Systematic Reviews and Meta- and Pooled Analyses

Association Between Television Viewing Time and All-Cause Mortality: A Meta-Analysis of Cohort Studies

Jiang-Wei Sun, Long-Gang Zhao, Yang Yang, Xiao Ma, Ying-Ying Wang, and Yong-Bing Xiang*

* Correspondence to Prof. Yong-Bing Xiang, Shanghai Cancer Institute, Renji Hospital, School of Medicine, Shanghai Jiaotong University, No. 25 Lane 2200, Xie Tu Road, Shanghai 200032, People's Republic of China (e-mail: ybxiang@shsci.org).

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Findings on the association between television (TV) viewing and all-cause mortality in epidemiologic studies have been inconsistent. Therefore, we conducted a meta-analysis of data from prospective cohort studies to quantify this association. Relevant articles were identified by searching MEDLINE (PubMed; National Library of Medicine, Bethesda, Maryland) and EMBASE (Elsevier B.V., Amsterdam, the Netherlands) from inception to March 1, 2015, and reviewing the reference lists of retrieved articles. Study-specific results were pooled using a random-effects model. Of 2,578 citations identified by the search strategy, 10 cohort studies (61,494 deaths among 647,475 individuals) met the inclusion criteria. The summary relative risk of all-cause mortality for the highest category of TV viewing time versus the lowest was 1.33 (95% confidence interval: 1.20, 1.47), with heterogeneity among studies ($I^2 = 66.7\%$, $P_{\text{heterogeneity}} = 0.001$). In dose-response meta-analysis, TV viewing time was statistically significantly associated with all-cause mortality risk in a J-shaped fashion ($P_{\text{nonlinearity}} = 0.001$). These results indicate that prolonged TV viewing time might increase the risk of all-cause mortality. Given the high prevalence of excessive TV viewing, public health recommendations or interventions aimed at decreasing the amount of TV viewing time in modern societies are warranted.

Sedentary behavior is characterized by any waking activity that requires an energy expenditure of 1.0–1.5 times the average basal metabolic rate and a sitting or reclining posture (1, 2). It has increasingly gained attention as an independent behavioral risk factor for the development of chronic illness (3), particularly given its high prevalence (4).

Television (TV) viewing has been reported to be the predominant leisure-time sedentary behavior in many populations around the world (5, 6). Largely in the past decade, cross-sectional and prospective evidence has burgeoned on the possible detrimental health impact of TV viewing time, such as weight gain (7, 8), obesity (9, 10), type 2 diabetes (11), insulin resistance (12), endometrial (13, 14) and colon (15) cancers, and cardiovascular risk biomarkers (16, 17). This kind of detrimental impact of TV viewing has also been observed in physically active adults (18, 19).

The relationship between TV viewing time and all-cause mortality has been investigated in many epidemiologic studies, but findings remain inconsistent (16, 20–27). When Grontved and Hu (29) combined the results of 3 cohort studies in a meta-analysis published in 2011, they found that prolonged TV viewing time was modestly associated with an increased risk of all-cause mortality (per 2 additional hours of TV viewing per day, relative risk (RR) = 1.13, 95% confidence interval (CI): 1.07, 1.18). However, the relatively small number of studies limited the statistical power of the analysis and the authors’ capacity to perform subgroup and dose-response analyses. Since 2011, 6 additional cohort studies on the association between TV viewing time and all-cause mortality have been published (20–25). Therefore, we carried out a meta-analysis to update the previous one and to explore the magnitude and shape of the association between TV viewing time and all-cause mortality.
Methods

Literature search

We searched MEDLINE (PubMed; National Library of Medicine, Bethesda, Maryland) and EMBASE (Elsevier B.V., Amsterdam, the Netherlands) from inception to March 1, 2015, with the terms “TV [or television] time,” “screen time,” or “sedentary behavior,” together with either “mortality” or “death.” The search strategy is given in detail in the Web Appendix (available at http://aje.oxfordjournals.org/). The reference lists of relevant publications were also screened for qualifying studies.

