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ORIGINAL PAPER

Television watching and colorectal cancer survival in men

Yin Cao[1] · Jeffrey A. Meyerhardt[2] · Andrew T. Chan[3,4] · Kana Wu[1] · Charles S. Fuchs[2,3] · Edward L. Giovannucci[1,3,5]

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Abstract
Purpose To assess the association between pre- and postdiagnostic time spent sitting watching TV as well as other sedentary behaviors (other sitting at home and at work/driving) and mortality from colorectal cancer or other causes, and overall mortality.
Methods We followed stage I–III colorectal cancer patients from the Health Professionals Follow-up Study (1986–2010). Cox models were used to calculate hazard ratios (HRs) and 95 % confidence intervals (CIs).
Results A total of 926 and 714 patients were included in the analysis of pre- and postdiagnostic TV watching, respectively, and 471 and 325 died during follow-up. Prolonged prediagnostic TV viewing was associated with increased risk of colorectal cancer-specific mortality independent of leisure-time physical activity. The HRs (95 % CIs) for 0–6, 7–13, 14–20, and ≥21 h/week were 1.00 (referent), 0.84 (0.56–1.25), 1.15 (0.75–1.78), and 2.13 (1.31–3.45) ($p_{trend} = 0.01$). The association was observed primarily among overweight and obese individuals. Prediagnostic TV watching was also associated with overall mortality within 5 years of diagnosis, largely due to the association with colorectal cancer mortality. Other prediagnostic sitting at home or at work/driving was not associated with mortality. Postdiagnostic TV viewing was associated with a nonsignificantly increased risk of colorectal cancer-specific mortality (HR for ≥21 vs 0–6 h/week = 1.45; 95 % CI 0.73–2.87) adjusting for TV viewing before diagnosis.
Conclusion Prolonged prediagnostic TV watching is associated with higher colorectal cancer-specific mortality independent of leisure-time physical activity among colorectal cancer patients.

Keywords Sedentary behavior · Television watching · Colorectal cancer · Survival

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✉ Yin Cao
yic576@mail.harvard.edu

[1] Department of Nutrition, Harvard T. H. Chan School of Public Health, 665 Huntington Avenue, Boston, MA 02115, USA

[2] Department of Medical Oncology, Dana-Farber Cancer Institute and Harvard Medical School, Boston, MA, USA

[3] Channing Division of Network Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, MA, USA

[4] Division of Gastroenterology, Massachusetts General Hospital and Harvard Medical School, Boston, MA, USA

[5] Department of Epidemiology, Harvard T. H. Chan School of Public Health, Boston, MA, USA

Introduction

Sedentary behaviors, characterized by an energy expenditure ≤1.5 METs (metabolic equivalent of task) while in a sitting or reclining posture, are increasingly prevalent in modern society [1]. These include sitting, lying down, reading, driving, watching television (TV), and other forms of screen-based entertainment. Although TV watching itself does not represent the entire spectrum of sedentary behaviors, it is the most widespread leisure-time sedentary behavior of adults in the USA and other western countries [2–4] and is effective in ranking individuals by sedentary lifestyle [5, 6]. Indeed, epidemiologic studies have linked

time spent watching TV with cardiometabolic biomarkers [5, 7, 8] and increased risk of obesity, diabetes [9–12], cardiovascular disease [13, 14], and all-cause mortality [3, 14], independent of physical activity levels. Stronger associations with TV viewing time than with occupational sitting time were also observed [10, 15]. A higher likelihood of having eating patterns linked to commercial advertisement and food cues appearing on TV may partially explain the additional deleterious effect of prolonged TV viewing [10].

The role of sedentary behaviors in colorectal carcinogenesis is of particular interest as obesity and diabetes are established risk factors for colorectal cancer [16–20]. Although data suggest modest positive associations of sitting time with risk of incident colorectal cancer [21–23], studies among colorectal cancer survivors are limited. Campbell et al. reported that ≥6 h/day of total leisure-time sitting (including sitting driving or sitting in a car/bus/train; sitting watching TV; and sitting at home reading) compared with <3 h/day was associated with colorectal-specific mortality [pre- and postdiagnostic hazard ratio (HR) and 95 % CI 1.33 (0.96–1.84) and 1.62 (1.07–2.44)] and higher all-cause mortality [pre- and postdiagnostic HR and 95 % CI 1.36 (1.10–1.68) and 1.27 (0.99–1.64)] [24]. Recently, Arem et al. [25] examined TV watching explicitly and found that TV watching before diagnosis was associated with all-cause mortality (HR for ≥5 vs 0–2 h/day = 1.22; 95 % CI 1.06–1.41) but with a nonsignificantly increased risk of colorectal cancer mortality (HR 1.18; 95 % CI 0.82–1.68); whereas postdiagnostic TV watching was associated with a nonsignificantly increased risk of all-cause mortality (HR 1.25; 95 % CI 0.93–1.67) and colorectal cancer mortality (HR 1.45; 95 % CI 0.85–2.47).

