Published in final edited form as:
JAMA. 2011 June 15; 305(23): 2448–2455. doi:10.1001/jama.2011.812.

Television Viewing and Risk of Type 2 Diabetes, Cardiovascular Disease, and All-Cause Mortality A Meta-analysis

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Abstract

Context—Prolonged television (TV) viewing is the most prevalent and pervasive sedentary behavior in industrialized countries and has been associated with morbidity and mortality. However, a systematic and quantitative assessment of published studies is not available.

Objective—To perform a meta-analysis of all prospective cohort studies to determine the association between TV viewing and risk of type 2 diabetes, fatal or nonfatal cardiovascular disease, and all-cause mortality.

Data Sources and Study Selection—Relevant studies were identified by searches of the MEDLINE database from 1970 to March 2011 and the EMBASE database from 1974 to March 2011 without restrictions and by reviewing reference lists from retrieved articles. Cohort studies that reported relative risk estimates with 95% confidence intervals (CIs) for the associations of interest were included.

Data Extraction—Data were extracted independently by each author and summary estimates of association were obtained using a random-effects model.

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Clinical Review Section Editor: Mary McGrae McDermott, MD, Contributing Editor. We encourage authors to submit papers for consideration as a Clinical Review. Please contact Mary McGrae McDermott, MD, at mdm608@northwestern.edu.

Author Contributions: Mr Grøntved had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Grøntved, Hu.
Acquisition of data: Grøntved, Hu.
Analysis and interpretation of data: Grøntved, Hu.
Drafting of the manuscript: Grøntved, Hu.
Critical revision of the manuscript for important intellectual content: Grøntved, Hu.
Statistical analysis: Grøntved.
Obtained funding: Grøntved, Hu.
Administrative, technical, or material support: Grøntved, Hu.
Study supervision: Hu.

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

Online-Only Material: The eFigure and eTable are available at http://www.jama.com.

Data Synthesis—Of the 8 studies included, 4 reported results on type 2 diabetes (175 938 individuals; 6428 incident cases during 1.1 million person-years of follow-up), 4 reported on fatal or nonfatal cardiovascular disease (34 253 individuals; 1052 incident cases), and 3 reported on all-cause mortality (26 509 individuals; 1879 deaths during 202 353 person-years of follow-up). The pooled relative risks per 2 hours of TV viewing per day were 1.20 (95% CI, 1.14-1.27) for type 2 diabetes, 1.15 (95% CI, 1.06-1.23) for fatal or nonfatal cardiovascular disease, and 1.13 (95% CI, 1.07-1.18) for all-cause mortality. While the associations between time spent viewing TV and risk of type 2 diabetes and cardiovascular disease were linear, the risk of all-cause mortality appeared to increase with TV viewing duration of greater than 3 hours per day. The estimated absolute risk differences per every 2 hours of TV viewing per day were 176 cases of type 2 diabetes per 100 000 individuals per year, 38 cases of fatal cardiovascular disease per 100 000 individuals per year, and 104 deaths for all-cause mortality per 100 000 individuals per year.

Conclusion—Prolonged TV viewing was associated with increased risk of type 2 diabetes, cardiovascular disease, and all-cause mortality.

Television (TV) viewing is the most commonly reported daily activity apart from working and sleeping in many populations around the world.[1-3] On average, 40% of daily free time is occupied by TV viewing within several European countries[1] and 50% in Australia.[2] This corresponds to a daily TV viewing time of about 3.5 to 4.0 hours. In the United States, the average number of daily hours of TV viewing has recently been reported to be 5 hours.[3]

Beyond altering energy expenditure by displacing time spent on physical activities, TV viewing is associated with unhealthy eating (eg, higher intake of fried foods, processed meat, and sugar-sweetened beverages and lower intake of fruits, vegetables, and whole grains) in both children and adults.[4-7] Furthermore, TV viewing may be associated with the intake of foods and beverages that are advertised on TV[4] and could attract some individuals to begin smoking.[8]

