Sedentary Behaviors and Emerging Cardiometabolic Biomarkers in Adolescents

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Objective To examine the associations of objectively measured sedentary time and television (TV) viewing time with emerging inflammatory and endothelial function markers in adolescents.

Study design This study comprised 183 adolescents (88 girls), aged 13 to 17 years. Sedentary time and moderate-to-vigorous physical activity was objectively measured with accelerometry, whereas TV viewing time was self-reported. White blood cell counts and levels of C-reactive protein, complement factors C3 and C4, interleukin-6, adiponectin, leptin, intercellular adhesion molecule 1, vascular cell adhesion molecule 1, E-selectin, L-selectin, and plasminogen activator inhibitor-1 were measured in fasted blood samples.

Results Sedentary time was not significantly associated with any of the examined cardiometabolic markers after controlling for potential confounders. However, TV viewing time was positively associated with soluble endothelial adhesion molecules intercellular adhesion molecule 1 (standardized $\beta = 0.19$, $P = .008$), vascular cell adhesion molecule 1 ($\beta = 0.17$, $P = .020$), L-selectin ($\beta = 0.18$, $P = .013$), and E-selectin ($\beta = 0.16$, $P = .023$) concentrations, after controlling for sex, age, pubertal status, moderate-to-vigorous physical activity, body mass index, and total sedentary time.

Conclusions High TV viewing time may play a key role in cardiovascular and metabolic diseases through the cell adhesion molecules in adolescence. *(J Pediatr 2012;160:104-10)*.

Cardiovascular and metabolic diseases continue to be a cause for concern worldwide.[1] Although these pathologies are considered to be adult diseases, they have started to appear in children and adolescents.[2] In addition to the conventional cardiometabolic risk factors (eg, high blood pressure, glucose, cholesterol), emerging risk factors such as low-grade inflammation and endothelial dysfunction markers (eg, leukocytes, inflammatory proteins, adhesion molecules, and cytokines) also have a key role in atherosclerosis and type 2 diabetes mellitus.[3-5] Indeed, these new biomarkers may be more useful than conventional risk factors in predicting future events,[5] thus providing insights into causal pathways beginning at early ages.

Although the etiology of cardiovascular and metabolic diseases is complex, unhealthy lifestyles are important in their development. More specifically, poor nutrition and low levels of physical activity have been considered to be major contributors in the current epidemic.[6] Recent evidence has also highlighted the potential role of sedentary behaviors, beyond low levels of physical activity, in the onset of these chronic diseases.[7] Sedentary behavior refers to activities that do not result in a substantial expenditure of energy greater than the resting level[8] and thus includes daily routine activities such as sitting, lying down, and watching television (TV).

High daily sitting time and prolonged time spent in TV viewing have shown detrimental associations with all-cause and cardiovascular mortality in adults.[9] A few studies in children and adolescents also have explored the associations between sedentary behaviors and conventional cardiometabolic factors.[10-14] However, the associations between sedentary behaviors and emerging cardiometabolic biomarkers in youth are widely unknown. We therefore examined the associations of objectively measured sedentary (mainly sitting) time and TV viewing time with emerging inflammatory and endothelial function markers in adolescents.

Methods

Adolescents included in this analysis were part of the Physical Activity as a Preventive Measure Against Overweight, Obesity, Infections, Allergies, and Cardio-

AFINOS	Physical Activity as a Preventive Measure Against Overweight, Obesity, Infections, Allergies, and Cardiovascular Disease Risk Factors in Adolescents
BMI	Body mass index
CRP	C-reactive protein
ICAM-1	Intercellular adhesion molecule 1
MVPA	Moderate-to-vigorous physical activity
TV	Television
VCAM-1	Vascular cell adhesion molecule 1

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vascular Disease Risk Factors in Adolescents (AFINOS) study. The AFINOS study rationale and methodologies have been presented in detail elsewhere.[15] In brief, the AFINOS study is a surveillance study in which health indicators and lifestyle factors were assessed with a questionnaire in a representative adolescent sample (approximate n = 2000), aged 13 to 17 years, from the region of Madrid, Spain. A set of more precise measurements, including body composition, accelerometry, and blood analysis, were performed in a convenient subsample of 232 adolescents. From this subsample, 186 adolescents had complete data for anthropometry, sedentary behaviors, and emerging cardiometabolic markers. To minimize the confounding influence of an ongoing infection, 3 adolescents (one boy and two girls) with C-reactive protein (CRP) concentrations >10 mg/L were excluded. In total, 183 participants (95 boys and 88 girls) were included in this study. No adolescent in the final sample reported diagnosed sleep-related disorders.