In this study, we assessed the association between time spent sitting while watching TV and colorectal cancer-specific mortality and overall mortality among individuals diagnosed with nonmetastatic enrolled in the Health Professionals Follow-up Study (HPFS), 1986–2010. We also assessed the influence of other sitting at home and at work/driving.

Methods

Study population

The HPFS is a cohort study of 51,529 US male health professionals aged 40–75 years at enrollment in 1986. Participants have been mailed questionnaires every 2 years since baseline to collect data on demographics, lifestyle factors, medical history, and disease outcomes, and every 4 years to report update in dietary intake. The overall follow-up rate was >94 %, and ascertainment of deaths was more than 98 % complete [26].

Ascertainment of colorectal cancer diagnosis

On each biennial follow-up questionnaire, participants were asked whether they had a diagnosis of colorectal cancer during the prior 2 years. When a participant (or the next of kin for decedents) reported colorectal cancer, we sought permission to obtain medical records and pathology reports. Study physicians, blinded to exposure data, reviewed all medical records related to colorectal cancer and recorded the disease stage, histologic findings, and tumor location. For nonresponders, we searched the National Death Index to discover deaths and to ascertain any diagnosis of colorectal cancer that contributed to death or was a secondary diagnosis.

In total, 1,222 men were diagnosed as having colorectal cancer in the HPFS between January 1986 and January 2010; we excluded 191 men with metastatic colorectal cancer at the time of diagnosis. Of 1,031 remaining men, 926 reported prediagnostic TV viewing time and 720 reported average hours of sitting watching TV between 6 months and 3 years after diagnosis. To minimize bias by occult recurrences or other undiagnosed major illnesses, we excluded 6 men who died within 6 months of their postdiagnostic TV watching assessment. A total of 714 men were eligible for the analysis of postdiagnostic TV viewing.

Assessment of TV watching and other sedentary behaviors

Starting from 1988, participants reported their average weekly time spent sitting watching TV (including videotapes) biennially. The 1988 questionnaire included six response categories (ranging from 0 to 1 to ≥40 h/week). Beginning in 1990, biennial questionnaires included 13 response categories (ranging from 0 to ≥40 h/week) for time spent sitting watching TV as well as sitting at work, driving, and other sitting at home (including reading, eating, or at desk), respectively, using the same response categories as TV watching. Similar assessment of sedentary behaviors was used in the Nurses' Health Study and was found to be associated with increased risk of obesity and diabetes [10]. We also reported previously that in a sample of participants the average number of hours of TV watching reported in 1994 was significantly positively associated with low-density lipoprotein cholesterol and significantly inversely associated with HDL cholesterol and apolipoprotein A1 [5].

To capture long-term sitting behavior, we calculated cumulative average hours of sitting (TV watching, at

work/driving, and other sitting at home) up to the time of diagnosis in the analyses of prediagnostic sedentary behavior. The median time from baseline to diagnosis was 11 years. As a sensitivity analysis, the response from the immediate prior survey was used (median, 12 months before diagnosis). For postdiagnostic analyses, the first assessment collected at least 6 months after diagnosis (median, 17 months after diagnosis) was used to avoid assessment during the period of active treatment, but within the period of highest likelihood of recurrences.

Assessment of physical activity and other covariates

Every 2 years, participants were asked to report the average amount of time they spent per week on each of the following activities: walking, jogging, running, bicycling, calisthenics or use of a rowing machine, lap swimming, squash or racquetball, and tennis, as well as usual walking pace. From this information, weekly energy expenditure in metabolic equivalent hours (MET-hrs) was calculated [27]. Information of body mass index (BMI), smoking, regular aspirin use, alcohol, folate, calcium, red meat intake, and energy intake was also obtained from the biennial questionnaire and considered in multivariable analyses as potential confounders.

Measurement of mortality

Men were followed up until death or 31 December 2011, whichever came first. Ascertainment of deaths included reporting by the family or by postal authorities. In addition, the names of consistent nonresponders were searched in the National Death Index [28]. The cause of death was assigned by study physicians blinded to exposure data. In the case of men who died of colorectal cancer not previously reported, we obtained medical records of the colorectal cancer diagnosis after receiving permission from the next of kin. More than 98 % of deaths in the HPFS have been identified using these methods [28].

Statistical analysis

In the main analysis, death from colorectal cancer was the primary end point, and deaths from other causes were censored. In secondary analyses, death from causes other than colorectal cancer and deaths from any cause were the end points. We estimated the Spearman correlation coefficients between pre- and postdiagnostic TV watching and between TV watching and BMI and physical activity. Due to limited number of colorectal cancer-specific deaths among patients who had a postdiagnostic TV measurement, the primary exposure of interest was sedentary behavior before the diagnosis of colorectal cancer. Participants were followed up from diagnosis in prediagnostic analysis or beginning 6 months from the date of the first postdiagnostic TV watching assessment for postdiagnostic analysis, to death or 31 December 2011, whichever came first. Four categories of sitting time were coded consistently across all questionnaires (0–6, 7–13, 14–20, ≥21 h/week). Test for trend was conducted using continuous hours of sitting time. Departures from the proportional hazards assumption were tested by likelihood ratio tests comparing models with and without the interaction terms of survival time by categories of sitting behavior. No significant violation was detected.