Physical inactivity, various dietary factors, and smoking are well-established independent risk factors of type 2 diabetes, cardiovascular disease, and all-cause mortality. Because TV viewing is the most prevalent and pervasive sedentary behavior, there is a great deal of interest in quantifying its independent association with health outcomes. However, a systematic and quantitative assessment of published studies is not available. Therefore, we conducted a meta-analysis to summarize all published prospective cohort studies to date on the incidence of type 2 diabetes, nonfatal or fatal cardiovascular disease, and all-cause mortality. Furthermore, we quantified the dose-response relationship of TV viewing with the risk of these health outcomes.

Methods

Search Strategy

The meta-analysis was conducted according to the checklist of the Meta-analysis of Observational Studies in Epidemiology.[9] We performed a systematic search of published studies in MEDLINE from 1970 to March 2011 and in EMBASE from 1974 to March 2011.

We used the following search terms without restrictions: *TV* or *television* or "*screen time*" and *diabetes* or *cardiovascular* or *myocardial* or *coronary* or *stroke* or *mortality* or *mortalities* or *death* or *fatal* and *risk* or *Cox* or *hazard* or "*survival analysis*" or *odds*. In addition, we reviewed the reference lists of retrieved articles to identify any studies that were not identified from the preliminary literature searches.

Inclusion Criteria

Studies were included in the meta-analysis if they met the following criteria: published in the English language, had a prospective design (cohort, case-cohort, and nested case-control), a study population that was healthy at baseline, and had estimates of relative risk (RR) or odds ratio with 95% confidence intervals (CIs) or reported data to calculate these.

Data Extraction

From each retrieved article, we extracted the following data: name of the first author, year of publication, country where the study was performed, specific outcomes, follow-up time, methods for assessment of outcome, proportion of men and women, total number of individuals, person-years of follow-up, number of cases, confounding factors that were adjusted for in the analysis, and the RRs or odds ratio estimates with corresponding 95% CIs. We extracted multivariable-adjusted estimates with and without adjustment for dietary variables and with and without adjustment for body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) or another obesity measure when available.

Data extraction was conducted independently by both authors (A.G. and F.B.H.) and any disagreements were resolved by consensus. In studies in which TV viewing was reported as hours per week or minutes per day, we converted this to hours per day. We pooled estimates of risk in increments of 2 hours of TV viewing per day. If a study did not report the association with TV viewing as a continuous variable, we estimated this using the method of generalized least squares for trend estimation described by Orsini et al.[10] For categories of TV viewing that were open (eg, 4-7 hours per day), we assigned the median values of TV viewing. If the upper bound in the highest category was not provided, we assumed that it had the same amplitude as the preceding category. This procedure also was performed for obtaining data for the dose-response meta-analysis. If the appropriate data were not obtainable, we requested the data from the study's investigators.

Statistical Analysis

We pooled RR estimates (assuming a linear relationship of the natural logarithm of RR with increasing TV viewing time and 95% CIs) from each study separately for each outcome using a random-effects meta-analysis. We evaluated the statistical heterogeneity of the RRs by calculating the I^2 statistic[11]; publication bias was assessed by using the Egger asymmetry test.[12] Low, moderate, and high degrees of heterogeneity correspond to I^2 values of 25%, 50%, and 75%, respectively. Sensitivity analyses evaluated whether the results could have been affected markedly by a single study,[13] and were repeated using a fixed-effects model.

Because obesity is a putative mediator of the association between TV viewing and respective health outcomes, we included (when possible) multivariable-adjusted models that did not adjust for BMI or another obesity measure. Whenever possible, we also separately performed a meta-analysis on the multi-variable-adjusted model with and then without adjustment for dietary variables and also with and then without BMI or other obesity measures to explore the possible mediating effect of diet, BMI, and obesity on the association of TV viewing with the study outcomes.