The entire data collection period in the AFINOS study subsample lasted 4 months (November 2007 to February 2008). Written parental consent and adolescents' assent were obtained after informing them about the nature and procedures of this study. The AFINOS study was approved by the ethics committee of Puerta de Hierro Hospital and the Bioethics Committee from the Spanish National Research Council (Madrid, Spain).

Weight and height were obtained with standardized procedures without shoes and light clothing. Body mass index (BMI) was calculated as weight/height squared (kg/m^2). Adolescents were categorized as non-overweight or overweight (including obesity) according to age- and sex-specific BMI cutoff points proposed by Cole et al.[16] Skinfold thicknesses were measured on the left side of the body to the nearest 0.1 mm with a Holtain caliper (Holtain Ltd, Crymych, Wales, United Kingdom) at 6 sites: triceps, biceps, subscapular, suprailiac, thigh, and calf. Body circumferences were measured with a nonelastic tape to the nearest 1 mm at 5 sites: biceps, contract biceps, waist, hip, and calf. The complete set of anthropometric measurements was performed twice, but not consecutively. This anthropometric protocol for adolescents has been previously standardized in the AVENA (Feeding and Assessment of Nutritional Status of Spanish Adolescents)and HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescents) studies.[17,18] In this study, BMI and the sum of 6 skinfolds were used as indicators of total body fat, and waist circumference was used as an indicator of abdominal fat. Pubertal status was determined on the basis of self-report according to Tanner and Whitehouse[19] for breast development and pubic hair in adolescent girls and pubic hair in adolescent boys.[20] Trained interviewers asked the adolescents to classify themselves in one of the 5 stages of pubertal maturity.[19]

Objectively measured sedentary time was obtained with the Actigraph uniaxial accelerometer (ActiGraph GT1M, ActiGraph, Pensacola, Florida). The Actigraph GT1M is a small, lightweight, and compact monitor that detects vertical accelerations and discriminates human movements from vibrations. The Actigraph has become a widely used tool in physical activity research[21] and is reliable and valid at capturing sedentary activities in adolescents.[22] Accelerometer protocols used in the AFINOS study have been described in detail elsewhere.[23] In brief, each adolescent wore the accelerometer at the lower back for 7 consecutive days, removing it during sleep hours and water-based activities. A 15-second epoch was used for data collection, and data were processed with non-commercial JAVA software developed specifically to analyze the output from the Actigraph. This software excluded bouts of 10 minutes of uninterrupted zeros from the analysis output, considering these periods as non-wearing time. The inclusion criteria for this study was an activity monitor recording of at least 10 hours per day for 4 days, one of which had to be a weekend day. The time spent in sedentary pursuits (hours/day) was calculated by using the standardized cutoff point of 100 counts per minute (25 counts per 15-seconds in this study) in adolescents who met the inclusion criteria.[22] This cutoff point has been shown to capture sitting activities (eg, watching TV, playing video games, painting) in these ages.[22,23] Additionally, the time spent in objectively measured moderate-to-vigorous physical activity (MVPA, minutes/day) was obtained with the Freedson age-specific cutoff points[23] for at least moderate physical activity (equivalent to 3 METs).

The time spent in TV viewing was obtained with self-report. A brief questionnaire was administered within the school hours, and adolescents reported the habitual number of hours watching TV separately for a typical weekday and weekend day with the question: "How many hours and/or minutes do you spend habitually watching TV?" The average time spent in TV viewing (hours/day) was calculated with this formula:

$$(\text{weekday TV viewing} \times 5 + \text{weekend TV viewing} \times 2)/7.$$

After overnight fasting for 10 hours, blood samples were collected in the early morning (8:00 to 9:00 am) at the schools. In all cases, 16 mL of blood was extracted with venipuncture from the antecubital vein and collected by a trained nurse.