Kaplan–Meier curves were plotted, and log-rank tests were performed. Cox proportional hazards models were used to calculate HRs, adjusting for other risk factors for cancer survival, including age at diagnosis (*year*), years of diagnosis (*prior to 1990, 1990–1999, 2000+*), stage (*I*, *II*, *III*, *missing and not metastatic*), grade (*well, moderate, poor/undifferentiated, unknown*), tumor location (*rectal, colon*), and smoking status (*never, past, current*). We also examined whether established or probable risk factors for colorectal cancer, including regular aspirin use (*yes/no*), alcohol (<5, 5 to <30, ≥30 g/day), folate (*in tertiles*), calcium (*in tertiles*), red meat intake (*in tertiles*), and energy intake (*in tertiles*), affect the associations of interest. We adjusted for leisure-time physical activity (<9, 9 to <18, 18 to <27, ≥27 MET-h/week) to assess whether the influence of sedentary behaviors was distinct from physical activity, which was inversely associated with colorectal cancer-specific mortality and overall mortality [29].

We adjusted for BMI to explore whether it mediates the association of interest. To fully assess whether observed associations may be explained by unhealthy diet, we adjusted for Alternate Health Eating Index (AHEI)-2010, an updated composite score from the original AHEI [30], which features higher consumption of vegetables (excluding potatoes), whole fruit, whole grains, nuts and legumes, long-chain omega-3 fatty acids, polyunsaturated fat; and a lower consumption of sugar-sweetened beverages, red/processed meat, sodium, trans fat, and moderate alcohol consumption. Adherence to the AHEI-2010 was associated with reduced risk of major chronic diseases [31]. For prediagnostic analysis, cumulative average (when applicable) of the potential confounders up to the time of diagnosis was used, and first assessment after diagnosis was used for postdiagnostic analysis.

We examined whether the association between TV watching and colorectal cancer-specific mortality differed by age at diagnosis (<70 vs ≥70 years), stage (I/II vs III vs missing, not known to be metastatic), tumor location (colon vs rectum), year of diagnosis (before 2000 vs after 2000), physical activity (<18 vs ≥18 MET-h/week), and BMI (<25 vs ≥25 kg/m^2). We evaluated interaction by entering a product term of continuous TV watching and the above

Table 1 Age-standardized* characteristics of colorectal cancer cases according to time spent sitting watching television

Characteristic	Prediagnostic sitting while watching TV, cumulative average (h/week) ($n = 926$)				Postdiagnostic sitting while watching TV (h/week) ($n = 714$)			
	0–6	7–13	14–20	≥21	0–6	7–13	14–20	≥21
No. of patients	339	313	180	94	333	128	139	114
Age at diagnosis (year)	71.2 (9.1)	72.2 (9.0)	71.3 (9.6)	70.4 (10.2)	71.4 (9.4)	67.9 (8.8)	69.8 (9.5)	70.5 (8.8)
Follow-up time (year)†	8.8 (5.9)	8.9 (5.7)	9.1 (6.7)	8.8 (6.5)	9.0 (5.7)	10.3 (5.9)	9.5 (5.7)	8.7 (6.2)
Sitting while watching TV (h/week)	3.9 (1.5)	10.1 (1.6)	16.5 (1.2)	27.4 (2.7)	2.8 (1.5)	8.5 (0.1)	15.5 (0.0)	29.5 (4.1)
Sitting at work/driving (h/week)	12.0 (8.6)	12.5 (9.0)	11.9 (7.6)	13.3 (7.4)	8.5 (9.8)	10.5 (6.9)	11.2 (7.9)	10.5 (7.2)
Other sitting at home (h/week)‡	7.9 (5.4)	11.1 (5.4)	12.2 (5.3)	14.9 (5.0)	7.3 (6.8)	13.1 (5.9)	14.8 (6.4)	19.2 (10.2)
Working full/part time (%)	57	46	43	42	44	48	36	25
History of endoscopy before diagnosis (%)	51	52	54	45	48	49	53	53
Year of diagnosis (%)								
Prior to 1990	5	4	7	5	9	18	14	10
1990–1999	44	46	55	53	50	46	43	57
2000+	51	50	38	42	41	36	43	33
Stage of disease (%)								
I	21	25	21	26	26	30	38	25
II	18	19	26	14	23	27	13	24
III	26	20	22	34	22	17	22	30
Missing, not metastatic	35	36	31	26	29	26	27	21
Grade of differentiation (%)								
Well	9	10	16	12	12	12	17	16
Moderate	50	49	45	58	49	52	50	59
Poor/undifferentiated	8	9	12	9	11	6	9	8
Unknown	33	32	27	21	28	30	24	17
Rectal cancer (%)	25	26	18	23	25	27	25	21
BMI (kg/m^2)	25.8 (2.9)	25.9 (2.4)	26.5 (2.4)	26.9 (1.7)	26.0 (3.1)	25.7 (1.9)	25.6 (1.9)	26.3 (2.3)
BMI change after diagnosis (kg/m^2)					−0.2 (1.5)	−0.2 (0.9)	−0.3 (1.1)	0.0 (0.9)
Physical activity (MET-hrs/week)	26.7 (18.6)	25.9 (15.2)	22.2 (11.9)	21.1 (8.1)	24.4 (24.5)	28.3 (17.6)	27.3 (18.6)	24.6 (16.8)
Smoking status (%)								
Never	35	40	29	29	40	38	31	27
Past	61	52	67	65	57	58	64	70
Current	4	8	4	6	3	4	5	3
Energy intake (kcal/day)	1,925 (481)	2022 (438)	2,015 (372)	1,991 (279)	1,880 (516)	2,029 (368)	1,979 (380)	2,017 (355)
Alternate Healthy Eating Index (AHEI) 2010	55.8 (8.5)	53.6 (8.2)	53.8 (7.5)	51.7 (5.8)	56.8 (9.7)	56.5 (7.0)	56.2 (7.6)	52.2 (6.5)

