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

Anders Grøntved, MPH, MSc
Frank B. Hu, MD, PhD

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.

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.

JAMA. 2011;305(23):2448-2455 www.jama.com

Author Affiliations: Institute of Sport Science and Clinical Biomechanics, Department of Exercise Epidemiology, Center of Research in Childhood Health, University of Southern Denmark, Odense (Mr Grøntved); and Departments of Nutrition (Mr Grøntved and Dr Hu) and Epidemiology (Dr Hu), Harvard School of Public Health, Channing Laboratory, Harvard Medical School and Brigham and Women’s Hospital (Dr Hu), Boston, Massachusetts.

Corresponding Author: Frank B. Hu, MD, PhD, Harvard School of Public Health, 655 Huntington Ave, Boston, MA 02115 (frank.hu@channing.harvard.edu).

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 mmd608@northwestern.edu.
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. 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 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. 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 I² statistic; publication bias was assessed by using the Egger asymmetry test. Low, moderate, and high degrees of heterogeneity correspond to I² values of 25%, 50%, and 75%, respectively. Sensitivity analyses evaluated whether the results could have been affected markedly by a single study, 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 multivariable-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, 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 piecewise regression with an inflection point based on the best goodness-of-fit model.

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.
Of the 10 studies, 8 were included in the meta-analysis. The study by Stamatelis et al 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 175938 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 34253 with 1052 incident cases; there was no indication of person-years at risk because 1 study lacked that information. For all-cause mortality (3 studies), the total number of individuals was 26509 with 1879 deaths during 202353 person-years of follow-up. The mean (SD) follow-up duration was 8.5 (7.4) 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 per day; \( P = .001 \)). 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 per day (\( P = .001 \)).

**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; \( P = .01 \); **FIGURE 2**). A linear dose-response relationship was observed (**FIGURE 3**: \( P = .07 \) for nonlinear response; goodness-of-fit \( \chi^2_{df} = 22.6, P = .07 \)). The corresponding absolute risk difference based on the most recent American Heart Association cardiovascular disease mortality rate statistics for the United States was estimated to be 28 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 (\( F = 0 \%), \( P = .73 \)) and there was no evidence of publication bias (\( P = .72 \)).

Only the study by Wijndaele et al reported estimates with and without adjustment for dietary variables (total energy intake) and BMI, respectively. The 3 other studies included dietary variables and BMI or waist circumference in their multivariable-adjusted model. When we repeated the meta-analysis and included the diet-adjusted point estimate from Wijndaele
### Table. Characteristics of the Studies Included in the Meta-analysis

<table>
<thead>
<tr>
<th>Source and Study Location</th>
<th>Ratio of Males to Females, %</th>
<th>Age at Baseline, y</th>
<th>Follow-up, y</th>
<th>Total No. of Individuals/Person-Years</th>
<th>No. of Cases</th>
<th>Outcome Assessment</th>
<th>Adjustment for Confounders</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type 2 diabetes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hu et al, 2001; United States</td>
<td>100:0</td>
<td>40-75</td>
<td>10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>37 918/347 040</td>
<td>1058</td>
<td>Self-report</td>
<td>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</td>
</tr>
<tr>
<td>Hu et al, 2003; United States</td>
<td>0:100</td>
<td>30-55</td>
<td>6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>68 497/396 900</td>
<td>1515</td>
<td>Self-report</td>
<td>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</td>
</tr>
<tr>
<td>Krishnan et al, 2009; United States</td>
<td>0:100</td>
<td>21-69</td>
<td>10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45 668/182 994</td>
<td>2928</td>
<td>Self-report</td>
<td>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</td>
</tr>
<tr>
<td>Ford et al, 2010; Germany</td>
<td>38:62</td>
<td>35-65</td>
<td>7.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>23 855/156 358</td>
<td>927</td>
<td>Self-report</td>
<td>Age, sex, educational status, occupational physical activity, smoking status, alcohol consumption, and leisure-time physical activity</td>
</tr>
<tr>
<td><strong>Cardiovascular disease (fatal or nonfatal)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dunstan et al, 2010; Australia</td>
<td>44:56</td>
<td>≥25</td>
<td>6.6&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8800/58 087</td>
<td>87</td>
<td>Registry</td>
<td>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</td>
</tr>
<tr>
<td>Warren et al, 2010; United States</td>
<td>100:0</td>
<td>20-89</td>
<td>21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7744/NA</td>
<td>377</td>
<td>Registry</td>
<td>Age, physical activity, smoking status, alcohol consumption, BMI, family history of cardiovascular disease, hypertension, diabetes, and hypercholesterolemia</td>
</tr>
<tr>
<td>Stamatakis et al, 2011; Scotland</td>
<td>43:57</td>
<td>≥35</td>
<td>4.3 (0.5)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4512/19 364</td>
<td>215</td>
<td>Registry</td>
<td>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</td>
</tr>
<tr>
<td>Wijndaele et al, 2011; United Kingdom</td>
<td>43:57</td>
<td>45-79</td>
<td>9.5 (1.6)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>13 197/124 002</td>
<td>373</td>
<td>Registry</td>
<td>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</td>
</tr>
<tr>
<td><strong>All-cause mortality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dunstan et al, 2010; Australia</td>
<td>44:56</td>
<td>≥25</td>
<td>6.6&lt;sup)c&lt;/sup&gt;</td>
<td>8800/58 087</td>
<td>284</td>
<td>Registry</td>
<td>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</td>
</tr>
<tr>
<td>Stamatakis et al, 2011; Scotland</td>
<td>43:57</td>
<td>≥35</td>
<td>4.3 (0.5)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4512/19 364</td>
<td>325</td>
<td>Registry</td>
<td>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</td>
</tr>
<tr>
<td>Wijndaele et al, 2011; United Kingdom</td>
<td>43:57</td>
<td>45-79</td>
<td>9.5 (1.6)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>13 197/124 002</td>
<td>1270</td>
<td>Registry</td>
<td>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</td>
</tr>
</tbody>
</table>