We then plotted the dose-response relationship based on the dose-response meta-analysis method described by Orsini et al,[10] using all available data points from each study. To flexibly plot the relationship of the natural logarithm of RRs with increasing TV viewing time without assuming linearity and to test if they were nonlinear, we added a quadratic term of TV viewing time; the changes in model fit were tested using the likelihood ratio test. For any nonlinear response, we proceeded to use piece-wise regression with an inflection point based on the best goodness-of-fit model.[10]

We calculated absolute risk differences based on the obtained summary estimate and incidence rates from the general US population using the formula: risk difference = background incidence rate × (RR-1). All statistical analyses were 2-sided and performed with Stata statistical software version 11 (StataCorp, College Station, Texas); an α level of .05 was chosen for significance.

Results

Literature Search

The results of the literature search are shown in Figure 1. We retrieved 1655 articles from our preliminary search. Of these, 10 articles were identified for full review (some reported analyses on > 1 relevant outcome). There were 4 studies reporting results on type 2 diabetes, 6 studies reporting on fatal or nonfatal cardiovascular disease, and 4 studies reporting on all-cause mortality. After full review, 1 study on incident cardiovascular disease was excluded because it was only published as an abstract[14] (this study also was a duplicate of a fatal cardiovascular disease analysis). Another study reporting on both fatal cardiovascular disease and all-cause mortality was excluded due to lack of specific report on the association with TV viewing.[15]

Of the 10 studies, 8 were included in the meta-analysis. The study by Stamatakis et al[16] on all-cause mortality and cardiovascular disease reported associations of screen time including both TV viewing and other types of screen time such as video game playing and computer use. Because total screen time predominantly stems from TV viewing, we choose to include this study.

Study Characteristics

The characteristics of the included studies are shown in the Table. For type 2 diabetes (4 studies), the total number of individuals was 175 938 with 6428 incident cases during 1.1 million person-years of follow-up. For fatal or nonfatal cardiovascular disease (4 studies), the total number of individuals was 34 253 with 1052 incident cases; there was no indication

of person-years at risk because 1 study[20] lacked that information. For all-cause mortality (3 studies), the total number of individuals was 26 509 with 1879 deaths during 202 353 person-years of follow-up. The mean (SD) follow-up duration was 8.5 (1.9) years for type 2 diabetes, 10.4 (7.4) years for fatal or nonfatal cardiovascular disease, and 6.8 (2.6) years for all-cause mortality. The number of potential confounding factors included in the multivariable-adjusted model varied (Table).

TV Viewing and Risk of Type 2 Diabetes

Figure 2 shows the results from the random-effects meta-analysis of the dose-response relationship between TV viewing and type 2 diabetes in the 4 studies. In the meta-analysis of the multivariable-adjusted estimates without adjustment for dietary variables, greater TV viewing time was associated with a higher risk of type 2 diabetes (pooled RR, 1.20 [95% CI, 1.14-1.27] per 2 hours of TV viewing time; $P < .001$) and a linear dose-response relationship was observed (Figure 3; $P = .08$ for nonlinear response; goodness-of-fit $\chi^2_{13}=20.5$, $P = .07$).

The corresponding absolute risk difference based on the most recent type 2 diabetes statistics[22] for the United States was estimated to be 176 cases per 100 000 individuals per year for every 2 hours of TV viewing per day. There was moderate heterogeneity between studies ($I^2 = 50.4\%$, $P = .11$). There was no statistical evidence of publication bias (Egger asymmetry test, $P = .21$).

Further adjusting for dietary variables slightly attenuated the risk estimate but an increased risk of type 2 diabetes remained with greater TV viewing time (pooled RR, 1.18 [95% CI, 1.12-1.25] per 2 hours of TV viewing time; $P<.001$). When individual studies were pooled with an additional adjustment for BMI or another obesity measure, the summary estimate was attenuated to 1.13 (95% CI, 1.08-1.18) per 2 hours of TV viewing time ($P<.001$).