* All values other than age at diagnosis and follow-up time have been directly standardized to the age distribution of colorectal cancer patients. Mean (SD) was presented for continuous variables

† For prediagnostic TV watching, follow-up time was defined from date of diagnosis to death or December 2011, whichever came first; for postdiagnostic TV watching, follow-up time was defined from date of return of the first postdiagnostic TV watching assessment questionnaire to death or December 2011, whichever came first

‡ Sitting at home reading, eating or at desk

Table 2 Prediagnostic TV watching, colorectal cancer-specific mortality, mortality from other causes and overall mortality

	Prediagnostic sitting watching TV (h/week)				p_{trend}	Per 14-h/week increment	≥21 versus <21
	0–6	7–13	14–20	≥21			
Colorectal cancer-specific mortality							
No. of deaths ($n = 169$)	61	45	36	27			
Age-adjusted	1.00 (ref)	0.75 (0.51–1.10)	1.13 (0.75–1.70)	1.72 (1.09–2.70)	0.03	1.33 (1.02–1.73)	1.85 (1.22–2.79)
Multivariable* with physical activity[†]	1.00 (ref)	0.81 (0.55–1.20)	1.12 (0.73–1.70)	1.99 (1.25–3.17)	0.01	1.41 (1.08–1.84)	2.09 (1.37–3.20)
Further adjusted for BMI[‡] and AHEI[§]	1.00 (ref)	0.84 (0.56–1.25)	1.15 (0.75–1.78)	2.13 (1.31–3.45)	0.01	1.47 (1.12–1.94)	2.20 (1.43–3.38)
Mortality from other causes							
No. of deaths ($n = 302$)	104	114	58	26			
Age-adjusted	1.00 (ref)	1.15 (0.88–1.50)	1.07 (0.77–1.47)	0.97 (0.63–1.50)	0.85	0.98 (0.79–1.22)	0.91 (0.61–1.36)
Multivariable* with physical activity[†]	1.00 (ref)	1.18 (0.90–1.55)	1.07 (0.77–1.50)	0.93 (0.60–1.45)	0.78	0.97 (0.78–1.21)	0.86 (0.57–1.30)
Further adjusted for BMI[‡] and AHEI[§]	1.00 (ref)	1.15 (0.87–1.52)	1.06 (0.76–1.48)	0.90 (0.57–1.41)	0.68	0.95 (0.76–1.19)	0.83 (0.55–1.27)
Overall mortality							
No. of deaths ($n = 471$)	165	159	94	53			
Age-adjusted	1.00 (ref)	0.99 (0.80–1.24)	1.07 (0.83–1.38)	1.24 (0.91–1.70)	0.28	1.10 (0.93–1.30)	1.23 (0.92–1.63)
Multivariable* with physical activity[†]	1.00 (ref)	1.03 (0.82–1.28)	1.02 (0.79–1.33)	1.27 (0.92–1.74)	0.30	1.09 (0.92–1.30)	1.25 (0.93–1.68)
Further adjusted for BMI[‡] and AHEI[§]	1.00 (ref)	1.02 (0.81–1.27)	1.02 (0.78–1.32)	1.26 (0.91–1.74)	0.30	1.10 (0.92–1.30)	1.25 (0.93–1.68)

* Adjusted for age at diagnosis (*continuous*), years of diagnosis (*prior to 1990, 1990–1999, 2000+*), stage of disease (*I, II, III, missing and not metastatic*), grade of differentiation (*well, moderate, poor/undifferentiated, unknown*), tumor location (*rectal, colon*) and prediagnostic smoking status (*never, past, current;* results were similar if additionally adjusted for regular aspirin use *(yes/no),* alcohol (<5, 5 to <30, ≥30 g/day), folate (*in tertiles*), calcium (*in tertiles*), red meat intake (*in tertiles*), and energy intake (*in tertiles*)

[†] Prediagnostic physical activity (<9, 9 to <18, 18 to <27, ≥27 MET-h/week)

[‡] Prediagnostic BMI (<25, 25 to <30, ≥30 kg/m^2)

[§] Prediagnostic AHEI 2010 (*in tertiles*) and energy intake (*in tertiles*)

variables. p value for interaction was determined by a log likelihood ratio test comparing the models with and without the interaction terms.

