Title Total sedentary behavior and TV viewing with risk of overweight/obesity, type 2 diabetes, and hypertension: a dose–response meta-analysis

Running title

Total sedentary behavior and TV viewing with health outcomes

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Total sedentary behavior and TV viewing with risk of overweight/obesity, type 2 diabetes, and hypertension: a dose–response meta-analysis

ABSTRACT

Aims: We aimed to explore the quantitative dose–response association of total sedentary behavior and TV viewing with overweight/obesity, type 2 diabetes, and hypertension in a meta-analysis.

Materials and methods: We searched 3 databases to identify English language reports that assessed the association of total sedentary behavior or TV viewing with above health outcomes. Restricted cubic splines were used to evaluate possible linear or nonlinear association of total sedentary behavior and TV viewing with above health outcomes.

Results: We included 48 articles (58 studies) with 1,071,967 participants in the meta-analysis; 21 (6 cohort and 15 cross-sectional studies) studies examined the association of total sedentary behavior with overweight/obesity, 23 (13 cohort and 10 cross-sectional studies) with type 2 diabetes and 14 (1 cohort and 13 cross-sectional studies) with hypertension. We found linear association between total sedentary behavior and type 2 diabetes ($P_{\text{nonlinearity}}$=0.190) and hypertension ($P_{\text{nonlinearity}}$=0.225) and a nonlinear association for overweight/obesity ($P_{\text{nonlinearity}}$=0.003). For each 1-h/day increase in total sedentary behavior, the risk increased by 5% for type 2

diabetes and 4% for hypertension. We also found linear association between TV viewing and type 2 diabetes ($P_{nonlinearity}$=0.948) and hypertension ($P_{nonlinearity}$=0.679) and a nonlinear association for overweight/obesity ($P_{nonlinearity}$=0.007). For each 1-h/day increase in TV viewing, the risk increased by 8% for type 2 diabetes and 6% for hypertension.

Conclusions: High levels of total sedentary behavior and TV viewing were associated with overweight/obesity, type 2 diabetes, and hypertension.

Keywords: Total sedentary behavior, TV viewing, meta-analysis, obesity, type 2 diabetes, hypertension.

Introduction

Sedentary behavior is defined as any activity with low energy expenditure that expends approximately 1.0 to 1.5 times the metabolic equivalent of task and is usually assessed as sitting and TV viewing time [1, 2]. The 2003-2004 National Health and Nutrition Examination Survey (NHANES) revealed that Americans spend 54.9% of their waking time in sedentary behavior, about 7.7 h/day [3]. A multiethnic study of 10 countries found people spend average 8.65 h/day in sedentary behavior [4]. TV viewing may be one of the most commonly reported daily sedentary behaviors [5]. Australians spend an estimated 50% of their leisure time, on average, watching TV, about 3.5-4.0 h/day [6] and Americans about 5 h/day [7]. In modern society, sedentary behavior is highly prevalent and is increasingly considered a potentially important risk factor for health problems and diseases [8].

In the past decades, the number of studies investigating the potential association between sedentary behavior and public health outcomes has increased exponentially. Epidemiological studies have suggested the harmful health effects of long periods of total sedentary behavior independent of the level of physical activity [8-11]. Two previous meta-analyses demonstrated a high level of total sedentary behavior associated with increased risk of obesity [12] and hypertension [13]. However, the dose–response association between sedentary behavior, especially TV viewing time,

and overweight/obesity and hypertension remain unclear. A recent meta-analysis showed a linear association of total sedentary behavior and TV viewing with type 2 diabetes, but this study examined prospective studies from only August 1, 2014 to September 30, 2016, with 11 studies, for limited evidence [14].

Therefore, we performed a dose–response meta-analysis to quantitatively evaluate possible linear or nonlinear association of total sedentary behavior and TV viewing with risk of overweight/obesity, type 2 diabetes, and hypertension among adults by using all available evidence.