Study selection criteria

Studies were included in our meta-analysis if the investigators had used a prospective study design and had presented estimates of relative risk with 95% confidence intervals or had reported data with which to calculate these. When multiple publications on the same study population were available, the publication with longer follow-up and more applicable information was selected for our meta-analysis.

Data extraction

For each qualifying cohort study, we extracted information on first author’s surname, year of publication, study location, name of the study, study size (number of deaths and total number of participants), age range or mean age of participants, sex distribution, duration of follow-up, definition and measurement of TV viewing time, relative risks and their 95% confidence intervals, and adjustment variables used in the study. A single author (J.-W.S.) extracted the data, which were double checked by another author (L.-G.Z.). Discrepancies were resolved through discussion.

Statistical analysis

Categorical and dose-response meta-analyses were conducted to evaluate associations between TV viewing time and all-cause mortality. Most studies combined males and females together, but in some studies they were classified separately. For studies that reported results separately for males and females, we pooled the results to obtain an overall estimate before combining the results with those from the rest of the studies. We used random-effects models to calculate summary relative risks and 95% confidence intervals for the highest level of TV viewing time versus the lowest, which considered both within- and between-study variation (30). To assess heterogeneity in the results of individual studies, we used Cochran’s Q test and I² statistics ($P < 0.10$ or $I^2 > 50\%$ was used as a threshold indicating statistically significant heterogeneity) (31). Heterogeneity between subgroups was evaluated by meta-regression. To examine the robustness of primary results, we conducted analyses stratified by study location, follow-up period, size of the cohort, and method of exposure assessment. We also conducted analyses stratified by whether the investigators had adjusted for potential confounders, including diet quality index, alcohol consumption, body mass index (weight (kg)/height (m)$^2$), physical activity, energy intake, ethnicity, history of diabetes, and history of hypertension.

For dose-response analysis, the numbers of deaths and persons/person-years for at least 3 TV viewing time categories and the mean or median values of the categories or, if these were not reported in the studies, the estimated midpoints of the categories had to be available. When the highest categories were open-ended, we assumed that the open-ended categories were of the same amplitude as the adjacent categories (32). We performed a 2-stage random-effects dose-response meta-analysis to examine the potential trend between TV viewing time and all-cause mortality (33, 34). This was applied by modeling TV viewing time using a restricted cubic spline model with 3 knots (2 spline transformations) chosen at the 10th, 50th, and 90th percentiles of the exposure distribution (35). In the first stage, we fitted a restricted cubic spline model to estimate the 2 study-level coefficients and the within-study covariance matrix by taking into account the correlation within each set of specific relative risks (33, 34). In the second stage, we derived the overall estimates with random effects by pooling the study-specific coefficient estimates and variance/covariance matrices that had been obtained in the first stage (36). A $P$ value for nonlinearity was calculated to test the hypothesis that the coefficient associated with the second spline was different from 0 (34).

Moreover, we first conducted sensitivity analyses by omitting one study at a time to explore whether summary relative risks were strongly influenced by a specific study (37). Second, to minimize reverse causality effects, we conducted sensitivity analyses by restricting analyses to studies that provided estimates with exclusion of early deaths. Publication bias was assessed using Egger’s test (38) and Begg’s test (39). All statistical analyses were performed with Stata, version 12 (StataCorp LP, College Station, Texas). A $P$ value of $<0.05$ was considered statistically significant, and all statistical tests were 2-sided.

Results

Literature search

Our search strategy identified 2,578 potentially relevant articles, the titles and abstracts of which were screened for inclusion. The full texts of 86 articles were retrieved, of which 10 (16, 20–28) met the inclusion criteria (Figure 1). Reasons for exclusion of the remaining articles included: the exposure was not TV viewing ($n = 46$), the outcome was not mortality ($n = 14$), or the study was a review ($n = 16$). We included studies that had considered “watching TV or video or using a computer” to be “screen time” (25, 26) in our meta-analysis because total screen time stemmed predominantly from TV viewing.