TV Viewing and Risk of Fatal or Nonfatal Cardiovascular Disease

Longer duration of TV viewing time was associated with an increased risk of fatal or nonfatal cardiovascular disease (RR, 1.15 [95% CI, 1.06-1.23] per 2 hours of TV viewing per day; $P<.001$; Figure 2). A linear dose-response relationship was observed (Figure 3; $P = .37$ for nonlinear response; goodness-of-fit $\chi^2_{14}=22.6$, $P = .07$). The corresponding absolute risk difference based on the most recent American Heart Association cardiovascular disease mortality rate statistics for the United States[23] was estimated to be 38 cases of fatal cardiovascular disease per 100 000 individuals per year for every 2 hours of TV viewing per day. There was no heterogeneity in the individual risk estimates for fatal or nonfatal cardiovascular disease ($I^2 = 0\%$, $P = .73$) and there was no evidence of publication bias ($P = .72$).

Only the study by Wijndaele et al21 reported estimates with and without adjustment for dietary variables (total energy intake) and BMI, respectively. The 3 other studies[16,19,20] included dietary variables and BMI or waist circumference in their multivariable-adjusted model. When we repeated the meta-analysis and included the dietadjusted point estimate from Wijndaele et al,[21] the results were not substantially changed (pooled RR, 1.15 [95% CI, 1.07-1.25] per 2 hours of TV viewing time per day; $P<.001$). When the primary meta-

analysis was repeated using the BMI-adjusted estimate from Wijndaele et al,[21] the point estimate was not substantially attenuated (pooled RR, 1.14 [95% CI, 1.06-1.23] per 2 hours of TV viewing time per day; $P = .001$).

TV Viewing and Risk of All-Cause Mortality

The results from the random-effects meta-analysis of TV viewing with the risk of all-cause mortality are shown in Figure 2. Greater TV viewing time was associated with an increased risk of all-cause mortality (pooled RR, 1.13 [95% CI, 1.07-1.18] per 2 hours of TV viewing time per day; $P<.001$). The corresponding absolute risk difference based on the most recent US mortality rate statistics[24] was estimated to be 104 deaths per 100 000 individuals per year for every 2 hours of TV viewing per day. No statistical heterogeneity between studies was observed ($I^2 = 0\%$, $P = .74$) and we observed no evidence of publication bias (Egger asymmetry test, $P = .67$). The test for a nonlinear dose-response relationship was significant (likelihood ratio test, $P = .007$), suggesting curvature in the relationship (Figure 3).

In piecewise regression analysis, we obtained the best fit at an inflection point of 3 hours of TV viewing per day ($P = .01$ for difference in slopes). There was no association for up to 3 hours of TV viewing time per day with all-cause mortality. However, the RR was 1.30 (95% CI, 1.06-1.56) for greater than 3 hours of TV viewing time per day (goodness-of-fit $\chi^2_5=4.8$, $P = .45$).

Only the study by Wijndaele et al[21] reported estimates with additional adjustment for total energy intake and BMI. When the primary meta-analysis was repeated using the adjusted point estimate for energy intake from Wijndaele et al,[21] the pooled RR was 1.13 (95% CI, 1.07-1.19) per 2 hours of TV viewing time per day. When the primary meta-analysis was repeated using the BMI-adjusted point estimate from Wijndaele et al,[21] the pooled RR was 1.12 (95% CI, 1.06-1.18) per 2 hours of TV viewing time per day.

Sensitivity Analysis

The summary estimates were consistent when analyses were repeated using a fixed-effects model (eFigure at http://www.jama.com). Omitting 1 study at a time and recalculating the pooled RRs for the remainder of the studies showed that none of the individual studies substantially influenced the pooled RR for any of the outcomes (eTable at http://www.jama.com).