Several inflammatory and endothelial dysfunction markers analyzed in the AFINOS study[17] were selected for this work. White blood cell counts were obtained with an automatic cell counter (ABX 120DX, Horiba, Spain). CRP and complement factors C3 and C4 levels were measured in serum with immunoturbidimetry (Olympus AU2700 Analyzer, Olympus UK Ltd, Watford, United Kingdom). Serum interleukin-6 levels were determined with the High Sensitivity Human Cytokine MILLIPLEX MAP kit (Millipore Corp, Billerica, Massachusetts) and collected with flow cytometry (Luminex-100 version 2.3, Luminex Corporation, Austin, Texas). Adiponectin, intercellular adhesion molecule 1 (ICAM-1), vascular cell adhesion molecule 1 (VCAM-1), E-selectin, and plasminogen activator inhibitor 1 levels in serum were measured by using the Luminex-100 with the Human Cardiovascular Disease Panel 1 (Linco Research, St. Charles, Missouri). L-selectin concentration was determined by using an enzyme-linked immunoassay with the CD62L kit (Diaclone, Besancon, France). Plasma leptin concentrations were obtained with the Human Gut Hormone multiplex kit (Linco Research) and performed

on the Luminex-100. Quality control of the assays was assured by the Regional Health Authority, as compulsory for all clinical laboratories in Spain.

Statistical Analysis

Descriptive statistics are presented as means (SD) or percentages. All the variables were checked for normality of distribution before the analyses. Several variables required transformation to account for skewness. Natural logarithm was applied to CRP, adiponectin, leptin, ICAM-1, VCAM-1, L-selectin, E-selectin, and MVPA. Square roots were applied to interleukin-6 and complement factors C3 and C4. Differences in the sexes were assessed with one-way ANOVA, and the χ^2 test for proportions was used for nominal data. Interaction factors for sex (sex times main exposures) were checked to determine whether sex modified the associations between sedentary behaviors and cardiometabolic markers. Because no significant interaction was found for sex, all analyses were performed with boys and girls together.

Partial correlations, controlling for age, sex, and pubertal status, were used to analyze the relationships between objectively measured sedentary time and TV viewing time. Partial correlations controlling for the same potential confounders were also used to analyze the relationships of these outcomes with objectively measured MVPA and with body fat measures (BMI, sum of 6 skinfolds, and waist circumference). For comparative purposes, partial correlations between emerging cardiometabolic biomarkers controlling for potential confounders, are shown in **Table I** (available at www.jpeds.com). Likewise, partial correlations between conventional and emerging cardiometabolic biomarkers, controlling for potential confounders, are also shown in **Table II** (available at www.jpeds.com). A detailed description of the blood methods for these conventional cardiometabolic factors has been reported elsewhere.[12,17]

Multiple linear regression models examined the associations of sedentary time and TV viewing time with cardiometabolic variables. Model 1 was initially adjusted for age, sex, and pubertal status. Model 2 included the same potential confounder variables as model 1 plus accelerometer-measured MVPA. A final model (model 3) included earlier confounder variables plus any body fat indicators, initially BMI. For illustrative purposes, all the linear regression models were also repeated by stratifying in sex-specific quartiles of time spent in sedentary time and groups of TV viewing taking into account: (1) the frequency distribution of this variable; and (2) the current public recommendations for TV viewing time in adolescents (ie, <2 hours/day).[24] Analyses were conducted with the Predictive Analytics SoftWare version 18.0 for Macintosh (SPSS Inc, Chicago, Illinois). Statistical significance was set at a P value <.05 for the main effects.

Results

Table III shows characteristics of the participants for the whole sample and by sex.

Partial correlation, adjusted for sex, age, and pubertal status, between sedentary time and TV viewing time were not statistically significant (r = −0.027, P = .716). Of the two outcomes, only sedentary time was significantly correlated with MVPA (r = −0.226, P = .002) after controlling for sex, age, and pubertal status. In addition, there were no significant associations of sedentary time and TV viewing time with body fat variables (all P > .20).

Table IV shows the associations between sedentary time and emerging cardiometabolic markers. The results of the regression analysis showed that objectively measured sedentary time was not significantly associated with cardiometabolic markers after controlling for sex, age, and pubertal status. The results did not change when MVPA and BMI were included in the model as co-variates or by stratifying sedentary time into sex-specific quartiles. Because sedentary time was positively associated with wear time (r = 0.73, P < .001), we repeated the analyses to account with differences in wearing time in adolescents, but the results did not change (data not shown).