Methods

Search Strategy

We followed the protocol for Meta-analysis of Observational Studies in Epidemiology (MOOSE) for this meta-analysis [15]. PubMed, EMBASE and Web of Science were searched up to July 4, 2019 for English language reports of studies examining the association between total sedentary behavior (including TV viewing) and overweight/obesity, type 2 diabetes, and hypertension among adults (≥18 years). We used various combinations of the following MeSH terms and keywords: *sedentary behavior*, *sitting time*, *TV viewing*, *body mass index*, *obesity*, *diabetes mellitus*, and *hypertension* (details in **Table S1**). We also manually screened the reference lists of relevant and review articles for additional publications.

Study Selection

Studies were included if 1) study participants were adults (≥18 years); 2) the exposure of interest was total sedentary behavior (including daily sitting, TV viewing, driving, reading, eating, and occupational sitting) and the outcomes were overweight/obesity (defined by body mass index, BMI), type 2 diabetes, and hypertension; and 3) the report provided multivariate-adjusted relative risks (RRs), odds ratios (ORs) or hazard ratios (HRs) with 95% confidence intervals (CIs) or reported data to calculate these. If multiple articles were published for the same study, we included data from the study with the most detailed report and/or the largest sample size. We excluded reviews, comments, letters and editorials.

Data Extraction and Quality Assessment

Two authors (CG and QZ) independently extracted data on the first author, publication year, country, study design, participant characteristics (sex and age), follow-up years, sample size, number of cases, definition and measurement of total sedentary behavior, outcomes assessment, confounding factors and ORs/RRs/HRs with 95% CIs (adjusted by the most confounders). Any disagreement was resolved by consensus.

Quality of eligible cohort studies was evaluated by the Newcastle-Ottawa Scale (NOS) [16], with a total score of 9 points (highest quality) for 8 aspects. Quality of

cross-sectional studies was assessed by the Agency for Healthcare Research and Quality (AHRQ) scale [17], which includes 11 items answered by ‘‘Yes’’ ‘‘No’’ or ‘‘Unclear’’. An item was scored 0 for “No” or “Unclear” and 1 for “Yes”. We assigned scores of 0-3, 4-7 and 8-11 for low, moderate and high quality [18].

Data Synthesis and Analysis

Extracted data were harmonized, converting each measure into total sedentary behavior, and quantified in hours/day (h/day). Studies separately reporting results for men and women or reporting on different domains of total sedentary behavior were combined by using a fixed-effects model before inclusion in the meta-analysis. TV viewing may be one of the most commonly reported daily sedentary behavior [5]. Therefore, we further explored the association between TV viewing and risk of overweight/obesity, type 2 diabetes, and hypertension.

We used the RRs (95% CIs) as the unified effect size for all studies, and assumed that HRs and ORs reported for outcomes in the original study were approximately RRs [19]. If the number of cases or participants were not provided in each category, we calculated these data from the available data [20]. Categories of total sedentary behavior were assigned a dose, either the mid-point or in case of open-ended categories, half the width of the adjacent interval from the boundary [21]. When the lowest exposure was not the reference category, we used the method proposed by

Hamling to convert risk estimates [22].

We used random-effects models to estimate the pooled RRs for the association of total sedentary behavior and TV viewing with risk of overweight/obesity, type 2 diabetes, and hypertension. Studies with at least 3 levels of total sedentary behavior and TV viewing were included in the dose–response analyses. We adopted restricted cubic splines with 3 knots (25th, 50th, and 75th percentiles) of exposure distribution to evaluate possible linear or nonlinear association between total sedentary behavior and the health outcomes [23]. Finally, we used the DerSimonian and Laird random effects model to pool the study-specific dose–response RRs (95% CIs) for each 1-h/day increase in total sedentary behavior and TV viewing if linear association were observed [24].