Comment

Our results from the meta-analysis of prospective cohort studies suggest that TV viewing is consistently associated with higher risk of type 2 diabetes, fatal or nonfatal cardiovascular disease, and all-cause mortality. We observed RRs of 1.20 for type 2 diabetes, 1.15 for cardiovascular disease, and 1.13 for all-cause mortality per every 2-hour increase in TV viewing per day. Based on incidence rates in the United States, we estimated that the absolute risk difference (cases per 100 000 individuals per year) per 2 hours of TV viewing per day was 176 for type 2 diabetes, 38 for fatal cardiovascular disease, and 104 for all-cause mortality.

The dose-response analysis revealed a linear increase in risk with the number of hours per day of TV viewing for both type 2 diabetes and cardiovascular disease; the association with all-cause mortality appeared stronger with TV viewing time of greater than 3 hours per day. However, more studies are needed on all-cause mortality to quantify with greater confidence the nature of the relationship with TV viewing.

There were some limitations to this meta-analysis. First, although not suggested by the formal statistical tests we undertook, there is still a possibility of publication bias considering that the tests were likely to be underpowered. Second, the relatively small number of studies limited our ability to identify subgroups of individuals who were more susceptible to the reported relationships. The small number of studies also limited our ability to determine whether heterogeneity in summary estimates was explained by factors related to study quality.

Third, we cannot exclude the possibility of residual confounding and bias due to misclassification. Although the included studies attempted to control for various known risk factors, the possibility of residual or unmeasured confounding cannot be ruled out. Fourth, although all of the included studies excluded participants with chronic disease at baseline, it is still possible that reverse causality may contribute to some of the associations reported herein if participants with subclinical stages of disease become more sedentary. Fifth, in all of the included studies, the assessment of TV viewing relied on self-report at baseline except for the study by Hu et al[7] and Krishnan et al,[17] in which self-report information was obtained on 5 occasions. Single-point measurement increases the chance of random-measurement error, which may underestimate the reported associations. Sixth, not all available studies controlled properly for physical activity.

Appropriate control for physical activity in an analysis with TV viewing as exposure can be performed using the isotemporal substitution model because TV viewing will displace time spent on other activities.[25] Such activities could be sleeping, physical activity at different intensities, or other activities (eg, reading). Future studies should consider several displacement options to further explore the influence of TV viewing time on health outcomes. Finally, unpublished data, non-English-language studies, and missed studies may exist and may have influenced our results.

Strengths of this study include large sample sizes, long durations of follow-up, and well-established prospective studies. In addition, our pooled estimates were based on prospective analyses with detailed adjustment for a wide range of confounding variables.

It is biologically plausible that prolonged TV viewing is associated with type 2 diabetes, cardiovascular disease, and all-cause mortality. Numerous prospective studies have reported associations of TV viewing with biological risk factors for these outcomes including obesity,[6,26,27] adverse lipid levels,[27] and clustered cardiovascular risk[28]; however, some studies did not report these associations.[29-31] Furthermore, associations of sedentary behaviors analogous to TV viewing (eg, sitting during work or while driving) with type 2 diabetes,[6] fatal or nonfatal cardiovascular disease,[32] fatal cardiovascular disease,[33,34] and all-cause mortality[33,34] have been reported in cohort studies. Experimental studies

specifically increasing exposure to inactivity are difficult to perform in humans; however, one study[35] showed detrimental changes in insulin sensitivity and postprandial lipid metabolism in participants who markedly reduced their daily steps to about 1500 per day during a 2-week period. Three randomized controlled trials have shown beneficial effects of reducing TV viewing time. One randomized school-based study of 9-year-old children (N = 192) found that reducing time of TV viewing and video game playing slowed increases in BMI and decreased the number of meals eaten in front of the TV but was not associated with change in self-reported physical activity.[36]

Another study of 70 children with BMIs above the 75th percentile showed that reducing TV viewing and computer time by 50% over 2 years resulted in a significant reduction of BMI and energy intake but did not increase objectively measured physical activity.[37] The third study was conducted in 36 overweight or obese adults and it did not find a significantly greater change in energy intake or BMI after restricting TV viewing time by 50% over a 3-week period; however, a significant increase in objectively measured energy expenditure was observed.[38] These short-term experimental studies suggest that reducing TV viewing time may lead to improvement in diet, physical activity, or BMI.

