Meta-analysis of the Relation of Television-Viewing Time and Cardiovascular Disease

Hisato Takagi, MD, PhD[a,b,*], Yosuke Hari, MD[a,b], Kouki Nakashima, MD, PhD[a,b], Toshiki Kuno, MD, PhD[c], and Tomo Ando, MD[d], for the ALICE (All-Literature Investigation of Cardiovascular Evidence) Group

To determine whether television (TV) viewing is associated with cardiovascular disease (CVD) risk, we performed a meta-analysis of currently available prospective cohort studies. We systematically searched PubMed and Web of Science through April 2019. Eligible for inclusion in the present meta-analysis was a prospective cohort study investigating the association of TV viewing time with CVD risk (CVD prevalence, CVD incidence, cardiovascular events, and cardiovascular mortality). From each study, adjusted hazard ratios (HRs) of CVD risk were extracted. We separately combined study-specific estimates for dichotomous, tertile, quartile, and continuous values of TV viewing time in the random-effects model. The pooled analysis for dichotomous time demonstrated that CVD risk was significantly higher in the longer than shorter viewing (HR 1.28; p = 0.02). In the meta-analysis for tertile time, CVD risk was significantly higher in the longest than shortest tertile (T1) (HR 1.26; p = 0.0006), but there was no significant difference between the middle tertile and T1 (p = 0.51). The meta-analysis for quartile time indicated that CVD risk was significantly higher in the longest than shortest quartile (Q1) (HR 1.32; p = 0.0007), but there were no significant differences between the second longest quartile and Q1 (p = 0.12) and between the second shortest quartile and Q1 (p = 0.60). In the meta-analysis for continuous time, longer viewing was significantly associated with higher CVD risk (HR per 1-h/day increment; 1.06; p = 0.005). In conclusion, longer TV viewing time is significantly associated with higher CVD risk. **(Am J Cardiol 2019;124:1674−1683)**

There is the association of sedentary time with cardiometabolic health markers (such as fasting glucose, fasting insulin, triglycerides, high-density lipoprotein cholesterol, and waist circumference),[1] diabetes mellitus (DM),[2] cardiovascular disease (CVD),[2,3] CV mortality,[2,3] and all-cause mortality.[2−4] Furthermore, television (TV) viewing is also associated with all-cause mortality. Sun et al[5] performed a meta-analysis of 10 prospective cohort studies with 647,475 individuals and showed that all-cause mortality was significantly higher in the highest category of TV viewing time than in the lowest category. Although CVD risk (CVD prevalence, CVD incidence, CV events, and CV mortality) is considered to mainly contribute to all-cause mortality, the association of TV viewing with CVD risk remains unclear. In the present article, to determine whether TV viewing is associated with CVD risk, we performed a meta-analysis of currently available prospective cohort studies.

Methods

We conducted the present meta-analysis according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (http://www.prisma-statement.org) and showed the PRISMA-P [PRISMA Protocols] 2015 checklist (http://www.prisma-statement.org/Extensions/Protocols.aspx) in Supplementary Table S1. We systematically searched PubMed (https://www.ncbi.nlm.nih.gov/pubmed/) and Web of Science (http://www.webofknowledge.com/wos) through April 2019 using keyword including "television"; and "cardiovascular disease(s)," "cardiovascular event(s)," "cardiovascular death(s)," or "cardiovascular mortality." Eligible for inclusion in the present meta-analysis was a prospective cohort study investigating the association of TV viewing time with CVD risk (CVD prevalence, CVD incidence, CV events, and CV mortality). We evaluated the quality of the studies using the RoBANS [Risk of Bias Assessment Tool for Nonrandomized Studies].[6] From each study, adjusted hazard ratios (HRs) of CVD incidence, CV events, and CV mortality (and adjusted odds ratios of CVD prevalence) with their confidence intervals (CIs) were extracted. Data were extracted in duplicate by 2 investigators (HT, TK) and independently verified by a third researcher

[a]Department of Cardiovascular Surgery, Shizuoka Medical Center, Shizuoka, Japan; [b]Department of Cardiovascular Surgery, Kitasato University School of Medicine, Sagamihara, Japan; [c]Department of Medicine, Mount Sinai Beth Israel Medical Center, New York, New York; and [d]Department of Cardiology, Detroit Medical Center, Detroit, Michigan. Manuscript received May 29, 2019; revised manuscript received and accepted August 19, 2019.

Author contribution: HT contributed to conception, design, acquisition, analysis, and interpretation, drafted manuscript, and agrees to be accountable for all aspects of work ensuring integrity and accuracy. YH and KN contributed to acquisition and analysis. TK contributed to design, analysis, and interpretation. TA contributed to conception, acquisition, analysis, and interpretation, and critically revised manuscript. All authors gave final approval.

See page 1683 for disclosure information.

*Corresponding author: Tel: (+81) 55-975-2000; fax: (+81) 55-975-2725.

E-mail address: kfgth973@ybb.ne.jp (H. Takagi).

0002-9149/
https://doi.org/10.1016/j.amjcard.2019.08.032

(TA). Disagreements were resolved by consensus. We separately combined study-specific estimates for dichotomous, tertile, quartile, and continuous values (per 1-h/day increment) of TV viewing time using inverse variance-weighted averages of logarithmic HRs in the random-effects model. To avoid combining duplicate data, several sensitivity analyses under-mentioned in the results section were performed. We mathematically assessed funnel plot asymmetry (suggesting publication bias) using the linear regression test. We assessed confidence in cumulative evidence according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) (http://www.gradeworkinggroup.org). All analyses were performed using Review Manager version 5.3 (available from http://tech.cochrane.org/revman) and Comprehensive Meta-Analysis version 3 (Biostat, Englewood, New Jersey).

Results

As illustrated in Supplementary Figure S1, we identified 15 eligible studies[7−21] with a total of 924,971 participants excluding duplicates (Table 1) and summarized the quality (risk of bias) of the studies in Supplementary Figures S2 and S3. Reported and generated relative risk estimates of CVD risk for TV viewing time were summarized in Table 2, and those included in the primary meta-analysis and the sensitivity analysis were listed in Table 3. In the study by Arem et al[7] and the study by Matthews et al[17] from the same "National Institutes of Health-AARP Diet and Health Study," the former[7] investigated "survivors of colorectal cancer," and the latter[17] researched "individuals without cancers (other than basal cell skin cancer)." In the study by Cassidy et al[8] and the study by Celis-Morales et al[9] from the same "UK Biobank," the former[8] provided an odds ratio of CVD "prevalence" for "dichotomous" TV viewing time, and the latter[9] reported HRs of CVD "incidence" and CV "mortality" for "quartile" TV viewing time. In the study by Dunstan et al[11] and the study by Grace et al[13] from the same "AusDiab [Australian Diabetes, Obesity and Lifestyle Study]," HRs of CV mortality for tertile TV viewing time from the former[11] were updated by those from the latter,[13] and accordingly we combined the latter[13] (not the former[11]) in the meta-analysis. Wijndaele et al performed 2 different studies[20,21] from the same "EPIC [European Prospective Investigation into Cancer and Nutrition Study] Norfolk." One study[20] provided an HR of CV "events" per 1-h/day increment of TV viewing time, and another study[21] reported HR of CV "mortality" per 1-h/day increment of TV viewing time. We combined the latter HR[21] in the primary meta-analysis and pooled the former HR[20] (instead of the latter HR[21]) in the sensitivity analysis. Celis-Morales et al[9] provided HRs of CVD "incidence" and HRs of CV "mortality," the latter was combined in the primary meta-analysis, and the former (instead of the latter) was pooled in the sensitivity analysis. Ford[12] reported HRs of CV mortality for "sextile" and "tertile" TV viewing time, and the latter (not the former) was combined in the meta-analysis. Ikehara et al[15] provided HRs of CV mortality for "sextile" TV viewing time, and we generated HRs of CV mortality for "tertile" and "quartile" TV viewing time. Matthews et al[17] reported HRs of CV mortality for "quintile" TV viewing time, and we produced HRs of CV mortality for "tertile" and "quartile" TV viewing time. As mentioned above, combining duplicate data was carefully and certainly avoided.