We assessed heterogeneity with the I^2 test [25]. I^2>50% was considered statistically significant. With I^2>50%, a random-effects model was used; otherwise, a fixed-effects model was used. Subgroup analyses were performed by study design, region, sex, assessment of exposure and outcomes and adjustment for confounders. We also performed sensitivity analyses by omitting 1 study at a time to examine the influence of each study on the pooled results. Publication bias was assessed by funnel plots and the Egger test [26].

All analyses were performed with Stata 12.0 (Stata Corp, College Station, TX).

All tests were 2-sided, with $P<0.05$ considered statistically significant.

Results

Study Selection

We identified 49,748 articles from PubMed, EMBASE and Web of Science, and 4 from the reference list search. After excluding duplicates (n=21,368) and title or abstract screening (n=28,189), we assessed 195 full-text articles. We further excluded 147 articles because of duplicate data from the same study (n=6); review and meta-analysis studies (n=7); exposures or outcomes not of interest (n=92); lacking available data (n=33), and other reasons (n=9). Finally, 48 articles (58 studies) were included in this meta-analysis (**Figure 1**).

Characteristics and Quality Assessment of Included Studies

The sample size of eligible studies ranged from 455 [27] to 240,086 [28], a total of 1,071,967 participants (**Table S2**). Eight articles reporting more than one health outcome were treated as independent studies [28-35]. Among these studies, 21 studies (6 cohort and 15 cross-sectional studies) examined the association between total sedentary behavior and overweight/obesity [32-52], 23 (13 cohort and 10 cross-sectional studies) type 2 diabetes [28-33, 35, 53-68], and 14 (1 cohort and 13 cross-sectional studies) hypertension [27-31, 33-35, 69-74]. Ten studies were conducted in North America [27, 32, 34, 39, 49, 53, 58, 62, 65, 73], 2 in South

America [67, 68], 9 in Australia[30, 31, 42-45, 50, 64, 70], 18 in Europe [29, 33, 36, 37, 40, 41, 46, 47, 51, 54-56, 60, 63, 66, 69, 71, 72], 7 in Asia [28, 35, 38, 48, 52, 57, 74], and 2 in other regions [59, 61]. Total sedentary behavior was objectively assessed in 5 studies by using accelerometers [61, 65, 66, 72, 74], but was otherwise self-reported by using questionnaires or interviews. Definitions of total sedentary behavior varied across studies: it was widely reported as sitting, TV viewing, job-related or other leisure inactive time. The mean quality score was 7.1 (range 6-9) assessed by the NOS for cohort studies and 7.5 (range 6-11) by the AHRQ for cross-sectional studies, which indicates high quality of included studies (**Table S3 a and b**).

Total Sedentary Behavior and TV Viewing and Overweight/Obesity

The pooled RR for overweight/obesity for the longest versus shortest category of total sedentary behavior was 1.38 (95% CI 1.22-1.56), with high heterogeneity (I^2=84.4%, $P_{\text{heterogeneity}}$<0.001) (**Figure S1**). Publication bias was detected (Egger test, P=0.001), but significant results were also found (1.12; 95% CI 1.00-1.27) after performing the trim and fill method. We included 15 studies for the dose–response analysis and observed a nonlinear association between total sedentary behavior and overweight/obesity ($P_{\text{nonlinearity}}$=0.003), and this trend did not change after adjustment for physical activity (**Figure S4**). The shape of the nonlinear curve was steeper when

total sedentary behavior time was <3 h/day, but the increase was more gradual after 3 h/day (**Figure 4**). For participants with total sedentary time 3 h/day, the risk of overweight/obesity was increased 38% (RR 1.38; 95% CI 1.20-1.58) **(Table 1)**.