Since most of deaths due to colorectal cancer occur within 5 years after diagnosis, we conducted sensitivity analysis to evaluate whether prolonged prediagnostic TV watching was associated with higher mortality within 5 years of diagnosis. All the analyses were performed using SAS v 9.3 (SAS Institute, Cary, NC), and the statistical tests were two-sided.

Results

A total of 926 and 714 eligible colorectal cancer patients were included in the analysis of prediagnostic and postdiagnostic TV watching, respectively. Patients who watched TV for longer time before diagnosis spent more time in other sedentary behaviors at home, engaged in fewer physical activities, and lower dietary scores (Table 1). Patterns of these factors were less obvious across TV watching after diagnosis. Using continuous variables, prediagnostic TV watching was modestly correlated with BMI ($r = 0.12$, $p < 0.001$) and physical activity ($r = -0.08$, $p = 0.01$), whereas postdiagnostic TV viewing time was not correlated with BMI ($r = 0.07$, $p = 0.07$) and physical activity ($r = -0.005$, $p = 0.88$). No appreciable differences of tumor characteristics were observed for either pre- or postdiagnostic TV viewing.

Prediagnostic TV watching, other sedentary behaviors and mortality

More time spent sitting watching TV before diagnosis was significantly associated with the increased risk of colorectal cancer-specific mortality and nonsignificantly elevated overall mortality after adjusting for age and year of diagnosis, stage, grade and location of the tumor, and smoking

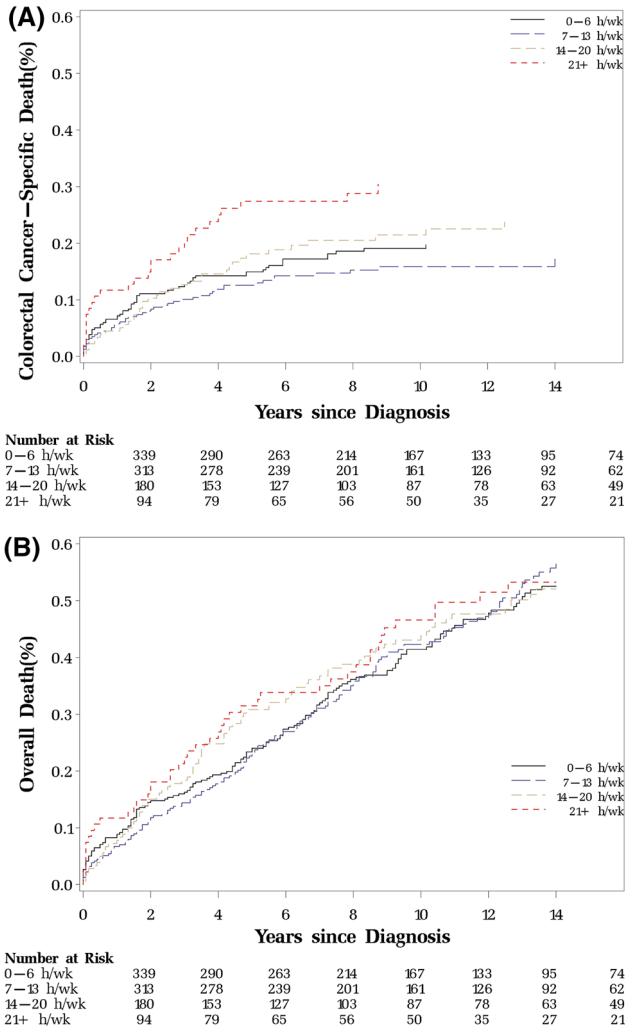

Fig. 1 Prediagnostic sitting watching TV and colorectal cancer-specific and overall mortality. **a** Colorectal cancer-specific mortality (p for log-rank test = 0.02). **b** Overall mortality (p for log-rank test = 0.83)

status (Table 2). Further adjusting for leisure-time physical activity or other known or suspected risk factors for colorectal cancer, including regular use of aspirin, alcohol, folate, calcium, red meat, and energy intake did not appreciably change the estimates. BMI and dietary score minimally mediated the observed association. The HRs (95 % CIs) of colorectal cancer-specific mortality across categories of prediagnostic TV watching (0–6, 7–13, 14–20, ≥21 h/week) were 1.00 (referent), 0.84 (0.56–1.25), 1.15 (0.75–1.78), 2.13 (1.31–3.45) (p for trend = 0.01) (Table 2; Fig. 1). When the response from the immediate survey prior to diagnosis was used instead of cumulative average TV watching time, the effect estimates were similar (Supplemental Table 1).