The pooled analysis for dichotomous TV viewing time demonstrated that CVD risk was significantly higher in the longer viewing (D2) than in the shorter viewing (D1) (Supplementary Figure S4). In the primary meta-analysis for tertile TV viewing time, CVD risk was significantly higher in the longest tertile (T3) than in the shortest tertile (T1) (Figure 1-1.2.1), but there was no significant difference in CVD risk between the middle tertile (T2) and the T1 (Figure 1-1.2.2). The primary meta-analysis for quartile TV viewing time indicated that CVD risk (CV mortality) was significantly higher in the longest quartile (Q4) than in the shortest quartile (Q1) (Figure 2-1.3.1), but there were no significant differences in CVD risk (CV mortality) between the second longest quartile (Q3) and the Q1 (Figure 2-1.3.2) and between the second shortest quartile (Q2) and the Q1 (Figure 2-1.3.3). In the primary meta-analysis for continuous TV viewing time (Figure 3), longer viewing was significantly associated with higher CVD risk (CV mortality).

The sensitivity analysis (Table 3) did not substantively alter the significant results of the primary meta-analysis (Supplementary Figures S5−S7). Funnel plot asymmetry (suggesting publication bias) of the primary meta-analysis for the T3 versus the T1 ($p = 0.31$; Supplementary Figure S8), the Q4 versus the Q1 ($p = 0.12$; Supplementary Figure S9), and continuous TV viewing time ($p = 0.35$; Supplementary Figure S10) was not detected by the linear regression test. The GRADE evidence profile was shown in Supplementary Table S2.

Discussion

The present meta-analysis suggests that longer (the longest quantile versus the shortest quantile and per 1-h/day increment) TV viewing time is significantly associated with higher CVD risk (mainly CV mortality), which was robust in sensitivity analyses without publication bias. Because the longest quantile was defined as ≥4 h/day[7,11−13,18] and ≥5 h/day[7,15−17] in the tertiles and ≥5 h/day[9,17] and ≥6 h/day[14,15] in the quartiles, individuals viewing TV for ≥4−6 h/day may be at risk of CVD. The association of TV viewing with all-cause mortality demonstrated in the previous meta-analysis[5] may be derived from the association of TV viewing with CVD risk (mainly CV mortality) suggested in the present meta-analysis.

Table 1
Study design

Study	Region	Patient number		Database	Inclusion criteria
Dunstan 2010[11]	Australia	8,800		AusDiab	Aged ≥25 years
Warren 2010[19]	US	7,744		ACLS	Healthy men
Stamatakis 2011[18]	UK	4,512		SHS03	Aged ≥35 years
Wijndaele 2011a[20]	UK	12,608		EPIC Norfolk	Aged 45−79 years
Wijndaele 2011b[21]	UK	13,197		EPIC Norfolk	Aged 45−79 years
Ford 2012[12]	US	7,350		NHANES	Aged ≥20 years
Matthews 2012[17]	US	240,819		NIH-AARP Diet and Health Study	Aged 50−71 years
Kim 2013[16]	US	134,596		MEC	Aged 45−75 years
Arem 2015[7]	US	Precancer diagnosis TV	3784	NIH-AARP Diet and Health Study	Aged 50−71 years, survivors of colorectal cancer
Arem 2015[7]	US	Postcancer diagnosis TV	1630	NIH-AARP Diet and Health Study	Aged 50−71 years, survivors of colorectal cancer
Ikehara 2015[15]	Japan	85,899		JACC Study	Aged 40−79 years
Cassidy 2016[8]	UK	233,110		UK Biobank	Aged 37−73 years
Grace 2017[13]	Australia	Current smokers	498	AusDiab	N/A
Grace 2017[13]	Australia	Nonsmokers	409	AusDiab	N/A
Hamer 2017[14]	UK	451		ELSA	N/A
Celis-Morales 2018[9]	UK	388,746		UK Biobank	Aged 40−69 years
Díaz-Gutiérrez 2018[10]	Spain	19,336		SUN project	N/A

Study	Exclusion criteria	Age (years)	Male (%)	Follow-up
Dunstan 2010[11]	CVD, pregnant, overreported or underreported total energy intake	50.5	43.7	Median 6.6 years
Warren 2010[19]	MI, stroke, cancer	47.1 ± 10.1	100	21 years
Stamatakis 2011[18]	N/A	43.5	54.1	4.3 ± 0.5 years
Wijndaele 2011a[20]	Stroke, MI, other vascular disease, cancer	61.4	43.3	6.9 ± 1.9 years
Wijndaele 2011b[21]	Stroke, MI, cancer	61.5	43.4	9.5 ± 1.6 years
Ford 2012[12]	N/A	45.3	49.2	Mean 5.8 years
Matthews 2012[17]	Heart disease, cancers other than basal cell skin cancer, stroke, emphysema, poor health status, extreme BMI, extreme energy intake	62.5	56	8.5 ± 0.7 years
Kim 2013[16]	Implausible dietary data, cancer, heart attack, stroke	58.6	45.6	Mean 13.7 years
Arem 2015[7]	Stage 0 or metastatic disease	N/A	N/A	Median 12.8 years
Arem 2015[7]	Stage 0 or metastatic disease	N/A	N/A	Median 7.1 years
Ikehara 2015[15]	CVD, cancer	57.3	41.9	1,398,591 person-years
Cassidy 2016[8]	N/A	N/A	51.4	None
Grace 2017[13]	CVD, pregnant, overreported or underreported energy intake	51.3	43.5	Median 13.6 years
Grace 2017[13]	CVD, pregnant, overreported or underreported energy intake	45.4	48.8	Median 13.6 years
Hamer 2017[14]	N/A	64.8	44.4	Up of 4 years
Celis-Morales 2018[9]	N/A	55.9	45.5	Median 5.0 (IQR 4.3−5.7) years
Díaz-Gutiérrez 2018[10]	CVD, energy intake outside the pre-defined limits	37.3	38.6	Median 10.4 years

ACLS = Aerobics Center Longitudinal Study; AusDiab = Australian Diabetes, Obesity and Lifestyle Study; BMI = body mass index; CVD = cardiovascular disease; ELSA = English Longitudinal Study of Ageing; EPIC = European Prospective Investigation into Cancer and Nutrition Study; IQR = interquartile range: JACC Study = Japan Collaborative Cohort Study for Evaluation of Cancer Risk sponsored by Monbusho; MI = myocardial infarction; MEC = Multi-ethnic Cohort Study; N/A = not available; NHANES = National Health and Nutrition Examination Survey; NIH = National Institutes of Health; SHS03 = 2003 Scottish Health Survey; SUN = Seguimiento Universidad de Navarra (University of Navarre Follow-up); TV = television.