For TV viewing, the pooled RR for overweight/obesity for the longest versus shortest category was 1.62 (95% CI 1.22-2.14), with high heterogeneity (I^2=90.5%, $P_{heterogeneity}$<0.001) (**Figure S1**). Publication bias was suggested (Egger test, P=0.018), but the main result was attenuated when the trim and fill method was used (1.05; 95% CI 1.11-1.34). We included 9 studies for the dose–response analysis and the association appeared to be nonlinear ($P_{nonlinearity}$=0.007); the shape of the nonlinear curve was steeper when TV viewing time was < 3 h/day, but the increase was more gradual after 3 h/day (**Figure 4**). For participants with TV viewing time 3 h/day, the risk of overweight/obesity was increased 53% (RR 1.53; 95% CI 1.26-1.87) **(Table 1)**. This trend was consistent after adjustment for physical activity (**Figure S4**).

Total Sedentary Behavior and TV Viewing and Type 2 Diabetes

The pooled RR for type 2 diabetes with the longest versus shortest total sedentary behavior was 1.35 (95% CI 1.23-1.47), with significant heterogeneity (I^2=75.4%, $P_{heterogeneity}$<0.001) (**Figure S2**). Publication bias was suggested (Egger test, P=0.012). When the trim and fill method was used, the RR was attenuated but remained significant (1.22; 95% CI 1.11-1.34). We included 18 studies for the

dose–response analysis and found a linear association between total sedentary behavior and type 2 diabetes ($P_{nonlinearity}$=0.190) (**Figure 4**) and the trend was consistent after adjustment for physical activity (**Figure S4**). With each 1-h/day increase in total sedentary behavior, the risk of type 2 diabetes was increased 5% (RR 1.05; 95% CI 1.04-1.07, I^2=83.4%, $P_{heterogeneity}$<0.001) (**Figure 2**). Publication bias was detected (Egger's test, P=0.014). When the trim and fill method was used, the main result was attenuated but remained significant (1.03; 95% CI 1.02-1.05).

For TV viewing, when comparing the longest to the shortest category, the pooled RR for type 2 diabetes was 1.46 (95% CI 1.26-1.69), with moderate heterogeneity (I^2=61.6%, $P_{heterogeneity}$=0.004) (**Figure S2**). We found no evidence of publication bias (Egger test, P=0.181). We included 8 studies for the dose–response analysis, and the association appeared to be linear ($P_{nonlinearity}$=0.948) (**Figure 4**). The results did not change after adjustment for physical activity (**Figure S4**). For type 2 diabetes, the pooled RR for each 1-h/day increase in TV viewing was 1.08 (95% CI 1.06-1.10), with no evidence of heterogeneity (I^2=0.0, $P_{heterogeneity}$=0.792) (**Figure 2**) or publication bias (Egger test, P=0.292).

Total Sedentary Behavior and TV Viewing and Hypertension

As compared with the shortest category of total sedentary behavior, with the longest category, risk of hypertension was 1.23 (95% CI 1.12-1.35), with significant

heterogeneity (I^2=71.4%, $P_{heterogeneity}$<0.001) (**Figure S1**). We found no evidence of publication bias (Egger test, P=0.281). We included 8 studies in the dose–response analysis and found linear association between total sedentary behavior and hypertension ($P_{nonlinearity}$=0.225) (**Figure 3**), and the association was consistent after adjustment for physical activity (**Figure S4**). With each 1-h/day increase in total sedentary behavior, the risk of hypertension was increased 4% (RR 1.04; 95% CI 1.00-1.07, I^2=87.8%, $P_{heterogeneity}$<0.001) (**Figure 3**). We found no evidence of publication bias (Egger test, P=0.609).

For TV viewing, as compared with the shortest category, with the longest category, the risk of hypertension was 1.28 (95% CI 1.19-1.38), with no heterogeneity (I^2=0.0%, $P_{heterogeneity}$=0.489) (**Figure S3**) or publication bias (Egger test, P=0.640). Three studies were included in the dose–response analysis, and the association appeared to be linear ($P_{nonlinearity}$=0.679) (**Figure 4**); results were consistent after adjustment for physical activity (**Figure S4**). For each 1-h/day increase in TV viewing, the pooled RR for hypertension was 1.06 (95% CI 0.99-1.14), with no heterogeneity (I^2=0.0, $P_{heterogeneity}$=0.454) (**Figure 3**). Publication bias was not assessed because only 3 studies were available for this association.