Because TV viewing is often accompanied by concurrent intake of foods[4,5] and food advertising on TV may promote an unhealthy diet,[39] it is possible that some of the associations reported herein are explained by diet. We attempted to explore whether these associations were mediated by diet and observed a small attenuation of effect estimates for type 2 diabetes but not for cardiovascular disease or all-cause mortality after pooling the available estimates with additional adjustment for dietary variables.

Because positive associations with TV viewing were observed in European, Australian, and US populations, who are subject to different amounts and types of food advertisements on TV, we do not believe that the associations are completely explained by changes in dietary behaviors induced by TV advertisement. However, we found that adjustment for BMI attenuated the association between TV viewing and the risk of type 2 diabetes.

Additional research quantifying the mediating influence of diet and physical inactivity is warranted. Future research also should assess the association of prolonged daily use of new media devices on energy balance and chronic disease risk.

In conclusion, findings from this meta-analysis of prospective studies suggest that longer duration of TV viewing time is consistently associated with higher risk of type 2 diabetes, fatal or nonfatal cardiovascular disease, and all-cause mortality. Further study is needed to determine whether reducing prolonged TV viewing can prevent chronic disease morbidity and mortality.

Acknowledgments

Funding/Support: Mr Grøntved is supported by the Danish Heart Foundation, Sygekassernes Helsefond (the Danish Health Fund), the Oticon Foundation, and the Augustinus Foundation. Dr Hu is supported by National Institutes of Health grant DK58845 and P30 DK46200.

Role of the Sponsor: None of the funding sponsors was involved in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript.

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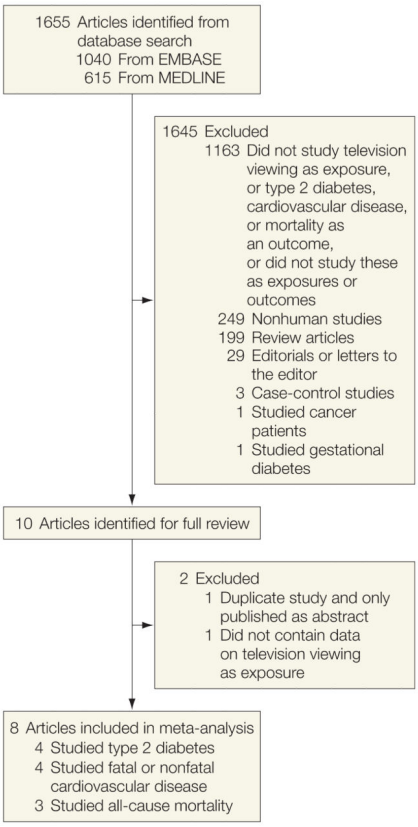