Sedentary time (probably including TV viewing time) is associated with surrogate makers and clinical risks (such as DM) of CVD, CVD incidence, CV mortality, and all-cause mortality, which may strength the present findings. Powell et al[1] reported, in their meta-analysis of 46 studies with a total of 70,576 individuals, that longer sedentary time was adversely associated with fasting glucose, fasting insulin, triglycerides, high-density lipoprotein cholesterol, and waist circumference. Biswas et al[3] showed, in their meta-analysis, that longer sedentary

Table 2
Reported and generated relative risk estimates of cardiovascular disease risk for television (TV) viewing time

Study	Adjustment covariate
Dunstan 2010[11]	Age, sex, smoking, education, total energy intake, alcohol intake, Diet Quality Index, waist circumference, HT, total plasma cholesterol, HDL-cholesterol, serum triglycerides, lipid-lowering medication use, glucose tolerance status
Warren 2010[19]	Age, physically inactive, current smoker, alcohol intake, BMI, family history of CVD, HT, DM, HC
Stamatakis 2011[18]	Age, sex, BMI, smoking, marital status, ethnicity, social class, long-standing illness, occupational physical activity, doctor-diagnosed DM and HT, moderate-to-vigorous physical activity
Wijndaele 2011a[20]	Age, sex, education level, smoking status, alcohol consumption, medication for HT, medication for dyslipidemia, medication for depression, baseline DM status, family history of CVD and sleep duration, total physical activity energy expenditure
Wijndaele 2011b[21]	Age, sex, education level, smoking status, alcohol consumption, medication for HT, medication for dyslipidemia, baseline history of DM, family history of CVD and family history of cancer, total physical activity energy expenditure
Ford 2012[12]	Age, sex, race or ethnicity, educational attainment, smoking status, leisure-time physical activity, Healthy Eating Index score, alcohol consumption, health status, health insurance coverage, histories of DM, CVD, cancer, BMI, SBP, concentrations of HDL cholesterol, non-HDL cholesterol, HbA1c
Ford 2012[12]	Ditto
Matthews 2012[17]	Age, sex, race, education, smoking history, diet quality, moderate-vigorous physical activity
Matthews 2012[17]	Ditto
Matthews 2012[17]	Ditto
Kim 2013[16]	Age, 5-year age groups at cohort entry, education, ethnicity, history of HT or DM at enrolment, alcohol consumption, energy intake, physical activity, trend of hours for other sitting behaviors, smoking history
Kim 2013[16]	Ditto
Arem 2015[7]	Age, sex, tumor site, tumor grade, tumor stage, surgery, radiation, chemotherapy, time reported in moderate to vigorous leisure time physical activity, smoking status, BMI, self-reported health
Arem 2015[7]	In addition to the above-mention covariates, pre- and postdiagnosis TV viewing
Ikehara 2015[15]	Age, sex, BMI, smoking, ethanol intake, education level, hours of sport, hours of walking, sleep duration, perceived mental stress, presence of job, frequency of fresh fish intake and depressive symptoms, histories of HT and DM
Ikehara 2015[15]	Ditto
Ikehara 2015[15]	Ditto
Ikehara 2015[15]	Ditto
Cassidy 2016[8]	Age, sex, BMI, sociodemographic, smoking, alcohol, diet
Grace 2017[13]	Age, sex, leisure-time physical activity, education, household income, total energy intake, alcohol intake, Dietary Guideline Index, HT, total plasma cholesterol, HDL-cholesterol, serum triglycerides, lipid-lowering medication use, glucose tolerance status
Grace 2017[13]	Ditto
Grace 2017[13]	Ditto
Grace 2017[13]	Ditto
Hamer 2017[14]	Age, sex, physical activity, smoking, alcohol intake, depressive symptoms, long standing illness, disability
Hamer 2017[14]	Ditto
Celis-Morales 2018[9]	Age, sex, ethnicity, deprivation index, professional qualifications, income, employment, smoking status, sleep duration categories, dietary intake (alcohol, red meat, processed meat, fruit and vegetable, and oily fish intake), SBP, prevalent DM, HT and medication for DM, HT, cholesterol
Celis-Morales 2018[9]	Ditto
Celis-Morales 2018[9]	Ditto
Celis-Morales 2018[9]	Ditto
Celis-Morales 2018[9]	Ditto
Celis-Morales 2018[9]	Ditto
Celis-Morales 2018[9]	Ditto
Celis-Morales 2018[9]	Ditto
Celis-Morales 2018[9]	Ditto
Celis-Morales 2018[9]	Ditto
Celis-Morales 2018[9]	Ditto
Celis-Morales 2018[9]	Ditto
Díaz-Gutiérrez 2018[10]	Sex, age, year of questionnaire completion, diabetes, CVD, HT, HC, HTG, all other variables
Díaz-Gutiérrez 2018[10]	Ditto

Study	Cardiovascular disease	Relative risk estimate (95% confidence interval) for TV viewing time				
Dunstan 2010[11]	Mortality	***Tertiles***	***≥4 h/day (T3):*** HR 1.80 (1.00−3.25)*	***2 to <4 h/day (T2):*** HR 1.19 (0.72−1.99)*	***<2 h/day (T1):*** HR 1 (Reference)	
Warren 2010[19]	Mortality	***Quartiles***	***>12 h/week (>1.7 h/day) (Q4):*** HR 0.96 (0.68−1.36)†	***8−12 h/week (1.1−1.7 h/day) (Q3):*** HR 1.27 (0.90−1.78)†	***4−8 h/week (0.6−1.1 h/day) (Q2):*** HR 1.02 (0.74−1.42)†	***<4 h/week (<0.6 h/day) (Q1):*** HR 1 (Reference)
Stamatakis 2011[18]	Events	***Tertiles***	***≥4 h/day (T3):*** HR 2.25 (1.30−3.89)†	***2 to <4 h/day (T2):*** HR 2.23 (1.31−3.80)†	***<2 h/day (T1):*** HR 1 (Reference)	
Wijndaele 2011a[20]	Events	***Continuous***	***per 1-h/day increment:*** HR 1.06 (1.03−1.08)‡			
Wijndaele 2011b[21]	Mortality	***Continuous***	***per 1-h/day increment:*** HR 1.08 (1.01−1.16)†			

(*continued on next page*)

Table 2 (***Continued***)