Table V shows the associations between TV viewing time and emerging cardiometabolic markers. TV viewing time was positively associated with soluble endothelial adhesion molecules ICAM-1 (β = 0.19, P = .008), VCAM-1 (β = 0.17, P = .020), L-selectin (β = 0.18, P = .013), and E-selectin (β = 0.16, P = .023) after controlling for sex, age, pubertal status, MVPA, and BMI. Additional regression analysis by groups of TV viewing showed that adolescents who watched TV ≥3 hours/day had significantly higher concentrations in all the cell adhesion molecules (all P < .05) compared with adolescent in the ≤1 hour/day TV viewing group (**Figure**). To analyze whether body fat modifies the associations between TV viewing and cardiometabolic markers, we included a TV viewing time times BMI interaction term in the model, but the interaction term did not explain a significant amount of the variance (data not shown).

In addition, all the analyses were repeated with skinfolds or waist circumference rather than BMI, and the main results did not materially change. A final analysis including sedentary time and TV viewing in the models also showed that the significant associations between TV viewing time and cell adhesion molecules were independent of sedentary time (data not shown).

Discussion

Our findings indicate that for adolescents, TV viewing time, but not total sedentary time, is positively associated with circulating cell adhesion molecules, independent of total sedentary time, physical activity, and body fat. The results have public health and clinical importance because these cardiometabolic markers have a key role in atherosclerosis and type 2 diabetes mellitus.[3-5]

In contrast to popular belief, physical inactivity and sedentary behavior are not synonymous or highly related to each

Table III. Physical characteristics of the study sample

	All	Boys	Girls
n	183	95	88
Age, years	14.8 (1.3)	14.7 (1.2)	15.0 (1.3)*
Weight, kg	60.8 (12.1)	64.2 (13.6)	57.1 (9.1)*
Height, cm	167.4 (8.2)	171.4 (7.7)	163.0 (6.3)*
Pubertal status I/II/III/IV/V, %	1/6/20/52/21	1/3/25/40/31	0/10/14/65/11
BMI, kg/m^2	21.6 (3.5)	21.7 (3.8)	21.5 (3.07)
BMI, Z-score	1.2 (1.0)	1.5 (1.1)	1.0 (1.0)
BMI, percentile	43.5 (28.0)	40.7 (29.4)	46.6 (26.2)
Overweight + obesity, %	24.6	29.5	19.3*
Sum of 6 skinfolds, mm	33.2 (12.2)	29.2 (12.01)	37.5 (10.7)*
Waist circumference, cm	73.4 (9.5)	75.3 (10.0)	71.4 (8.7)*
WBC, cel·10^3/mm^3	6.35 (1.51)	6.17 (1.29)	6.53 (1.71)
CRP, mg/L†	0.75 (1.27)	0.88 (1.50)	0.61 (0.96)
IL-6, pg/mL‡	16.31 (27.98)	16.30 (26.57)	16.32 (29.56)
C3, g/L‡	1.16 (0.20)	1.17 (0.21)	1.15 (0.19)
C4, g/L‡	0.24 (0.07)	0.24 (0.06)	0.24 (0.07)
Adiponectin, μg/mL†	2.13 (1.13)	1.91 (1.09)	2.36 (1.13)*
Leptin, ng/mL†	7.82 (7.03)	4.51 (4.98)	11.39 (7.19)*
ICAM-1, ng/mL†	137.18 (48.05)	145.45 (48.61)	128.25 (46.07)*
VCAM-1, ng/mL†	962.00 (261.44)	1028.69 (261.10)	890.02 (243.36)*
L-selectin, μg/mL†	2.41 (0.9)	2.27 (0.81)	2.56 (1.01)*
E-selectin, ng/mL†	34.01 (16.05)	36.13 (15.55)	31.73 (16.36)
PAI-1, ng/mL	95.48 (26.65)	100.65 (27.23)	89.90 (24.98)*
Sedentary time, h/d	8.8 (1.2)	8.9 (1.2)	8.7 (1.1)
TV viewing, h/d	1.7 (0.9)	1.7 (0.9)	1.7 (0.9)
MVPA, min/d†	73.9 (26.6)	84.8 (27.4)	62.15 (20.0)*

WBC, white blood cells; *CRP*, C-reactive protein; *IL-6*, interleukin-6; *C3*, complement factor 3; *C4*, complement factor 4; *PAI-1*, plasminogen activator inhibitor-1.
*$P < .05$ for sex comparisons.
†Values were natural log-transformed before analysis, but non-transformed values are presented.
‡Values were square root transformed before analysis, but non-transformed values are presented.