To examine whether the association with colorectal cancer-specific mortality differed according to tumor or patient characteristics, we combined the first three categories of TV watching (HR for ≥21 vs <21 h/week = 2.20; 95 % CI 1.43–3.38) based on the observed dose–response relationship. The association was primarily observed among overweight and obese men (BMI ≥ 25 kg/m^2), but not among patients with BMI < 25 kg/m^2 ($p_{\text{interaction}} = 0.05$). The HR estimates were similar for cases diagnosed before and after age 70, stage I and II and stage III cancer, colon and rectal cancer, cancer diagnosed before and after 2000, and those engaged in <18 and ≥18 MET-hrs per week of physical activity (Fig. 2).

When restricted to mortality within 5 year after diagnosis, prolonged TV watching before diagnosis was also associated with higher overall mortality (HR for ≥21 vs <21 h/week = 1.56; 95 % CI 1.04–2.33) (Supplemental Table 2).

Neither sitting at home nor sitting at work/driving was associated with colorectal cancer-specific mortality or overall mortality (Supplemental Table 3).

Postdiagnostic TV watching and mortality

Time spent sitting watching TV after diagnosis was correlated with prediagnostic TV viewing time ($r = 0.54$, $p < 0.001$). Although power was limited, postdiagnostic time spent sitting watching TV was associated with a nonsignificantly increased risk of colorectal cancer-specific mortality even after adjusting for prediagnostic TV watching (HR for ≥21 vs 0–6 h/week = 1.45; 95 % CI 0.73–2.87) (Table 3).

Discussion

In this cohort of male colorectal cancer patients, excessive sitting watching TV before diagnosis was significantly associated with an increased risk of colorectal cancer-specific mortality, independent of levels of leisure-time physical activity. Postdiagnostic time spent sitting watching TV was associated with a nonsignificantly increased risk of colorectal cancer-specific mortality.

Emerging evidence suggests that, distinct from physical activity, excessive TV viewing time have adverse health consequences among colorectal cancer survivors [7, 25]. However, comparison across these studies is challenging owing to heterogeneities in the referent group selected, range of sedentary time, timing of assessment, and length of follow-up. Arem et al. [25] found that baseline TV watching (median, 5 years) before diagnosis was associated with all-cause mortality but with a nonsignificantly increased risk of colorectal cancer mortality. In comparison, we utilized repeated measurement of TV watching and other covariates before diagnosis to reflect long-term