Study	Cardiovascular disease		Relative risk estimate (95% confidence interval) for TV viewing time					
Ford 2012[12]	Mortality		***Sextiles*** (TV viewing or computer use)	***≥5 h/day (S6):*** HR 1.13 (0.57−2.24)*	***4 h/day (S5):*** HR 0.88 (0.39−1.99)*	***3 h/day (S4):*** HR 1.39 (0.69− 2.80)*	***2 h/day (S3):*** HR 0.77 (0.43− 1.38)*	***1 h/day (S2):*** HR 1.14 (0.56− 2.32)*	***<1 h/day (S1):*** HR 1 (Reference)
Ford 2012[12]	Mortality		***Tertiles*** (TV viewing or computer use)	***≥4 h/day (T3):*** HR 0.96 (0.60−1.52)†	***2 to <4 h/day (T2):*** HR 0.98 (0.56−1.71)†	***<2 h/day (T1):*** HR 1 (Reference)			
Matthews 2012[17]	Mortality		***Quintiles***	***≥7 h/day (QUI5):*** HR 1.85 (1.56−2.20)*	***5−6 h/day (QUI4):*** HR 1.36 (1.17−1.59)*	***3−4 h/day (QUI3):*** HR 1.15 (1.00−1.33)*	***1−2 h/day (QUI2):*** HR 1.00 (0.86−1.16)*	***<1 h/day (QUI1):*** HR 1 (Reference)	
Matthews 2012[17]	Mortality		***Tertiles***[d]	***≥5 h/day (T3):*** HR 1.59 (1.17−2.14)†,§	***1−4 h/day (T2):*** HR 1.08 (0.93−1.24†,§	***<1 h/day (T1):*** HR 1 (Reference)			
Matthews 2012[17]	Mortality		***Quartiles***[d]	***≥5 h/day (Q4):*** HR 1.59 (1.17−2.14)†,§	***3−4 h/day (Q3):*** HR 1.15 (1.00−1.33)†	***1−2 h/day (Q2):*** HR 1.00 (0.86−1.16)†	***<1 h/day (Q1)):*** HR 1 (Reference)		
Kim 2013[16]	Mortality	Female	***Tertiles***	***≥5 h/day (T3):*** HR 1.33 (1.14−1.55)†	***1−4 h/day (T2):*** HR 1.02 (0.90−1.15)†	***<1 h/day (T1):*** HR 1 (Reference)			
Kim 2013[16]	Mortality	Male	***Tertiles***	***≥5 h/day (T3):*** HR 1.20 (1.05−1.37)†	***1−4 h/day (T2):*** HR 0.99 (0.89−1.10)†	***<1 h/day (T1):*** HR 1 (Reference)			
Arem 2015[7]	Mortality	Post-cancer diagnosis	***Tertiles***	***>4 h/day (T3):*** HR 0.72 (0.36−1.42)†	***>2 to 4 h/day (T2):*** HR 1.09 (0.62−1.90)†	***0−2 h/day (T1):*** HR 1 (Reference)			
Arem 2015[7]	Mortality	Pre-cancer diagnosis	***Tertiles***	***≥5 h/day (T3):*** HR 1.55 (1.07−2.23)†	***3−4 h/day (T2):*** HR 1.29 (0.92−1.80)†	***0−2 h/day (T1):*** HR 1 (Reference)			
Ikehara 2015[15]	Mortality		***Sextiles***	***≥6 h/day (S6):*** HR 1.14 (1.02−1.28)*	***5 h/day (S5):*** HR 1.03 (0.93−1.14)*	***4 h/day (S4):*** HR 0.96 (0.87−1.05)*	***3 h/day (S3):*** HR 0.95 (0.88−1.04)*	***2 h/day (S2):*** HR 1.00 (0.92−1.08)*	***<2 h/day (S1):*** HR 1 (Reference)
Ikehara 2015[15]	Mortality		***Tertiles***[d]	***≥5 h/day (T3):*** HR 1.08 (0.98−1.20)†,§	***2−4 h/day (T2):*** HR 0.97 (0.92−1.02)†,§	***<2 h/day (T1):*** HR 1 (Reference)			
Ikehara 2015[15]	Mortality		***Quartiles***[d]	***≥6 h/day (Q4):*** HR 1.14 (1.02−1.28)†	***4−5 h/day (Q3):*** HR 0.99 (0.92−1.06)†,§	***2−3 h/day (Q2):*** HR 0.98 (0.92−1.04)†,§	***<2 h/day (Q1):*** HR 1 (Reference)		
Ikehara 2015[15]	Mortality		***Continuous***	***per 1-h/day increment:*** HR 1.01 (1.00−1.03)†					
Cassidy 2016[8]	Prevalence		***Dichotomous***	***>3 h/day (D1):*** OR 1.42 (1.39−1.45)†	***≤3 h/day (D2):*** OR 1 (Reference)				
Grace 2017[13]	Mortality	Current-smokers	***Tertiles***	***≥4 h/day (T3):*** HR 2.02 (0.80−5.12)†	***2 to <4 h/day (T2):*** HR 1.11 (0.46−2.63)†	***<2 h/day (T1):*** HR 1 (Reference)			
Grace 2017[13]	Mortality	Current-smokers	***Continuous***	***per 1-h/day increment:*** HR 1.14 (0.97−1.35)†					
Grace 2017[13]	Mortality	Non-smokers	***Tertiles***	***≥4 h/day (T3):*** HR 1.04 (0.69−1.57)†	***2 to <4 h/day (T2):*** HR 0.93 (0.69−1.26)†	***<2 h/day (T1):*** HR 1 (Reference)			
Grace 2017[13]	Mortality	Non-smokers	***Continuous***	***per 1-h/day increment:*** HR 0.97 (0.88−1.07)†					
Hamer 2017[14]	Mortality		***Quartiles***	***≥6 h/day (Q4):*** HR 1.98 (1.25−3.15)†	***4 to <6 h/day (Q3):*** HR 1.49 (0.92−2.39)†	***2 to <4 h/day (Q2):*** HR 1.63 (1.02−2.61)†	***<2 h/day (Q1):*** HR 1 (Reference)		
Hamer 2017[14]	Mortality		***Continuous***	***per 1-SD (4.2-h/day) increment:*** HR 1.17 (1.06−1.28)*	***per 1-h/day increment:*** HR 1.04 (1.01−1.06)†,§				
Celis-Morales 2018[9]	Incidence	HPA	***Quartiles***	***>5 h/day (Q4):*** HR 1.02 (0.95−1.10)†	***4−5 h/day (Q3):*** HR 1.02 (0.95−1.09)†	***2−3 h/day (Q2):*** HR 0.98 (0.90−1.07)†	***<2 h/day (Q1):*** HR 1 (Reference)		
Celis-Morales 2018[9]	Incidence	HPA	***Continuous***	***per 1-h/day increment:*** HR 1.01 (0.98−1.03)†					
Celis-Morales 2018[9]	Incidence	MPA	***Quartiles***	***>5 h/day (Q4):*** HR 1.10 (1.01−1.22)*,¶, 1.14 (1.01−1.29)†,§	***4−5 h/day (Q3):*** HR 1.02 (0.94−1.10)*,¶, 1.05 (0.94−1.17)†,§	***2−3 h/day (Q2):*** HR 0.98 (0.92−1.05)*,¶, 1.01 (0.91−1.12)†,§	***<2 h/day (Q1):*** HR 0.98 (0.90−1.05)*,¶, 1 (Reference)		
Celis-Morales 2018[9]	Incidence	MPA	***Continuous***	***per 1-h/day increment:*** HR 1.04 (1.03−1.06)†					

(*continued on next page*)

Table 2 (***Continued***)