Subgroup and Sensitivity Analyses

Table 2 shows the results from subgroup analyses examining the stability of the

pooled results and exploring the potential sources of heterogeneity. The linear dose–response association between total sedentary behavior and risk of type 2 diabetes and hypertension were consistent across different subgroups by study design, geographic location, participants, assessment of sedentary behavior, drinking alcohol, smoking, education level and adjustment for physical activity at baseline etc. (**Table 2**). Similar results were found for TV viewing and type 2 diabetes (**Table S4**). We did not perform subgroup analyses for TV viewing and hypertension because of insufficient studies (n=3). Sensitivity analyses for all the above outcomes by omitting one study at a time gave similar results.

Discussion

This meta-analysis, involving 1,071,967 participants, showed that high levels of total sedentary behavior or TV viewing may increase the risk of overweight/obesity, type 2 diabetes, and hypertension as compared with low levels of sedentary behavior and TV viewing, independent of physical activity. As well, the association with TV viewing were stronger than those for total sedentary behavior for all outcomes. We found a dose–response relation between total sedentary behavior and TV viewing and overweight/obesity, type 2 diabetes, and hypertension.

Results of previous meta-analyses evaluating the association between sedentary behavior and overweight/obesity, type 2 diabetes, and hypertension were consistent

with our study [12-14]. However, previous research on overweight/obesity involving a traditional binary meta-analysis to explore the association between total sedentary behavior and overweight/obesity based on 6 studies [12], we quantitatively explored the dose–response association and further explored the association between TV viewing and overweight/obesity. Different from the meta-analysis by Lee *et al.*, including both adults and children [13], our study focused on adults and further explored the dose–response association between TV viewing and risk of hypertension. Unlike the previous study which based on 11 studies, with a smaller sample size (n=400,292) [14], the present meta-analysis included more comprehensive original research and had a larger sample size, which increased the accuracy and reliability of the effect estimates.

Our meta-analysis revealed a non-linear association between sedentary behavior and risk of overweight/obesity but a linear association for type 2 diabetes and hypertension. The effect of sedentary behavior on type 2 diabetes and hypertension was larger than that on overweight/obesity, especially when sedentary behavior time was ≥3 h/day. The finding may be explained by the effect of sedentary behavior on type 2 diabetes and hypertension being from not only the direct effect of sedentary behavior on type 2 diabetes and hypertension but also the indirect effect of obesity in the association between sedentary behavior and type 2 diabetes and hypertension.

Further studies exploring the potential mechanism of sedentary lifestyle combined with obesity on the risk of type 2 diabetes and hypertension are needed.

Potential mechanisms have been suggested to explain the positive association between total sedentary behavior and risk of overweight/obesity, type 2 diabetes, and hypertension. A commonly acknowledged mechanism for high level of total sedentary behavior is diminished muscle contractile activity. High amounts of sedentary time may cause infrequent skeletal muscle contractile activity and thus reduce lipoprotein lipase activity in muscle, a key enzyme regulating lipid metabolism [75, 76]. Low lipoprotein lipase activity is associated with increased levels of glucose and lipids (also known as postprandial dysmetabolism), a risk factor for cardiovascular disease [77-79]. Excess sedentary behavior also leads to reduced energy expenditure, which is inversely associated with body weight, blood pressure, and glucose concentration [80, 81]. Indeed, intervention trials demonstrated that breaking up high level of sitting with standing or walking reduced postprandial glucose, insulin and lipid concentrations [82-84].

The stronger association between TV viewing and outcomes as compared with total sedentary behavior may have several explanations. First, TV viewing may increase total energy intake because of an association with snacking behavior [85], with eating behavior affected by food advertising [86]. Second, typical TV viewing

time is usually after dinner in the evening, and prolonged postprandial sitting may cause glucose and lipid dysmetabolism [87]. Finally, potential confounders (e.g., dietary factors) for TV viewing may be more difficult to fully account for.