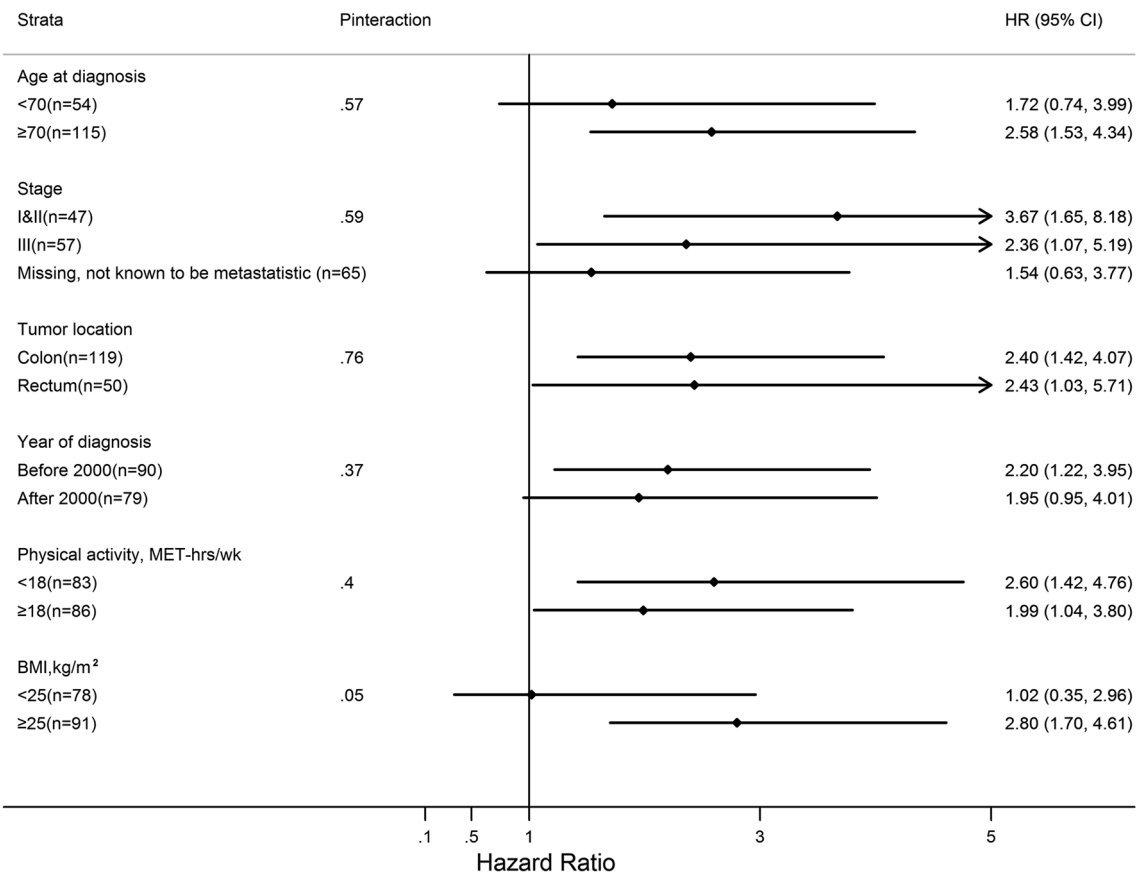

Fig. 2 Stratified analysis of prediagnostic TV watching (≥21 vs <21 h/week) and colorectal cancer-specific mortality

behavior and found that prolonged TV watching was associated with colorectal mortality, but not with all-cause mortality. More research is needed.

In our analysis, a significant association between TV watching but not sitting at work and colorectal cancer survival was observed. Similar stronger associations with TV viewing time were also suggested for obesity and diabetes [10]. Leisure-time sitting or sitting at work may have distinct roles in disease etiology. It is also possible that sitting watching TV or at work is associated differentially with other disease-related correlates [8]. One hypothesis is that prolonged TV watching was associated with increased consumption of unhealthful food [9, 10, 32]; however, in our study, the positive significant association persisted after adjusting for dietary factors. Additional reasons underlying these observations merit further exploration.

Similar to Arem et al., we reported that prolonged sitting TV viewing time after colorectal cancer diagnosis was associated with a nonsignificantly increased risk of colorectal cancer mortality, and the association was attenuated after adjusting for prediagnostic TV watching. In addition, we also observed a stronger association between prediagnostic TV watching, either cumulative average exposure up to diagnosis or a single most recent measurement before diagnosis, and colorectal cancer-specific mortality, when compared to the first assessment after diagnosis, suggesting that TV watching may have long-term effects on colorectal cancer progression (i.e., enhances the likelihood that metastatic cells may have seeded before the diagnosis and removal of colorectum). Limited power may also partially explain the nonsignificantly increased risk of postdiagnostic TV watching. Whether reducing TV viewing time after diagnosis would be beneficial for colorectal cancer prognosis requires additional research.

Pathways through which sedentary behaviors affect risk and progression of colorectal cancer are yet to be investigated. Obesity may represent an intermediate step [33]. A study among Australian colorectal cancer survivors suggests that watching ≥5 versus 2 h of TV per day was associated with a mean increase in BMI 0.71 kg/m^2 over approximately 18 months [34]. In our analysis, adjusting for BMI did not materially alter the association observed, but the association between prediagnostic TV watching and increased colorectal cancer mortality was observed primarily among overweight and obese patients. Because BMI is not an optimal indicator of overweight and obesity in the

Table 3 Postdiagnostic TV watching, colorectal cancer-specific mortality, mortality from other causes, and overall mortality