Study characteristics

Ten cohort studies on the relationship between TV viewing and all-cause mortality (61,494 deaths among 647,475 individuals) were published between 2007 and 2015 (Web Table 1). Four studies were conducted in the United States.
(20, 23–25), 3 in Europe (16, 21, 22), 2 in Australia (26, 27), and 1 in Asia (28). Of the 10 studies, 3 (20, 23, 28) reported outcomes for men and women separately, while 7 provided data for both sexes combined. Sample sizes ranged from 4,512 (26) to 240,819 (24), and the median follow-up time varied from 3.3 years (22) to 13.7 years (23). Some studies adjusted for sex (n = 8), alcohol consumption (n = 4), energy intake (n = 3), body mass index (n = 5), physical activity (n = 8), history of diabetes (n = 5), history of hypertension (n = 4), and ethnicity (n = 3).

**TV viewing time and total mortality**

**Categorical meta-analysis.** In combined estimates for the highest category versus the lowest, TV viewing time was associated with all-cause mortality risk (RR = 1.33, 95% CI: 1.20, 1.47), with substantial heterogeneity among studies ($I^2 = 66.7\%, P_{\text{heterogeneity}} = 0.001$) (Figure 2). No significant publication bias was observed according to the funnel plot (Web Figure 1), Begg’s test ($P = 0.180$), or Egger’s test ($P = 0.737$).

**Dose-response meta-analysis.** Three studies (16, 20, 23) could not be included in the dose-response meta-analysis because the numbers of deaths or participants in each category were not available. In dose-response meta-analysis, TV viewing time was significantly associated all-cause mortality risk in a J-shaped fashion, and the nonlinear trend was significant ($P_{\text{nonlinearity}} = 0.001$; Figure 3). A significantly increased risk (RR = 1.12, 95% CI: 1.00, 1.25) was detected at a daily TV viewing time of 4 hours, followed by a continuously increasing risk with ascending exposure level (Figure 3).

**Subgroup and sensitivity analyses**

In subgroup analyses of the relationship of TV viewing time with all-cause mortality (Table 1), all strata showed significant positive associations, except for the study conducted in Asia (28). Authors of Australian studies tended to report stronger associations, while studies that adjusted for possible confounding factors (e.g., alcohol consumption, energy intake, diabetes, hypertension, or ethnicity) tended to find slightly weaker associations than those that did not adjust for those variables. For studies that adjusted for body mass index, the pooled relative risk was 1.34 (95% CI: 1.21, 1.48; $I^2 = 2.1\%, P_{\text{heterogeneity}} = 0.395$), which was similar to that for studies that did not adjust for body mass index (RR = 1.32, 95% CI: 1.12, 1.55; $I^2 = 82.5\%, P_{\text{heterogeneity}} < 0.001$). We detected significant heterogeneity in the subgroup stratified according to whether the original study adjusted for diet quality index ($P_{\text{heterogeneity}} = 0.002$). In studies that adjusted for diet quality index, the pooled relative risk was 1.59 (95% CI: 1.46, 1.73), with little heterogeneity ($I^2 = 0.0\%, P_{\text{heterogeneity}} = 0.589$).
The positive association was attenuated when the analysis was restricted to the studies that did not adjust for diet quality index (RR = 1.26, 95% CI: 1.18, 1.34; $I^2 = 13.1\%$, $P_{\text{heterogeneity}} = 0.330$).

In the sensitivity analysis, summary estimates remained statistically significant when each study was omitted in turn. The pooled relative risks for all-cause mortality ranged from 1.26 (95% CI: 1.19, 1.34; the study by Matthews et al. (24) was excluded) to 1.36 (95% CI: 1.21, 1.51; the study by Wijndaele et al. (16) was excluded). When we restricted the analyses to the 6 studies that excluded early deaths to minimize the effect of reverse causality (21, 23–27), the results were not substantially changed (RR = 1.48, 95% CI: 1.25, 1.76; $I^2 = 62.0\%$, $P_{\text{heterogeneity}} = 0.022$). We also chose 4 studies (25–28) that used identical categories (<2, 2–4, or ≥4 hours/day), with TV viewing time of <2 hours per day as the reference category; the results were robust, and the summary relative risk was 1.23 (95% CI: 1.08, 1.39; $I^2 = 0.0\%$, $P_{\text{heterogeneity}} = 0.425$).