Study	Cardiovascular disease		Relative risk estimate (95% confidence interval) for TV viewing time			
Celis-Morales 2018[9]	Incidence	LPA	***Quartiles***	***>5 h/day (Q4):*** HR 1.17 (1.06−1.29)*,¶, 1.11 (0.98−1.25)†,§	***4−5 h/day (Q3):*** HR 1.09 (1.01−1.18)*,¶, 1.04 (0.93−1.15)†,§	***2−3 h/day (Q2):*** HR 1.08 (1.00−1.17)*,¶, 1.03(0.92−1.14)†,§	***<2 h/day (Q1):*** HR 1.05 (0.98−1.13)*,¶ 1 (Reference)
Celis-Morales 2018[9]	Incidence	LPA	***Continuous***	***per 1-h/day increment:*** HR 1.05 (1.02−1.07)‡			
Celis-Morales 2018[9]	Mortality	HPA	***Quartiles***	***>5 h/day (Q4):*** HR 1.21 (0.89−1.63)†	***4−5 h/day (Q3):*** HR 0.96 (0.75−1.24)†	***2−3 h/day (Q2):*** HR 0.92 (0.73−1.15)†	***<2 h/day (Q1):*** HR 1 (Reference)
Celis-Morales 2018[9]	Mortality	HPA	***Continuous***	***per 1-h/day increment:*** HR 1.06 (0.96−1.21)†			
Celis-Morales 2018[9]	Mortality	MPA	***Quartiles***	***>5 h/day (Q4):*** HR 1.34 (1.03−1.74)*,¶, 1.59 (1.08−2.35)†,§	***4−5 h/day (Q3):*** HR 0.93 (0.72−1.19)*,¶, 1.10 (0.75−1.61)†,§	***2−3 h/day (Q2):*** HR 0.89 (0.71−1.12)*,¶, 1.06 (0.74−1.53)†,§	***<2 h/day (Q1):*** HR 0.84 (0.63−1.12)*,¶, 1 (Reference)
Celis-Morales 2018[9]	Mortality	MPA	***Continuous***	***per 1-h/day increment:*** HR 1.08 (0.98−1.20)†			
Celis-Morales 2018[9]	Mortality	LPA	***Quartiles***	***>5 h/day (Q4):*** HR 1.51 (1.18−1.89)*,¶, 1.40 (1.01−1.94)†,§	***4−5 h/day (Q3):*** HR 1.21 (1.02−1.51)*,¶, 1.16 (0.86−1.57)†,§	***2−3 h/day (Q2):*** HR 1.13 (0.85−1.48)*,¶, 1.05 (0.73−1.50)†,§	***<2 h/day (Q1):*** HR 1.06 (0.85−1.34)*,¶, 1 (Reference)
Celis-Morales 2018[9]	Mortality	LPA	***Continuous***	***per 1-h/day increment:*** HR 1.15 (1.11−1.18)†			
Díaz-Gutiérrez 2018[10]	Incidence		***Dichotomous***	***≥2 h/day (D2):*** HR 1 (Reference), 1.33 (0.91−1.92)†,§	***<2 h/day (D1):*** HR 0.75 (0.52−1.09)*, 1 (Reference)		
Díaz-Gutiérrez 2018[10]	Prevalence		***Dichotomous***	***≥2 h/day (D2):*** OR 1 (Reference), 1.05 (0.82−1.33)†,§	***<2 h/day (D1):*** OR 0.96 (0.75−1.22)*, 1 (Reference)		

BMI = body mass index; DM = diabetes mellitus; Hb = hemoglobin; HC = hypercholesterolemia; HDL = high-density lipoprotein; HPA = higher physical activity; HR = hazard ratio; HT = hypertension; HTG = hypertriglyceridemia; LPA = lower physical activity; MPA = middle physical activity; OR = odds ratio; SBP = systolic blood pressure.

* Not included in the present meta-analysis.

† Included in the primary meta-analysis.

‡ Included in the sensitivity analysis.

§ Generated by us using the reported HRs.

¶ Versus <2 h/day in higher physical activity.

HRs in Dunstan 2010,[11] which were updated in Grace 2017,[13] were not included in the present meta-analysis.

Table 3
Relative risk estimates of cardiovascular disease risk for television viewing included in the primary meta-analysis and the sensitivity analysis

Study	Database	Cardiovascular disease		Relative risk estimate (95% confidence intervals) for television viewing time			Primary meta-analysis	Sensitivity analysis
Dichotomous				***D2 vs D1 (Figure S1)***				
Cassidy 2016[8]	UK Biobank	Prevalence	OR	1.42 (1.39−1.45)			√	Not included
Díaz-Gutiérrez 2018[10]	SUN project	Incidence	HR	1.33 (0.91−1.92)			√	Not included
Díaz-Gutiérrez 2018[10]	SUN project	Prevalence	OR	1.05 (0.82−1.33)			√	Not included
Tertile				***T3 vs T2 (Figure 1-1.2.1)***	***T2 vs T1 (Figure 1-1.2.2)***			
Arem 2015[7]	NIH-AARP Diet and Health Study	Mortality	Postcancer diagnosis	0.72 (0.36−1.42)	1.09 (0.62−1.90)		√	√
Arem 2015[7]	NIH-AARP Diet and Health Study	Mortality	Precancer diagnosis	1.55 (1.07−2.23)	1.29 (0.92−1.80)		√	√
Ford 2012[12]	NHANES	Mortality		0.96 (0.60−1.52)	0.98 (0.56−1.71)		√	√
Grace 2017[13]	AusDiab	Mortality	Current-smokers	2.02 (0.80−5.12)	1.11 (0.46−2.63)		√	√
Grace 2017[13]	AusDiab	Mortality	Nonsmokers	1.04 (0.69−1.57)	0.93 (0.69−1.26)		√	√
Ikehara 2015[15]	JACC Study	Mortality		1.08 (0.98−1.20)	0.97 (0.92−1.02)		√	√
Kim 2013[16]	MEC	Mortality	Female	1.33 (1.14−1.55)	1.02 (0.90−1.15)		√	√
Kim 2013[16]	MEC	Mortality	Male	1.20 (1.05−1.37)	0.99 (0.89−1.10)		√	√
Matthews 2012[17]	NIH-AARP Diet and Health Study	Mortality		1.59 (1.17−2.14)	1.08 (0.93−1.24		√	√
Stamatakis 2011[18]	SHS03	Events		2.25 (1.30−3.89)	2.23 (1.31−3.80)		√	Not included
Quartile				***Q4 vs Q1 (Figure 2-1.3.1)***	***Q3 vs Q1 (Figure 2-1.3.2)***	***Q2vs Q1 (Figure 2-1.3.3)***		
Celis-Morales 2018[9]	UK Biobank	Incidence	HPA	1.02 (0.95−1.10)	1.02 (0.95−1.09)	0.98 (0.90−1.07)	Not included	√
Celis-Morales 2018[9]	UK Biobank	Incidence	MPA	1.14 (1.01−1.29)	1.05 (0.94−1.17)	1.01 (0.91−1.12)	Not included	√
Celis-Morales 2018[9]	UK Biobank	Incidence	LPA	1.11 (0.98−1.25)	1.04 (0.93−1.15)	1.03(0.92−1.14)	Not included	√
Celis-Morales 2018[9]	UK Biobank	Mortality	HPA	1.21 (0.89−1.63)	0.96 (0.75−1.24)	0.92 (0.73−1.15)	√	Not included
Celis-Morales 2018[9]	UK Biobank	Mortality	MPA	1.59 (1.08−2.35)	1.10 (0.75−1.61)	1.06 (0.74−1.53)	√	Not included
Celis-Morales 2018[9]	UK Biobank	Mortality	LPA	1.40 (1.01−1.94)	1.16 (0.86−1.57)	1.05 (0.73−1.50)	√	Not included
Hamer 2017[14]	ELSA	Mortality		1.98 (1.25−3.15)	1.49 (0.92−2.39)	1.63 (1.02−2.61)	√	√
Ikehara 2015[15]	JACC Study	Mortality		1.14 (1.02−1.28)	0.99 (0.92−1.06)	0.98 (0.92−1.04)	√	√
Matthews 2012[17]	NIH-AARP Diet and Health Study	Mortality		1.59 (1.17−2.14)	1.15 (1.00−1.33)	1.00 (0.86−1.16)	√	√
Warren 2010[19]	ACLS	Mortality		0.96 (0.68−1.36)	1.27 (0.90−1.78)	1.02 (0.74−1.42)	√	√
Continuous				***per 1-h/day increment (Figure 3)***				
Celis-Morales 2018[9]	UK Biobank	Incidence	HPA	1.01 (0.98−1.03)			Not included	√
Celis-Morales 2018[9]	UK Biobank	Incidence	MPA	1.04 (1.03−1.06)			Not included	√
Celis-Morales 2018[9]	UK Biobank	Incidence	LPA	1.05 (1.02−1.07)			Not included	√
Celis-Morales 2018[9]	UK Biobank	Mortality	HPA	1.06 (0.96−1.21)			√	Not included
Celis-Morales 2018[9]	UK Biobank	Mortality	MPA	1.08 (0.98−1.20)			√	Not included
Celis-Morales 2018[9]	UK Biobank	Mortality	LPA	1.15 (1.11−1.18)			√	Not included
Grace 2017[13]	AusDiab	Mortality	Current-smokers	1.14 (0.97−1.35)			√	√
Grace 2017[13]	AusDiab	Mortality	Non-smokers	0.97 (0.88−1.07)			√	√
Hamer 2017[14]	ELSA	Mortality		1.04 (1.01−1.06)			√	√
Ikehara 2015[15]	JACC Study	Mortality		1.01 (1.00−1.03)			√	√
Wijndaele 2011a[20]	EPIC Norfolk	Events		1.06 (1.03−1.08)			Not included	√
Wijndaele 2011b[21]	EPIC Norfolk	Mortality		1.08 (1.01−1.16)			√	Not included