Figure 1. Selection of Studies Included in the Meta-analysis

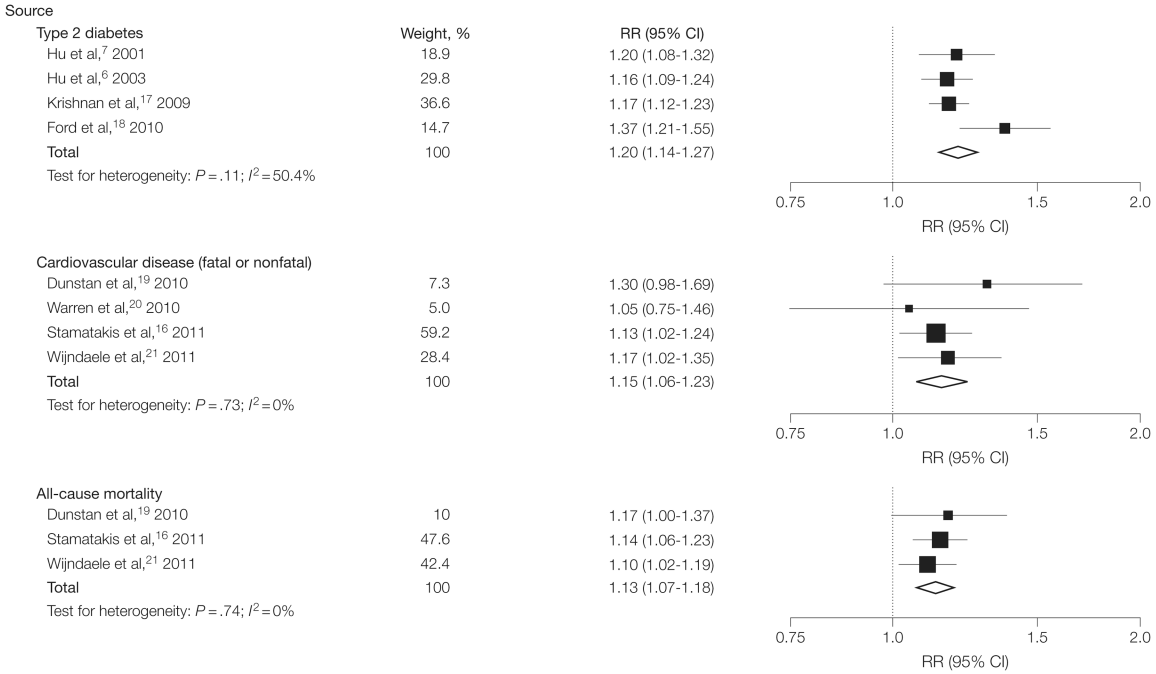

Figure 2. Risk of Type 2 Diabetes, Cardiovascular Disease, and All-Cause Mortality

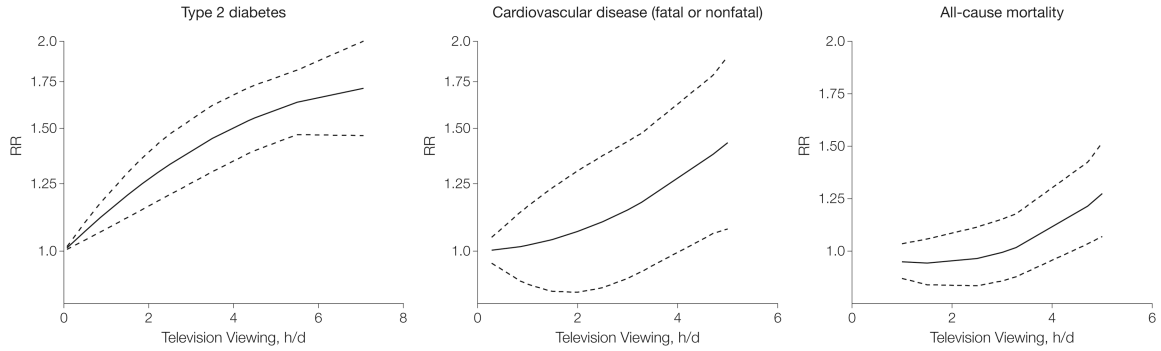

Figure 3. Dose-Response Relationship Between Television Viewing and Risk of Type 2 Diabetes, Cardiovascular Disease, All-Cause Mortality