**DISCUSSION**

The primary finding from our meta-analysis is that prolonged TV viewing is associated with a higher risk of all-cause mortality in the general population. Comparing persons in the highest category of TV viewing time with those in the lowest, the risk of all-cause mortality was increased by 33%. In dose-response meta-analysis, TV viewing time was associated with all-cause mortality in a J-shaped fashion, with a significantly increased risk at approximately 4 hours per day. Additionally, the direction of the association was markedly consistent across almost all strata in subgroups and sensitivity

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**Figure 2.** Relative risk (RR) of all-cause mortality for the highest category of television viewing time versus the lowest in a meta-analysis of 10 cohort studies, 2007–2015. Squares indicate study-specific relative risks (the size of each square reflects the study-specific statistical weight, i.e., the inverse of the variance); horizontal lines represent study-specific 95% confidence intervals (CIs); and the diamond indicates the summary relative risk estimate and its 95% CI.

**Figure 3.** Relative risk of all-cause mortality according to television viewing time in a meta-analysis of 7 cohort studies, 2007–2015. CI, confidence interval.
Table 1. Relative Risk of All-Cause Mortality for Persons in the Highest Category of Television Viewing Time Versus Those in the Lowest Category in a Meta-Analysis, by Study Characteristic, 2007–2015

<table>
<thead>
<tr>
<th>Study Characteristic</th>
<th>No. of Studies</th>
<th>Pooled RR</th>
<th>95% CI</th>
<th>I², %</th>
<th>( P_{\text{heterogeneity}} )</th>
<th>( P_{\text{heterogeneity}} )</th>
</tr>
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<td>All studies</td>
<td>10</td>
<td>1.33</td>
<td>1.20, 1.47</td>
<td>66.7</td>
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<td>Europe</td>
<td>3</td>
<td>1.20</td>
<td>1.07, 1.36</td>
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<td>America</td>
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<td>1.21, 1.46</td>
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<td>≥8</td>
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<td>80.6</td>
<td>&lt;0.001</td>
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</table>

Abbreviations: CI, confidence interval; NA, not available; RR, relative risk; TV, television.

\( P_{\text{heterogeneity}}^a \) value for heterogeneity within each subgroup.

\( P_{\text{heterogeneity}}^b \) value for heterogeneity between subgroups in meta-regression analysis.

Studies that considered “watching TV or video or using a computer” to be “screen time” were included in the meta-analysis, since screen time predominantly stemmed from TV viewing.

\( d \) Weight (kg)/height (m)².

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analyses, adding further support to our main conclusion that TV viewing time might be an independent risk factor for all-cause mortality. As compared with the previous quantitative review of 3 studies by Grøntved and Hu (29), our meta-analysis of 10 published cohort studies produced a somewhat weaker association.

It is plausible that prolonged TV viewing time may increase all-cause mortality risk by increasing the risk of major chronic diseases, including cardiovascular disease (40, 41), obesity (9, 10), cancer (13–15), and type 2 diabetes (11). For example, sedentary behaviors, particularly TV viewing, may promote obesity and weight gain, which are related to increased risk of mortality, through increased energy intake (42–44). Furthermore, associations between sedentary behaviors analogous to TV viewing (e.g., sitting or driving) and type 2 diabetes (45), cardiovascular disease (46, 47), and all-cause mortality (19, 47, 48) have also been reported in perspective studies. Results from bed-rest studies or animal experiments have provided further insight into the etiological mechanisms linking sedentary behavior to mortality. In one human bed-rest trial, van der Ploeg et al. (49) found that inactivity had metabolic consequences, including insulin resistance and dysglycemia. In another trial, Hamburg et al. (50) found that 14 days of bed rest in young volunteers resulted in a proinflammatory response, with increased circulating levels of C-reactive protein and interleukin 6. Animal studies by Hamilton et al. (51, 52) have shown that the acute drop in skeletal muscle lipoprotein lipase activity caused by muscle inactivity (which typically occurs while sitting or lying down) can disrupt triglyceride metabolism and high-density lipoprotein cholesterol metabolism and result in elevated glucose levels. Such events can potentially create a milieu that is conductive to the development of coronary heart disease and cardiovascular risk factors (53). Overall, evidence from these epidemiologic and experimental studies lends more credence to our findings about a positive association between TV viewing time and all-cause mortality.

