variables. Differences in measurement error between these self-reported behavioral variables might bias results. Measurement error in explanatory variables biases associations toward the null because of the regression dilution bias, and the greater the measurement error, the greater the bias toward the null (22). Therefore, the associations shown here may actually be underestimates of the true association. Some misclassification might also exist for those participants who did spend some of their TV viewing time in a physically active way. However, we aimed to minimize this type of misclassification by adding the following phrase to the question estimating time spent watching TV or videos: "This is when it was the main activity you were doing; for example, you would not include time when the television was switched on and you were preparing a meal." Furthermore, residual confounding might exist, especially for the categorical predictors. We had no information on parental history of cardiovascular disease but probably partially accounted for its confounding effect by adjusting for medication for dyslipidemia and hypertension at follow-up and excluding participants with self-reported angina, stroke, or myocardial infarction or were taking medications for hypertension or dyslipidemia at baseline. Similarly, we have not adjusted for prevalent musculoskeletal problems, which might possibly confound the associations examined; however, we probably partially accounted for this by adjusting for physical activity levels. Also, although TV viewing is the most prevalent leisure time sedentary behavior, and a marker of overall leisure time sedentary behavior in women (28), we have not examined total sedentary behavior. Thus, caution is needed in generalizing these results to other types of sedentary behavior (e.g., workplace sitting). Also, because TV viewing time might be associated with other sedentary behaviors (28), this may be another source of residual confounding. The sensitivity analysis, including 8078 participants (after applying the original exclusion criteria), showed similar or stronger associations, which indicates that any bias caused by missing data is likely to mean that we have underestimated, rather than overestimated, the true association. Further, the exclusion criteria for this analysis probably contributed to a disproportionally healthy cohort, shown by the difference in baseline characteristics comparing the current study group with those only participating in the baseline 1999–2000 survey without further exclusion. Therefore, the exclusion criteria might also have resulted in an underestimation of the true association. In addition, change in TV viewing time did not precede change in cardiometabolic risk, so inference about the causality of the associations found cannot be made. However, in contrast to previous cross-sectional studies that estimated the effect of TV viewing time on metabolic risk between subjects, the change models applied here estimated the effect within

subjects. Within-subject effect estimates are less prone to unmeasured time-independent confounders (e.g., genetic factors) because each subject acts as his or her own control. Between-subject estimates rely on the strong assumption that changes in risk observed between groups of individuals with low and high levels of exposure would be repeated (on average) in an individual, if that person changed his or her exposure from low to high.

Several reasons might account for the differences in results found for baseline and change in TV viewing time. First, baseline TV viewing time is a proxy measure of long-term TV viewing behavior preceding the 5-yr change in cardiometabolic risk. However, almost 80% of participants in this study either increased or decreased their TV viewing time during the 5 yr, which indicates that this is not a stable behavior (and with slightly more participants increasing their TV viewing time, which might be an age-related effect). Second, measurement error, introduced through, for example, systematic underreporting by overweight/obese subjects, is smaller for change in TV viewing compared with baseline TV viewing. This is because these individuals will underreport in a similar way at two different time points, and a difference between two time points will have lower measurement error than one single measurement (if their weight status does not change substantially from baseline to follow-up). Third, it is still unknown whether the effects of TV viewing on cardiometabolic risk are predominantly short term (<5 yr) or long term (>5 yr). Predominantly short-term effects might explain why no associations were found for baseline TV viewing time. Finally, because change in TV viewing time, in all covariates, and in cardiometabolic risk occurred concurrently during the same period, we cannot be sure about the direction of causality. However, we did adjust for baseline cardiometabolic risk, which supports unidirectional causality of the findings.

The significant positive association between change in TV viewing time and change in waist circumference and clustered cardiometabolic risk may reflect changes in energy intake, particularly that induced through snacking, while watching TV (7). Although we adjusted for overall diet quality and energy intake, the measurement tool did not specifically measure snacking. TV viewing time may be displacing physical activity, particularly light-intensity activity, which has been associated with lower waist circumference and overall cardiometabolic risk (17). Previous research has reported that sedentary time and light-intensity physical activity time are highly correlated (whereas the correlation with moderate-to-vigorous physical activity time is weak) (17). Thus, the increases in risk observed here with increased TV viewing may be due to the reduction in energy expenditure resulting from reduced time spent in light-intensity activity.

For TV viewing time as a categorical variable, significant associations were observed with triglycerides and HDL-cholesterol. Cross-sectionally, significant associations have been reported between objectively measured sedentary time and triglycerides (17) and borderline significant associations ($P < 0.1$) between sedentary time and HDL-cholesterol (11). Studies in animals have shown sensitivity of skeletal muscle lipoprotein lipase to be suppressed by muscle inactivity, resulting in a rapid local impairment in triglyceride and HDL-cholesterol metabolism (13). This process is specific to sedentary behaviors (such as TV viewing), which are characterized by absence of whole body movement and muscle contractions (13). Consistent with these experimental studies, research in free-living adults has reported that regular interruptions to sedentary time were beneficially associated with triglycerides (15).

The associations for change in TV viewing time seem stronger for women than for men, but interaction effects were nonsignificant (results not shown). At baseline, men showed more unfavorable values compared with women for several exposures (poorer diet quality, higher energy intake, more heavy smokers, and more moderate to heavy drinkers) and all outcomes. This might suggest a ceiling effect in men, through which these variables only have limited opportunity to become worse, possibly explaining the results found. Future prospective studies should further examine whether gender differences exist in the effect of TV viewing on cardiometabolic risk. Further, prospective studies in different age groups are necessary to infer whether potential effects on these cardiometabolic risk factors are age-specific. Within our study, we could not find evidence for a moderation effect by baseline age (≤45 vs >45 yr; results not shown). One longitudinal birth cohort study (14) has shown a significant association between child and adolescent TV viewing and higher serum cholesterol at age 26 yr.

This study reported that 5-yr increases in TV viewing time were significantly associated with unfavorable 5-yr changes in clustered cardiometabolic risk, waist circumference, and diastolic blood pressure, largely independent of physical activity and other potential confounding variables. Although further evidence is needed to confirm the causal nature of these associations, these findings suggest that irrespective of persons' physical activity level, an increase in their TV viewing time may have negative cardiometabolic health consequences. This supports the need to consider sedentary behavior guidelines, complementary to the established public health guidelines that exist for physical activity in adults. Interventions aiming to reduce cardiometabolic risk may need to focus on reducing TV viewing time in addition to adhering to the physical activity health guidelines.

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