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

<sup>a</sup>Value expressed as mean.

<sup>b</sup>Value expressed as median.

<sup>c</sup>Value expressed as mean.

<sup>d</sup>Value expressed as mean (SD).
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).

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

<table>
<thead>
<tr>
<th>Source</th>
<th>Weight (%)</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type 2 diabetes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hu et al,6 2001</td>
<td>16.9</td>
<td>1.20 (1.08-1.32)</td>
</tr>
<tr>
<td>Hu et al,² 2003</td>
<td>29.0</td>
<td>1.16 (1.09-1.24)</td>
</tr>
<tr>
<td>Krishnan et al,¹⁷ 2009</td>
<td>36.5</td>
<td>1.17 (1.12-1.23)</td>
</tr>
<tr>
<td>Ford et al,¹⁸ 2010</td>
<td>14.7</td>
<td>1.37 (1.21-1.55)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
<td>1.20 (1.14-1.27)</td>
</tr>
</tbody>
</table>

Cardiovascular disease (fatal or nonfatal)

<table>
<thead>
<tr>
<th>Source</th>
<th>Weight (%)</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunstan et al,19 2010</td>
<td>7.3</td>
<td>1.30 (0.98-1.69)</td>
</tr>
<tr>
<td>Warren et al,20 2010</td>
<td>5.0</td>
<td>1.05 (0.75-1.46)</td>
</tr>
<tr>
<td>Stamatakis et al,16 2011</td>
<td>59.2</td>
<td>1.13 (1.02-1.24)</td>
</tr>
<tr>
<td>Wijndaele et al,²¹ 2011</td>
<td>28.4</td>
<td>1.17 (1.02-1.35)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
<td>1.15 (1.06-1.23)</td>
</tr>
</tbody>
</table>

All-cause mortality

<table>
<thead>
<tr>
<th>Source</th>
<th>Weight (%)</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunstan et al,19 2010</td>
<td>10</td>
<td>1.17 (1.00-1.37)</td>
</tr>
<tr>
<td>Stamatakis et al,16 2011</td>
<td>47.6</td>
<td>1.14 (1.06-1.23)</td>
</tr>
<tr>
<td>Wijndaele et al,²¹ 2011</td>
<td>42.4</td>
<td>1.10 (1.02-1.19)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
<td>1.13 (1.07-1.18)</td>
</tr>
</tbody>
</table>

The summary estimates were obtained using a random-effects model. The data markers indicate the adjusted relative risks (RRs) per 2 hours of television viewing per day. The size of the data markers indicates the weight of the study. The diamond data markers indicate the pooled RRs. CI indicates confidence interval.

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

Dotted lines represent the 95% confidence intervals for the fitted trend. The dose-response relationship plot between television (TV) viewing (hours per day) and risk of type 2 diabetes (4 studies), cardiovascular disease (4 studies), and all-cause mortality (3 studies) was estimated with random-effects meta-regression,¹⁰ which allowed for a nonlinear response by including a quadratic term of TV viewing time. The test for a nonlinear relationship was only significant for all-cause mortality (P=.007). In subsequent piecewise regression, the best model fit was obtained at an inflection point of 3 hours of TV viewing per day (P=.01 for difference in slopes).
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\(^2\) 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 \( \chi^2 = 4.8 \), \( P = .45 \)).

Only the study by Wijndaele et al\(^\text{21}\) 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,\(^\text{21}\) 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,\(^\text{21}\) 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,\(^1^\) 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.\(^2^5\) 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,\(^6^,\) adverse lipid levels,\(^2^7\) and clustered cardiovascular risk\(^2^8\); however, some studies did not report these associations.\(^2^9^,\)\(^3^1\) Furthermore, associations of sedentary behaviors analogous to TV viewing (eg, sitting during work or while driving) with type 2 diabetes,\(^6\) fatal or nonfatal

©2011 American Medical Association. All rights reserved.
cardiovascular disease,32 fatal cardiovascular disease,13,34 and all-cause mortality33,34 have been reported in cohort studies. Experimental studies specifically increasing exposure to inactivity are difficult to perform in humans; however, one study35 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 foods45 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.

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.

Funding/Support: Mr Grøntved is supported by the Danish Heart Foundation, Sygekassernes Helsesond (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.

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

REFERENCES


19. Dunstan DW, Barr ELM, Healy GN, et al. Television...


Every nail driven should be as another rivet in the machine of the universe, you carrying on the work.

—Henry David Thoreau (1817-1862)