Adjustment for physical activity did not affect the positive association between TV viewing time and all-cause mortality, which indicated that the detrimental association with prolonged TV viewing time was not fully explained by the absence of physical activity. Prior observations of deleterious associations of TV viewing time with metabolic risk and mortality in adults who met exercise guidelines also clarified our finding (18, 19). For example, in a population of 4,064 healthy Australian adults who met the public health guidelines for physical activity (18), TV viewing time was positively associated with systolic blood pressure and 2-hour plasma glucose level in men and women and with fasting plasma glucose, triglycerides, and high-density lipoprotein cholesterol in women. Meanwhile, TV viewing time has been shown to be poorly associated with physical activity (21, 27, 54). This suggests that physical activity alone is insufficient to control mortality risk in persons who have higher levels of sedentary behavior. Therefore, substituting physical activity for TV viewing time may result in an additive reduction of mortality risk.

Obesity is considered a likely intermediate variable in the biological pathway linking sedentary behavior to mortality, and controlling for it might lead to overadjustment and thus bias results towards the null (55). However, the positive relationship between TV viewing time and all-cause mortality was not attenuated when the analysis was restricted to studies that adjusted for body mass index. Body mass index might be an imperfect measure of adiposity, because it also accounts for lean body mass; thus, in future studies, investigators should use measures that differentiate between fat mass and lean mass to assess the true contribution of adiposity to the association between TV viewing time and mortality.

We detected significant heterogeneity in the subgroup stratified according to whether the original study adjusted for diet quality index. This observed result might have been due to chance, which is implausible. Because diet quality has been associated with both prolonged TV viewing time (56) and all-cause mortality (57–59), theoretically, failure to adjust for diet quality index may have produced a more pronounced risk estimate. The stronger association observed in studies that adjusted for diet quality index might have been partly due to the inconsistency between categories in the original articles, particularly differences between cutoffs for the highest category. Meanwhile, the pooled relative risk in studies that adjusted for diet quality index was largely dependent on the estimates from the study by Matthews et al. (24), whose cohort was much larger than that of Ford (25), and the study by Dunstan et al. (27) (Web Figure 2). Because participants with a chronic disease (and consequently a higher risk of death (60, 61)) at baseline might spend more time watching TV (16, 23, 26), a more pronounced relationship was also observed in studies that did not adjust for history of diabetes or hypertension than in those that did.

Although most studies indicated a positive association between TV viewing time and all-cause mortality, significant heterogeneity was observed in our meta-analysis, which could limit the interpretability of the pooled estimates. There are several potential explanations for the observed between-study heterogeneity. First, lack of consistency in the categories, particularly the cutoffs for the highest category, certainly could have contributed to interstudy differences in the strength of the observed associations. The highest category of TV viewing time in most of the studies included in our meta-analysis was ≥4 hours/day or ≥5 hours/day, but the highest category in the study by Matthews et al. (24) was ≥7 hours/day. Initial evidence for study heterogeneity ($I^2 = 66.7\%$, $P_{heterogeneity} = 0.001$) was no longer evident after we excluded the study by Matthews et al. (24) (RR = 1.26, 95% CI: 1.19, 1.34; $I^2 = 0.0\%$, $P_{heterogeneity} = 0.469$). In order to improve consistency in the cutoffs for the highest category, we used the method of Hamling et al. (62) to derive the combined estimate for the alternative comparison group (≥5 hours/day) from the estimates presented for the exposure levels of 5–6 hours/day and ≥7 hours/day in the study by Matthews et al. (24). Hazard ratios were given as 1.31 (95% CI: 1.21, 1.42) for 5–6 hours/day and 1.61 (95% CI: 1.47, 1.76) for ≥7 hours/day, and the method of Hamling et al. produced a combined estimate of 1.39 (95% CI: 1.29, 1.51) for ≥5 hours/day. We then combined this alternative estimate with the estimates of the rest of the studies using a random-effects model; this showed that prolonged TV viewing time was significantly associated with all-cause mortality.
also be explained to some extent by the different study methodologies. For example, 3 studies (16, 21, 26) measured TV viewing time separately on weekdays and weekend days, while the remaining studies did not consider the difference between weekdays and weekend days and only asked about the amount of TV viewing time per day. However, no significant heterogeneity was observed in the subgroup stratified by this methodological difference ($P_{\text{heterogeneity}} = 0.261$).