other[8]; thus, it is important to study the relationship between sedentary behaviors and health outcomes. In this study, sedentary time measured with accelerometry was not associated with emerging cardiometabolic biomarkers. Earlier studies in adults have shown that prolonged sedentary time (mainly sitting) measured with accelerometry and self-report is associated with mortality and conventional cardiometabolic risk factors.[9] In youth, only 3 studies have shown significant associations of objectively measured sedentary time with conventional cardiovascular risk factors,[10-12] but these associations were not independent of MVPA. The lack of associations between sedentary time and cardiometabolic markers in children and adolescents might have an age-specific explanation. It is known that sedentary time increases from childhood to adulthood[25]; therefore, the effect of lifelong sedentariness on health in apparently healthy individuals may not be observed until adulthood. This hypothesis can also be supported with experimental studies in animals

Table IV. Associations between sedentary time and emerging cardiometabolic biomarkers in adolescents (n = 183)

	Objectively measured sedentary time, h/d								
	Model 1			Model 2			Model 3		
Outcomes	β	*P* value	Adjusted R^2	β	*P* value	Adjusted R^2	β	*P* value	Adjusted R^2
WBC, cel·10^3/mm^3	0.06	.421	0.00	0.06	.458	0.01	0.07	.375	0.02
CRP, mg/L*	−0.11	.151	0.01	−0.10	.206	0.01	−0.10	.183	0.08
IL-6, pg/mL†	−0.04	.598	−0.02	−0.03	.702	−0.02	−0.03	.702	−0.02
C3, g/L†	−0.07	.341	0.03	−0.06	.402	0.03	−0.05	.497	0.28
C4, g/L†	−0.08	.262	0.07	−0.08	.314	0.07	−0.06	.379	0.21
Adiponectin, μg/mL*	−0.07	.351	0.04	−0.09	.218	0.05	−0.10	.170	0.09
Leptin, ng/mL*	−0.02	.795	0.34	−0.03	.660	0.34	−0.01	.867	0.60
ICAM-1, ng/mL*	0.01	.868	0.06	0.03	.677	0.06	0.03	.665	0.06
VCAM-1, ng/mL*	0.07	.327	0.07	0.09	.222	0.08	0.09	.234	0.07
L-selectin, μg/mL*	0.01	.927	0.03	0.01	.910	0.03	0.01	.911	0.02
E-selectin, ng/mL*	−0.01	.881	0.08	0.00	.961	0.08	0.01	.944	0.08
PAI-1, ng/mL	−0.01	.869	0.06	−0.03	.728	0.05	−0.02	.788	0.07

WBC, white blood cells; *CRP*, C-reactive protein; *IL-6*, interleukin-6; *C3*, complement factor 3; *C4*, complement factor 4; *PAI-1*, plasminogen activator inhibitor-1.
Model 1 adjusted for age, sex, and pubertal status.
Model 2 adjusted for model 1 plus accelerometer-measured MVPA.
Model 3 adjusted for Model 2 plus BMI.
*Values were natural log-transformed before analysis.
†Values were square root transformed before analysis.

Table V. Associations between TV viewing and emerging cardiometabolic biomarkers in adolescents (n = 183)

	TV viewing time, h/d								
	Model 1			Model 2			Model 3		
Outcomes	β	*P* value	Adjusted R^2	β	*P* value	Adjusted R^2	β	*P* value	Adjusted R^2
WBC, cel·10^3/mm^3	−0.03	.677	0.00	−0.03	.675	0.01	−0.03	.658	0.01
CRP, mg/L*	0.03	.734	−0.01	0.02	.746	−0.01	0.02	.772	0.07
IL-6, pg/mL†	0.02	.824	−0.03	0.02	.834	−0.03	0.02	.842	−0.03
C3, g/L†	−0.01	.988	0.03	−0.01	.973	0.02	−0.01	.893	0.27
C4, g/L†	0.03	.698	0.07	0.03	.713	0.06	0.02	.741	0.21
Adiponectin, μg/mL*	0.04	.521	0.04	0.04	.576	0.04	0.04	.543	0.08
Leptin, ng/mL*	0.04	.551	0.35	0.04	.621	0.34	0.03	.666	0.60
ICAM-1, ng/mL*	0.19	.007	0.10	0.19	.008	0.10	0.19	.008	0.10
VCAM-1, ng/mL*	0.17	.019	0.10	0.17	.020	0.10	0.17	.020	0.09
L-selectin, μg/mL*	0.18	.013	0.07	0.18	.013	0.06	0.18	.013	0.06
E-selectin, ng/mL*	0.16	.021	0.11	0.16	.022	0.11	0.16	.023	0.11
PAI-1, ng/mL	0.13	.071	0.07	0.13	.067	0.07	0.13	.068	0.09