	Postdiagnostic sitting watching TV (h/week)				p_{trend}	Per 14-h/week increment	≥21 versus <21
	0–6	7–13	14–20	≥21			
Colorectal cancer-specific mortality							
No. of deaths ($n = 72$)	34	8	11	19			
Age-adjusted	1.00 (ref)	0.61 (0.28–1.32)	0.78 (0.40–1.55)	1.80 (1.03–3.16)	0.11	1.28 (0.95–1.73)	2.08 (1.23–3.52)
Multivariable* with physical activity[†]	1.00 (ref)	0.63 (0.28–1.38)	0.75 (0.36–1.56)	1.42 (0.80–2.52)	0.26	1.20 (0.87–1.64)	1.63 (0.96–2.79)
Further adjusted for BMI, change in BMI[‡] and AHEI[§]	1.00 (ref)	0.60 (0.27–1.35)	0.67 (0.32–1.44)	1.53 (0.84–2.77)	0.20	1.24 (0.89–1.71)	1.81 (1.03–3.16)
Further adjusted for prediagnostic TV watching	1.00 (ref)	0.62 (0.27–1.41)	0.68 (0.30–1.54)	1.45 (0.73–2.87)	0.27	1.23 (0.86–1.76)	1.79 (0.97–3.28)
Mortality from other causes							
No. of deaths ($n = 253$)	122	45	51	35			
Age-adjusted	1.00 (ref)	1.06 (0.75–1.50)	1.11 (0.80–1.54)	0.98 (0.67–1.43)	0.96	1.00 (0.84–1.20)	0.95 (0.66–1.35)
Multivariable* with physical activity[†]	1.00 (ref)	1.10 (0.77–1.57)	1.15 (0.82–1.62)	0.98 (0.66–1.43)	0.90	0.99 (0.83–1.18)	0.93 (0.64–1.34)
Further adjusted for BMI, change in BMI[‡] and AHEI[§]	1.00 (ref)	1.07 (0.74–1.55)	1.08 (0.76–1.54)	0.98 (0.67–1.45)	0.81	0.98 (0.81–1.17)	0.96 (0.66–1.39)
Further adjusted for prediagnostic TV watching	1.00 (ref)	1.08 (0.74–1.57)	1.09 (0.75–1.59)	1.03 (0.66–1.60)	0.94	0.99 (0.80–1.23)	0.98 (0.65–1.49)
Overall mortality							
No. of deaths ($n = 325$)	156	53	62	54			
Age-adjusted	1.00 (ref)	0.95 (0.69–1.30)	1.03 (0.77–1.38)	1.17 (0.85–1.59)	0.43	1.06 (0.91–1.24)	1.17 (0.87–1.57)
Multivariable* with physical activity[†]	1.00 (ref)	1.00 (0.72–1.38)	1.06 (0.78–1.44)	1.11 (0.81–1.52)	0.67	1.03 (0.89–1.21)	1.10 (0.81–1.48)
Further adjusted for BMI, change in BMI[‡] and AHEI[§]	1.00 (ref)	0.96 (0.69–1.34)	0.98 (0.72–1.35)	1.12 (0.81–1.54)	0.74	1.03 (0.88–1.20)	1.13 (0.83–1.53)
Further adjusted for prediagnostic TV watching	1.00 (ref)	0.98 (0.70–1.37)	1.01 (0.72–1.42)	1.16 (0.80–1.68)	0.66	1.04 (0.87–1.25)	1.16 (0.83–1.63)

* Adjusted for age at diagnosis, years of diagnosis, stage of disease, grade of differentiation, tumor location, and postdiagnostic smoking status; results were similar if additionally adjusted for regular aspirin use, alcohol, folate, calcium, red meat, and energy intake

[†] Postdiagnostic physical activity

[‡] Postdiagnostic BMI and change in BMI (*postdiagnostic BMI–prediagnostic BMI*; lessthan −2, −2 to <2, ≥2 kg/m^2)

[§] Postdiagnostic AHEI 2010 and energy intake

elderly [35], the possibility that sedentary behaviors correlate more with visceral adiposity could not be ruled out. In fact, prospective studies in both the USA and Australia have found associations between TV viewing and increased waist circumference [36, 37], which reflects both subcutaneous and visceral adipose. Inflammation may also involve in the link between sedentary behaviors and colorectal cancer progression. C-reactive protein, a general marker of inflammation, was recently observed to be positively associated with sedentary time [15, 38] and colorectal cancer-specific mortality [39].

Strengths of our study include the ability to capture long-term prediagnostic sedentary behavior, minimizing measurement errors through detailed assessments of time spent "sitting" watching TV while excluding TV viewing coupled with other nonsedentary activities (e.g., cooking, on treadmills). We were also able to differentiate domains in which sedentary behavior occurs and control for a variety of potential confounders and mediators. Advantages also included prospective collection of exposure and covariate data and the comprehensive medical record review of self-reported colorectal cancer and of deaths.

Our study had several limitations. First, sedentary behaviors were self-reported. However, objective measurements (i.e., accelerometer) alone are unable to identify the domains in which behavior occurs. Future research may benefit from combining self-reports and objective measures. Secondly, although the average hours of sitting watching

TV (11 h/week) was lower than the national estimates (34 h/week in adults aged 50–64) [4] and we had limited number of patients with high levels of TV watching, a widespread distribution of TV viewing time in our study (an average of 4 h/week among the least and 27 h/week in the most sedentary men) allowed us to assess the potential health benefit of a less sedentary lifestyle. Assessment of time spent sitting at computer and/or other screens (e.g., tablets, smart phones), the increasingly prevalent sedentary behaviors, may also be informative. Thirdly, treatment data were not collected. However, fairly homogenous nature of this cohort (male health professionals) would likely increase the probability of at least standard therapy which would be expected to be closely correlated with stage at diagnosis [40]. Additionally, possibility of residual confounding, especially from physical activity, could not be ruled out even though our leisure-time physical activity questions have been previously validated and occupational physical activities engaged by these health professionals were limited. Finally, our data are limited in power to assess the influence of postdiagnostic TV watching.

In conclusion, independent of leisure-time physical activity, prolonged TV watching before diagnosis was associated with poorer colorectal cancer survival and postdiagnostic TV viewing was associated with a non-significantly increased risk of colorectal cancer-specific mortality. As intention to make positive lifestyle adjustments by engaging more physical activity has been noted among cancer survivors [41, 42], reducing sedentary time, in particular TV viewing time, may confer benefits to patients with colorectal cancer.

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Compliance with ethical standards

Conflict of interest None.

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