Second, the observed between-study heterogeneity might also be explained to some extent by the different study methodologies. For example, 3 studies (16, 21, 26) measured TV viewing time separately on weekdays and weekend days, while the remaining studies did not consider the difference between weekdays and weekend days and only asked about the amount of TV viewing time per day. However, no significant heterogeneity was observed in the subgroup stratified by this methodological difference ($P_{\text{heterogeneity}} = 0.261$).

Third, although no significant heterogeneity between subgroups was observed in Table 1, we cannot rule out the possibility that the different sizes of the cohorts, the various study follow-up periods, or the potential confounders for which the researchers adjusted might also have contributed to some of the heterogeneity reported herein.

A strength of this meta-analysis was the prospective design of the included cohort studies, which should have greatly reduced the potential of selection bias. The large study population (61,494 deaths among 647,475 participants) enabled us to conduct a wide range of informative subgroup analyses to confirm the positive association between TV viewing time and all-cause mortality. In addition, the combined use of categorical and dose-response meta-analyses further provided a comprehensive description of the shape of the association. Furthermore, 9 (16, 20–27) out of 10 available articles were published after 2010, which provided us with important timely data linking TV viewing time with all-cause mortality.

However, a few limitations of our meta-analysis should be considered. First, we could not exclude potential biases due to the different methods used to assess TV viewing time, the different ranges between the lowest and highest categories, and the misclassification of TV viewing time, because all of the studies relied on self-reported data. Self-reported data would act to weaken the association, since respondents are more likely to systematically underreport their sedentary behavior (5, 63). Second, of the 10 prospective studies included in the meta-analysis, none of them accounted for change in TV viewing over time, and the assessment of TV exposure was made at baseline only, which would have increased the chance of random measurement error. Third, we included only published cohort data in our meta-analysis, which could have increased the risk of publication bias through the exclusion of unpublished studies. However, after carefully examining all relevant articles, including several meta-analyses (13, 29, 54) and systematic reviews (64–68), we were not aware of any relevant unpublished studies on this topic. Finally, although the included studies attempted to control for various known risk factors such as age, smoking, and education, it is still possible that residual confounding could have contributed to the association reported herein due to unknown confounders or imprecise adjustment.

Current physical activity guidelines generally focus on raising the level of physical activity in the population and do not specifically prescribe precise reductions in sedentary behavior. For example, the World Health Organization’s global recommendations on physical activity for health promotion lack recommendations on sedentary behavior (69). The American Cancer Society advocates limiting the amount of time spent being sedentary, such as sitting or watching TV, to reduce cancer risk, but it does not specifically define the threshold level (70). The Canadian Society for Exercise Physiology, in collaboration with stakeholder organizations, launched guidelines on sedentary behavior for children and adolescents (e.g., no more than 2 hours per day) but not for adults (persons aged ≥18 years) (71). This emphasizes the need for additional work in this area.

In conclusion, our meta-analysis, based on 10 prospective cohort studies, indicated that prolonged TV viewing time might increase the risk of all-cause mortality among adults. Given the high prevalence of TV viewing, our finding underscores the importance of public health recommendations and interventions aimed at decreasing the amount of TV viewing time in modern societies.

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Author affiliations: State Key Laboratory of Oncogenes and Related Genes and Department of Epidemiology, Shanghai Cancer Institute, Renji Hospital, School of Medicine, Shanghai Jiaotong University, Shanghai, China (Jiang-Wei Sun, Long-Gang Zhao, Yang Yang, Xiao Ma, Ying-Ying Wang, Yong-Bing Xiang).

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