WBC, white blood cells; *CRP*, *C*-reactive protein; *IL-6*, interleukin-6; *C3*, complement factor 3; *C4*, complement factor 4; *PAI-1*, plasminogen activator inhibitor-1.
Model 1 adjusted for age, sex, and pubertal status.
Model 2 adjusted for model 1 plus accelerometer-measured MVPA.
Model 3 adjusted for model 2 plus BMI.
*Values were natural log-transformed before analysis.
†Values were square root transformed before analysis.

with forced immobility[7] and young people with spinal cord dysfunction.[26]

We found that sedentary time was negatively associated with MVPA, and therefore sedentary time might be partially displacing physical activity time in adolescents, as suggested elsewhere.[27] Because there is compelling evidence that MVPA enhances cardiovascular health in adolescents,[28] these results support the need for new recommendations on sedentary behavior in addition to the current physical activity guidelines.[29] To date, only one recommendation related to excessive sedentary time has been promoted in youth. This recommendation suggests limiting extended periods ≥2 hours in sedentary activities during daytime hours.[30] However, further evidence from prospective and experimental studies is required to determine how much sedentary time is too much in both youth and adults. However, only one experimental intervention has aimed to break the time spent in sedentary time in youth.[31] The TAKE10! intervention (www.take10.net) is a classroom-based program that interrupts regular class seated activities and provides for MVPA during 10 minutes. These 10-minute bouts performed in the classroom, when accumulated in 2 to 3 sessions per day, may help to accumulate physical activity at the recommended levels and break prolonged sitting time.[31]

We also considered perhaps the most common leisure-time sedentary pursuit—TV viewing. Earlier studies in both youth and adults were limited to conventional cardiometabolic risk factors.[9,14,32] In this study, we found that the time spent watching TV was positively associated with several adhesion molecules in adolescents. These findings have clinical importance because recognized evidence supports a key role of soluble cell adhesion molecules in the development of atherosclerosis and plaque instability.[4] In addition, sedentary time was not associated with TV viewing time, which is similar to earlier studies.[33] Therefore, this finding further supports that TV viewing time cannot be used as a marker of a broader pattern of sedentary behavior in youth.

Previously, we had suggested 4 mechanisms by which TV viewing may have a harmful influence on health outcomes[13]: (1) displacing physical activity; (2) increasing sedentary time; (3) disrupting sleep duration at night; and (4) eating unhealthy food. In this study, we showed that the associations between TV viewing time and cell adhesion molecules were independent of 2 of the 4 plausible mechanisms (ie, sedentary time and physical activity). Post hoc analyses also showed that these associations were also independent of sleep duration. Thus, these results suggest that inadequate dietary habits (eg, saturated fats, sweet and salty snacks, soft drinks, and lower intakes of fruit and vegetables) during TV viewing are likely to be a relevant cause of the detrimental association between TV viewing and circulating cell adhesion molecules during adolescence.[34-36] Unfortunately, dietary intake during TV viewing time was not assessed in the AFINOS study, and therefore this limitation must be considered when interpreting our results. Furthermore, the reason why only cell adhesion molecules showed significant associations with TV viewing time require further research because studies for comparative purposes are scarce.

To the best of our knowledge, only two studies have examined the association between self-reported screen time and emerging cardiometabolic markers. Pirkola et al[37] did not find significant associations between adolescents' screen time (TV viewing + computer + reading books) and low-grade inflammation (ie, white blood cell counts and CRP levels) after controlling for body fat variables. Hardy et al[38] also found no associations between screen time (TV viewing + computer) and CRP levels. Although our results concur with these earlier findings, the time spent watching TV has a specific context and should be analyzed separately from the rest of other sedentary behaviors.[13] The most widely supported recommendation on media use or screen time is that of the American Academy of Pediatrics,[24] which suggests limiting children's screen time to no more than 2 hours per day. However, the modern generation of video games (eg, Wii Fit) has shown some potential