Table

Characteristics of the Studies Included in the Meta-analysis

Source and Study Location	Ratio of Males to Females, %	Age at Baseline, y	Follow-up, y	Total No. of Individuals/ Person-Years	No. of Cases	Outcome Assessment	Adjustment for Confounders
Type 2 diabetes							
Hu et al,[7] 2001; United States	100:0	40-75	10[a]	37 918/347 040	1058	Self-report	Age, length of smoking, parental history of diabetes, alcohol consumption, total physical activity; and intakes of saturated fat, monounsaturated fat, polyunsaturated fat, *trans*-fatty acids, and cereal fiber
Hu et al,[6] 2003; United States	0:100	30-55	6[a]	68 497/396 900	1515	Self-report	Age, hormone use, family history of diabetes, alcohol consumption, total physical activity, glycemic load; and intakes of polyunsaturated fatty acid, cereal fiber, and *trans*-fatty acids
Krishnan et al,[17] 2009; United States	0:100	21-69	10[a]	45 668/182 994	2928	Self-report	Age, family history of diabetes, years of education, family income, marital status, smoking status, alcohol consumption, energy intake, coffee consumption, vigorous physical activity, and walking as physical activity
Ford et al,[18] 2010; Germany	38:62	35-65	7.8[b]	23 855/156 358	927	Self-report	Age, sex, educational status, occupational physical activity, smoking status, alcohol consumption, and leisure-time physical activity
Cardiovascular disease (fatal or nonfatal)							
Dunstan et al,[19] 2010; Australia	44:56	≥25	6.6[c]	8800/58 087	87	Registry	Age, sex, smoking status, educational level, total energy intake, alcohol intake, diet-quality index, waist circumference, hypertension, total cholesterol, HDL cholesterol, triglycerides, lipid-lowering medication use, and glucose-tolerance status
Warren et al,[20] 2010; United States	100:0	20-89	21[a]	7744/NA	377	Registry	Age, physical activity, smoking status, alcohol consumption, BMI, family history of cardiovascular disease, hypertension, diabetes, and hypercholesterolemia
Stamatakis et al,[16] 2011; Scotland	43:57	≥35	4.3 (0.5)[d]	4512/19 364	215	Registry	Age, sex, BMI, smoking status, marital status, ethnicity, social class, long-standing illness, occupational physical activity, physician-diagnosed diabetes and hypertension, and moderate and vigorous physical activity
Wijndaele et al,[21] 2011; United Kingdom	43:57	45-79	9.5 (1.6)[d]	13 197/124 902	373	Registry	Age, sex, educational level, smoking status, alcohol consumption, medication for hypertension, medication for dyslipidemia, baseline history of diabetes, family history of

Source and Study Location	Ratio of Males to Females, %	Age at Baseline, y	Follow-up, y	Total No. of Individuals/ Person-Years	No. of Cases	Outcome Assessment	Adjustment for Confounders
							cardiovascular disease, family history of cancer, total physical activity energy expe
							cardiovascular disease, family history of cancer, total physical activity energy expe
All-cause mortality							
Dunstan et al,[19] 2010; Australia	44:56	≥25	6.6[c]	8800/58 087	284	Registry	Age, sex, smoking status, education, total energy intake, alcohol intake, diet-quality index, waist circumference, hypertension, total cholesterol, HDL cholesterol, triglycerides, lipid-lowering medication use, and glucose tolerance status
Stamatakis et al,[16] 2011; Scotland	43:57	≥35	4.3 (0.5)[d]	4512/19 364	325	Registry	Age, sex, BMI, smoking status, marital status, ethnicity, social class, long-standing illness, occupational physical activity, physician-diagnosed diabetes and hypertension, and moderate and vigorous physical activity
Wijndaele et al,[21] 2011; United Kingdom	43:57	45-79	9.5 (1.6)[d]	13 197/124 902	1270	Registry	Age, sex, educational level, smoking status, alcohol consumption, medication for hypertension, medication for dyslipidemia, baseline history of diabetes, family history of cardiovascular disease, family history of cancer, total physical activity energy expenditure, and total energy intake

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); HDL, high-density lipoprotein; NA, data not available.

[a] Either mean or median follow-up time were not specified by the study's authors.

[b] Value expressed as mean.

[c] Value expressed as median.

[d] Value expressed as mean (SD).