Our findings may have important implications for public health. The prevalence of overweight/obesity, type 2 diabetes, and hypertension is increasing at an alarming rate worldwide [88-90]. Meanwhile, sedentary behavior is prevalent and pervasive in modern society, and data from adults in high-income countries suggest that most of the awaking time is spent being sedentary [91, 92]. Currently, the United States and other high-income countries have mainly focused on physical activity promotion and have issued health guidelines [93], but few guidelines exist for sedentary behavior [94]. This absence represents an important gap in the public health guidelines because of the severe consequences and profound burden of total sedentary behavior. Given the association between sedentary lifestyle and poor health outcomes observed in the present and other studies [8, 14, 95], public health campaigns to reduce the risk of chronic disease should advocate regular physical activity as well as a decrease in sedentary time, especially TV viewing time.

The main strength of this study is that our meta-analysis explored the separate association between total sedentary behavior and TV viewing with overweight/obesity, type 2 diabetes, and hypertension. In addition, we investigated the dose–response

association for all exposure-outcome combinations with higher statistical power than traditional binary meta-analysis. Moreover, to our knowledge, this is the first dose–response meta-analysis exploring the association of total sedentary behavior as well as TV viewing with risk of overweight/obesity and hypertension. We also conducted sensitivity analyses after adjustment for physical activity to identify its meditation of the association between total sedentary behavior and risk of all outcomes.

Our study also has several limitations. First, sedentary behavior in most included studies was self-reported, which may imply recall bias and misclassification of exposure. Future studies with objectively measured sedentary behavior such as accelerometry and long-term follow-up are needed to confirm our findings. Second, other sedentary behaviors such as Internet and computer use might also affect the development of metabolic disorders among young adults. However, we did not explore the association between computer use and risk of these health outcomes because of the relatively few numbers of studies. Third, although extracted risk estimates were adjusted for various known risk factors, we cannot rule out residual or unmeasured confounding. Finally, most studies assessed total sedentary behavior only once, and single-point measurement can increase the chance of random measurement error, which might over- or underestimate the reported effects.

Conclusion

In conclusion, our dose–response meta-analysis found that high levels of total sedentary behavior and TV viewing may increase the risk of overweight/obesity, type 2 diabetes, and hypertension among adults. More longitudinal and intervention studies are needed to clarify whether reducing total sedentary behavior as well as TV viewing can prevent chronic disease or reduce the progression of related disease.

Conflict of interest

The authors declare that they have no conflict of interest.

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Table 1. Non-linear dose–response analysis of the association of total sedentary behavior and TV viewing with overweight/obesity

Total sedentary behavior (h/day)	Overweight/obesity RR (95% CI)
1	1.13 (1.07-1.19)
3	1.38 (1.20-1.58)
5	1.44 (1.26-1.64)
7	1.46 (1.27-1.67)
TV viewing (h/day)	
1	1.17 (1.08-1.26)
3	1.53 (1.26-1.87)
5	1.75 (1.36-2.26)
7	1.97 (1.43-2.71)

Abbreviations: RR, relative risk; 95% CI, 95% confidence interval; h, hour.

Table 2. Dose–response subgroup analyses of the association of total sedentary behavior (per 1-h/day increase) and type 2 diabetes and hypertension.