√ = included in the analysis; ACLS = Aerobics Center Longitudinal Study; AusDiab = Australian Diabetes, Obesity and Lifestyle Study; D1 = shorter dichotomy; D2 = longer dichotomy; ELSA English Longitudinal Study of Ageing; HPA = higher physical activity; HR = hazard ratio; LPA = lower physical activity; MEC = Multiethnic Cohort Study; MPA = middle physical activity; NHANES = National Health and Nutrition Examination Survey; JACC Study = Japan Collaborative Cohort Study for Evaluation of Cancer Risk sponsored by Monbusho; NIH = National Institutes of Health-AARP Diet and Health Study; OR = odds ratio; SHS03 = 2003 Scottish Health Survey; Q1 = shortest quartile; Q2 = second shortest quartile; Q3 = second longest quartile; Q4 = longest quartile; SUN = Seguimiento Universidad de Navarra (University of Navarre Follow-up); T1 = shortest tertile; T2 = middle tertile; T3 = longest tertile.

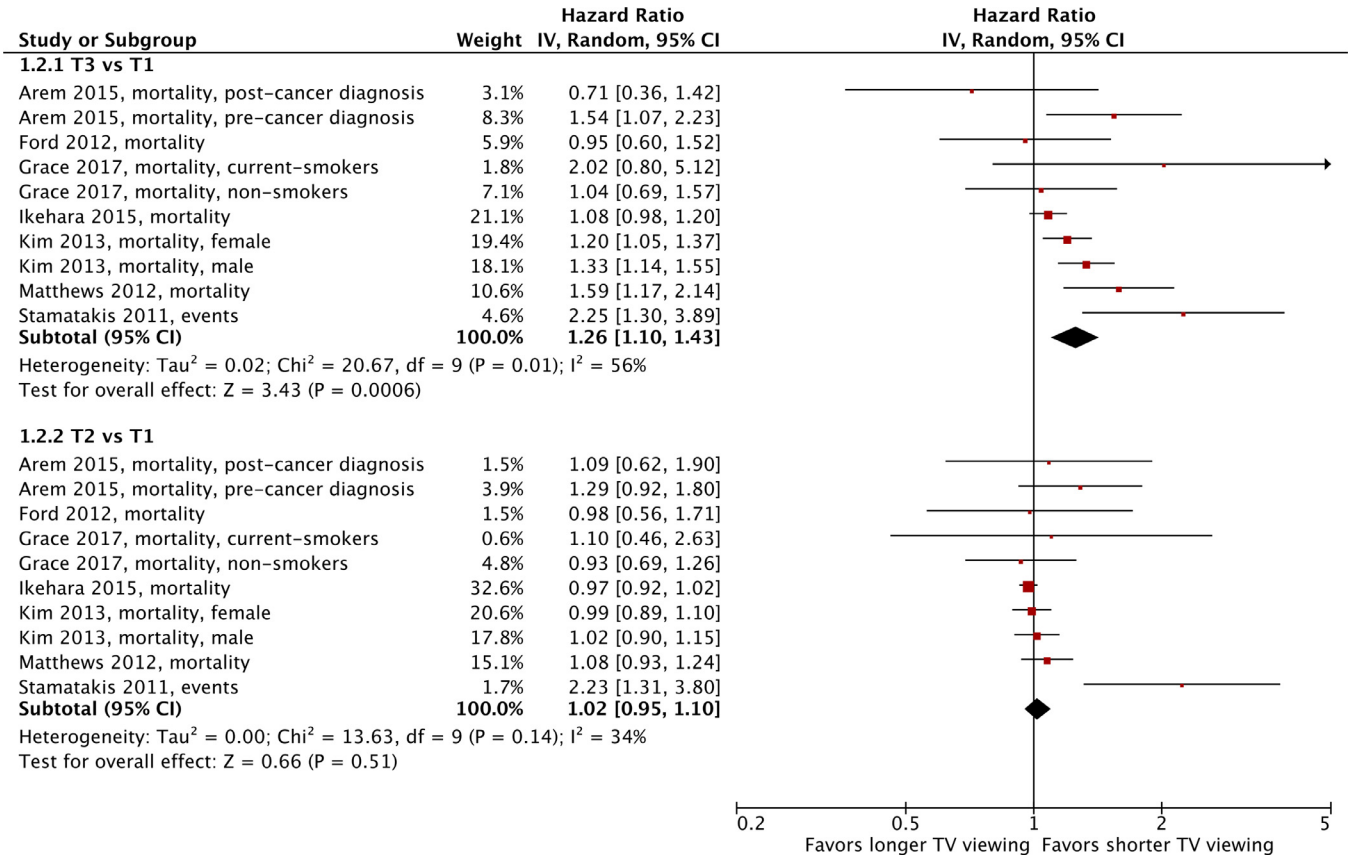

Figure 1. The primary meta-analysis for the longest tertile (T3) versus the shortest tertile (T1) (1.2.1) and the middle tertile (T2) versus the T1 (1.2.2) of television (TV) viewing time. CI = confidence interval; IV = inverse variance.

time was associated with higher type 2 DM incidence, CVD incidence and CV mortality, and all-cause mortality. Pandey et al[22] also reported, in their meta-analysis of 9 studies with a total of 720,425 individuals, that compared with the lowest category of sedentary time (median, 2.5 h/ day), the highest category of sedentary time (median, 12.5 h/day) was associated with higher CVD incidence and CV mortality despite no association of the middle category of sedentary time (median, 7.5 h/ day) with CVD incidence and CV mortality. Furthermore, Wilmot et al[2] showed, in their meta-analysis of 18 studies with a total of 794,577 participants, that longer sedentary time was associated with higher DM incidence, CV events, CV mortality, and all-cause mortality.