Subgroup	Type 2 diabetes				Hypertension			
	No. of studies	RR (95% CI)	I^2 (%)	*P*	No. of studies	RR (95% CI)	I^2 (%)	*P*
All studies	18	1.05 (1.04-1.07)	83.4	0.000	8	1.04 (1.00-1.07)	87.8	0.000
Study design								
Cohort study	13	1.04 (1.02-1.06)	80.4	0.000	1	1.04 (1.00-1.07)	-	-
Cross-sectional study	5	1.08 (1.04-1.11)	87.8	0.000	7	1.03 (0.99-1.08)	89.5	0.000
Region								
America	7	1.06 (1.03-1.09)	89.3	0.000	2	1.06 (0.96-1.16)	59.1	0.118
Europe	5	1.06 (1.01-1.11)	85.0	0.000	3	1.02 (1.00-1.05)	27.6	0.251
Australia	2	1.03 (1.02-1.04)	0.0	1.000	2	1.01 (1.00-1.02)	0.0	1.000
Asia	2	1.05 (1.04-1.07)	0.0	0.336	1	1.14 (1.00-1.30)	-	-
Other	2	1.08 (1.03-1.13)	48.5	0.163	0	-	-	-
Participants								
Men	2	1.03 (1.02-1.04)	0.0	0.438	1	1.01 (1.00-1.02)	-	-
Women	4	1.06 (1.02-1.10)	93.5	0.000	0	-	-	-
Men and women	12	1.06 (1.03-1.08)	79.7	0.000	7	1.04 (1.00-1.08)	77.1	0.000

Assessment of exposure								
Questionnaire	15	1.05 (1.03-1.06)	82.0	0.000	6	1.03 (0.99-1.07)	90.9	0.000
Objective measured	3	1.10 (1.00-1.23)	80.2	0.002	2	1.12 (1.00-1.25)	0.0	0.665
Assessment of outcomes								
Self-reported	8	1.05 (1.03-1.07)	81.4	0.000	2	1.02 (0.99-1.05)	62.2	0.104
Objective measured	10	1.06 (1.03-1.08)	85.2	0.000	6	1.04 (0.99-1.10)	79.7	0.000
Controlling for physical activity								
Yes	16	1.05 (1.03-1.06)	83.5	0.000	6	1.05 (1.00-1.09)	90.9	0.000
No	2	1.08 (1.05-1.12)	0.0	0.759	2	1.00 (0.97-1.03)	0.0	0.772
Controlling for BMI								
Yes	12	1.05 (1.03-1.07)	82.6	0.000	3	1.02 (1.00-1.04)	30.6	0.237
No	6	1.06 (1.05-1.08)	33.4	0.185	5	1.05 (0.99-1.11)	82.7	0.000
Controlling for drinking alcohol								
Yes	14	1.05 (1.03-1.08)	84.6	0.000	4	1.02 (1.00-1.04)	0.0	0.407
No	4	1.05 (1.02-1.09)	82.8	0.001	4	1.05 (0.99-1.12)	94.5	0.000
Controlling for smoking								
Yes	17	1.06 (1.04-1.07)	83.8	0.000	7	1.01 (1.00-1.03)	12.7	0.333
No	1	1.01 (0.99-1.04)	-	-	1	1.09 (1.07-1.11)	-	-
Controlling for education level								
Yes	14	1.05 (1.03-1.07)	85.7	0.000	5	1.01 (1.00-1.02)	0.0	0.926
No	4	1.06 (1.04-1.07)	0.0	0.582	3	1.07 (1.03-1.12)	68.7	0.041
Controlling for family history of diabetes								

Yes	7	1.05 (1.02-1.08)	87.4	0.000	1	1.04 (1.00-1.07)	-	-
No	11	1.06 (1.03-1.08)	81.6	0.000	7	1.03 (0.99-1.08)	89.5	0.000

Abbreviations: RR, relative risk; CI, confidence intervals; BMI, body mass index.

Figure legends

Figure 1. Flow chart of article selection.

Figure 2. Forest plot of study-specific relative risk for type 2 diabetes per 1-h/day increase in total sedentary behavior and TV viewing.

Figure 3. Forest plot of study-specific relative risk for hypertension per 1-h/day increase in total sedentary behavior and TV viewing.

Figure 4. Dose–response association of total sedentary behavior and TV viewing with risk of overweight/obesity, type 2 diabetes, and hypertension modeled by restricted cubic splines.