Leisure personal computer screen time, as well as TV viewing time, may be associated with CVD incidence, CV mortality, and all-cause-mortality. Celis-Morales et al[9] reported, in their prospective cohort study with 204,216 individuals from the "UK Biobank," that longer leisure PC screen time was independently associated with higher CVD incidence, CV mortality, and all-cause mortality. Long screen (including TV viewing and leisure personal computer screen) time and physical inactivity may be adversely consequent upon low level functional capacity and be implicated in public health strategies to reduce CVD risk.[9]

A number of limitations in the present meta-analysis, however, should be considered. First, TV viewing time may be misclassified, because all of the included studies depended upon self-reported data. Second, the included studies assessed TV viewing time at baseline only and did not take account of changes of TV viewing time during follow-up. Third, the explosive diffusion of mobile devices in the modern era has brought about fundamental transition of what "TV viewing" means. Although comparing the impact of TV viewing with that of mobile-device viewing upon CVD risk would be required, no study has unfortunately investigated the comparison to date. Future researches should be conducted. Fourth, TV viewing may be a mere surrogate measure of a sedentary lifestyle. In most studies,[7,9,12–21] however, occupational and leisure-time physical activity (lower physical activity probably being more associated with a sedentary lifestyle) was entered into the multivariate analysis as one of covariates together with TV viewing, and accordingly TV viewing is a risk factor of

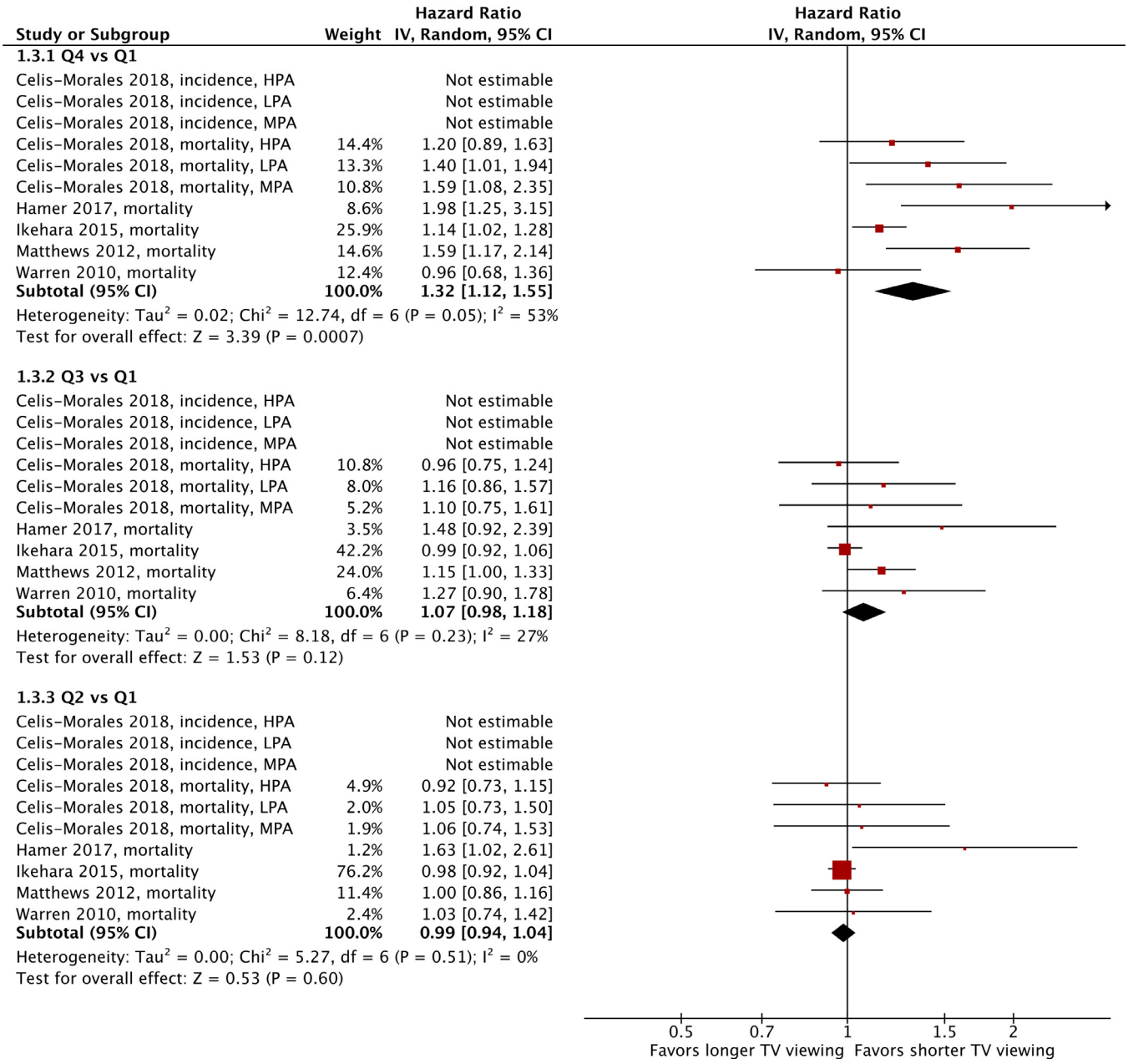

Figure 2. The primary meta-analysis for the longest quartile (Q4) versus the shortest quartile (Q1) (1.3.1), the second longest quartile (Q3) versus the Q1 (1.3.2), and the second shortest quartile (Q2) versus the Q1 (1.3.3) of television (TV) viewing time. CI = confidence interval; HPA = higher physical activity; IV = inverse variance; LPA = lower physical activity; MPA = middle physical activity.

CVD independently of physical activity and probably a sedentary lifestyle. Finally, because only published studies were included in the present meta-analysis, publication bias excluding unpublished studies may exist. The present linear regression test, however, did not identify funnel plot asymmetry, which suggests no publication bias. Although the included studies endeavored to adjust for a variety of known confounders, residual unknown confounders or imprecise adjustment could affect the association of TV viewing time with CVD risk.

In conclusion, longer TV viewing time is significantly associated with higher CVD risk (mainly CV mortality).

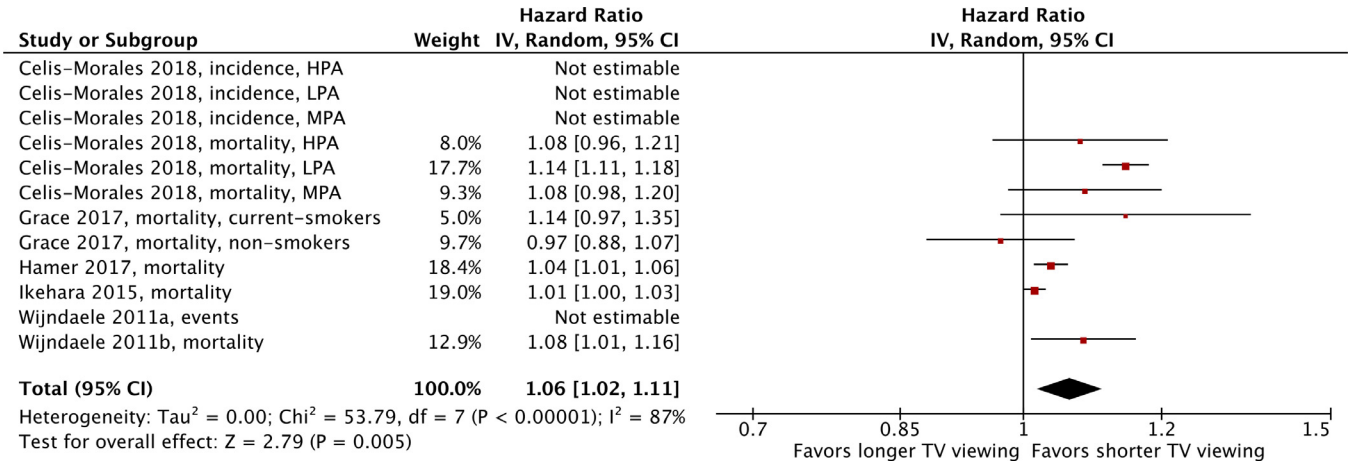

Figure 3. The primary meta-analysis for continuous television (TV) viewing time (hazard ratios per 1-h/day increment of TV viewing time). CI = confidence interval; HPA = higher physical activity; IV = inverse variance; LPA = lower physical activity; MPA = middle physical activity.

Disclosures

The authors have no conflicts of interest to disclose.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2019.08.032.

1. Powell C, Herring MP, Dowd KP, Donnelly AE, Carson BP. The cross-sectional associations between objectively measured sedentary time and cardiometabolic health markers in adults - a systematic review with meta-analysis component. *Obes Rev* 2018;19:381–395.
2. Wilmot EG, Edwardson CL, Achana FA, Davies MJ, Gorely T, Gray LJ, Khunti K, Yates T, Biddle SJ. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. *Diabetologia* 2012;55:2895–2905. Erratum in: *Diabetologia* 2013;56:942−943.
3. Biswas A, Oh PI, Faulkner GE, Bajaj RR, Silver MA, Mitchell MS, Alter DA. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med* 2015;162:123–132.
4. Chau JY, Grunseit AC, Chey T, Stamatakis E, Brown WJ, Matthews CE, Bauman AE, van der Ploeg HP. Daily sitting time and all-cause mortality: a meta-analysis. *PLoS One* 2013;8:e80000.
5. Sun JW, Zhao LG, Yang Y, Ma X, Wang YY, Xiang YB. Association between television viewing time and all-cause mortality: a meta-analysis of cohort studies. *Am J Epidemiol* 2015;182:908–916.
6. Kim SY, Park JE, Lee YJ, Seo HJ, Sheen SS, Hahn S, Jang BH, Son HJ. Testing a tool for assessing the risk of bias for nonrandomized studies showed moderate reliability and promising validity. *J Clin Epidemiol* 2013;66:408–414.
7. Arem H, Pfeiffer RM, Engels EA, Alfano CM, Hollenbeck A, Park Y, Matthews CE. Pre- and postdiagnosis physical activity, television viewing, and mortality among patients with colorectal cancer in the National Institutes of Health-AARP Diet and Health Study. *J Clin Oncol* 2015;33:180–188.
8. Cassidy S, Chau JY, Catt M, Bauman A, Trenell MI. Cross-sectional study of diet, physical activity, television viewing and sleep duration in 233,110 adults from the UK Biobank; the behavioural phenotype of cardiovascular disease and type 2 diabetes. *BMJ Open* 2016;6:e010038.
9. Celis-Morales CA, Lyall DM, Steell L, Gray SR, Iliodromiti S, Anderson J, Mackay DF, Welsh P, Yates T, Pell JP, Sattar N, Gill JMR. Associations of discretionary screen time with mortality, cardiovascular disease and cancer are attenuated by strength, fitness and physical activity: findings from the UK Biobank study. *BMC Med* 2018;16:77.
10. Díaz-Gutiérrez J, Ruiz-Canela M, Gea A, Fernández-Montero A, Martínez-González MÁ. Association between a healthy lifestyle score and the risk of cardiovascular disease in the SUN Cohort. *Rev Esp Cardiol (Engl Ed)* 2018;71:1001–1009.
11. Dunstan DW, Barr EL, Healy GN, Salmon J, Shaw JE, Balkau B, Magliano DJ, Cameron AJ, Zimmet PZ, Owen N. Television viewing time and mortality: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Circulation* 2010;121:384–391.
12. Ford ES. Combined television viewing and computer use and mortality from all-causes and diseases of the circulatory system among adults in the United States. *BMC Public Health* 2012;12:70.
13. Grace MS, Lynch BM, Dillon F, Barr EL, Owen N, Dunstan DW. Joint associations of smoking and television viewing time on cancer and cardiovascular disease mortality. *Int J Cancer* 2017;140:1538–1544.
14. Hamer M, Yates T, Demakakos P. Television viewing and risk of mortality: exploring the biological plausibility. *Atherosclerosis* 2017;263:151–155.
15. Ikehara S, Iso H, Wada Y, Tanabe N, Watanabe Y, Kikuchi S, Tamakoshi A, JACC Study Group. Television viewing time and mortality from stroke and coronary artery disease among Japanese men and women − the Japan Collaborative Cohort Study. *Circ J* 2015;79:2389–2395.
16. Kim Y, Wilkens LR, Park SY, Goodman MT, Monroe KR, Kolonel LN. Association between various sedentary behaviours and all-cause, cardiovascular disease and cancer mortality: the Multiethnic Cohort Study. *Int J Epidemiol* 2013;42:1040–1056.
17. Matthews CE, George SM, Moore SC, Bowles HR, Blair A, Park Y, Troiano RP, Hollenbeck A, Schatzkin A. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. *Am J Clin Nutr* 2012;95:437–445.
18. Stamatakis E, Hamer M, Dunstan DW. Screen-based entertainment time, all-cause mortality, and cardiovascular events: population-based study with ongoing mortality and hospital events follow-up. *J Am Coll Cardiol* 2011;57:292–299.
19. Warren TY, Barry V, Hooker SP, Sui X, Church TS, Blair SN. Sedentary behaviors increase risk of cardiovascular disease mortality in men. *Med Sci Sports Exerc* 2010;42:879–885.
20. Wijndaele K, Brage S, Besson H, Khaw KT, Sharp SJ, Luben R, Bhaniani A, Wareham NJ, Ekelund U. Television viewing and incident cardiovascular disease: prospective associations and mediation analysis in the EPIC Norfolk Study. *PLoS One* 2011;6:e20058.
21. Wijndaele K, Brage S, Besson H, Khaw KT, Sharp SJ, Luben R, Wareham NJ, Ekelund U. Television viewing time independently predicts all-cause and cardiovascular mortality: the EPIC Norfolk study. *Int J Epidemiol* 2011;40:150–159.
22. Patterson R, McNamara E, Tainio M, de Sá TH, Smith AD, Sharp SJ, Edwards P, Woodcock J, Brage S, Wijndaele K. Sedentary behaviour and risk of all-cause, cardiovascular and cancer mortality, and incident type 2 diabetes: a systematic review and dose response meta-analysis. *Eur J Epidemiol* 2018;33:811–829.