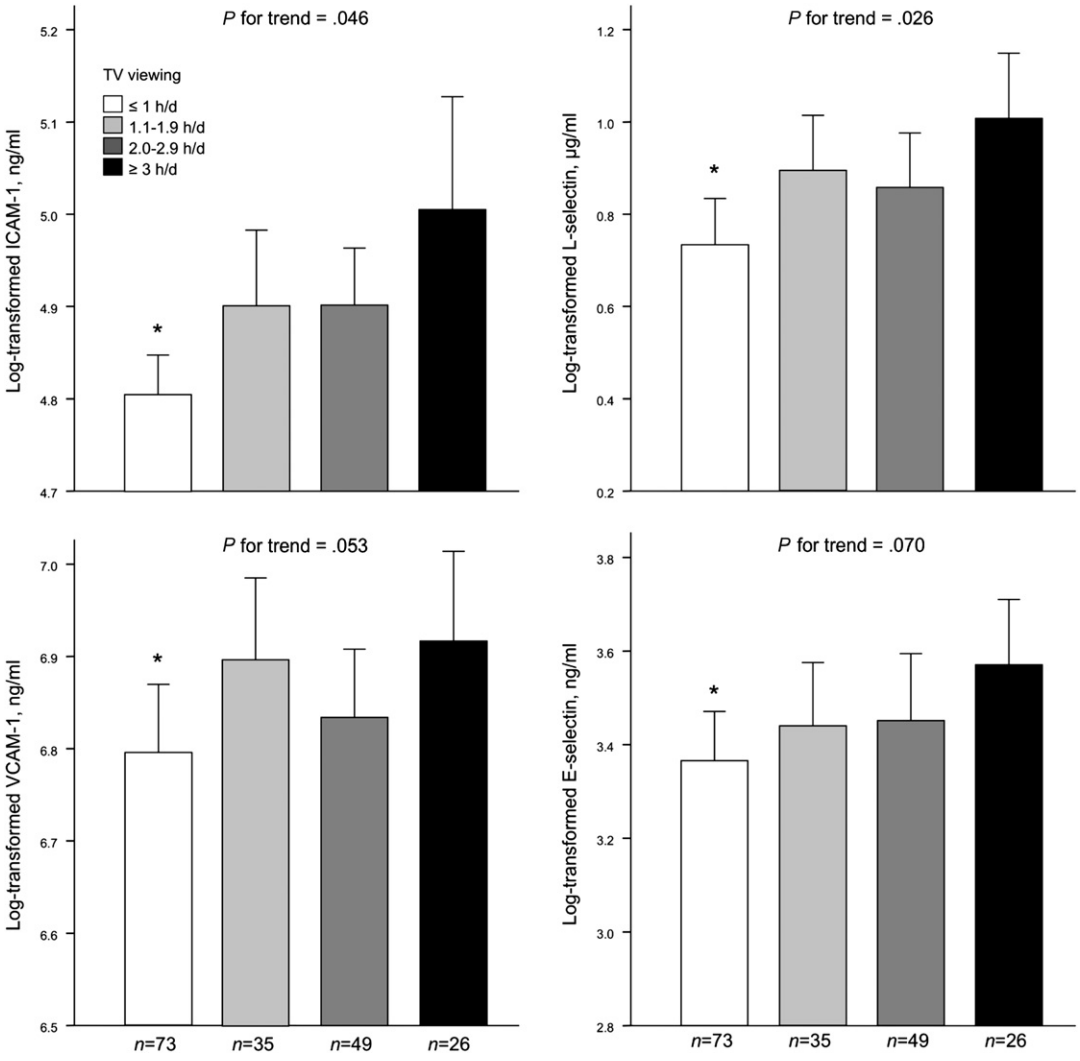

Figure. Differences in serum cell adhesion molecules levels stratified in groups by time spent in TV viewing in adolescents (n = 183). Values are estimated marginal means (SE) adjusted for age, sex, pubertal status, accelerometer-measured MVPA, and BMI. *$P < .05$ compared with the ≥3 hours/day group.

to slightly increase physical activity levels and a differential effect on cardiovascular reactivity in youth.[39,40] Consequently, new public health recommendations are promoting separate recommendations for watching TV and video game/computer usage for youth (www.healthypeople.gov).

Other limitations of this study must be also acknowledged. The cross-sectional design of this study is a limitation that makes it difficult to infer a causal relationship. Also, the results from this study may not be generalizable because it is not a random representative sample, and further studies, mainly prospective studies or experimental trials, are necessary to confirm these findings. In addition, the time spent in TV viewing and pubertal status were obtained by self-report, and thus these results must be also interpreted with caution. Finally, some relevant factors were not included in our statistical analyses (eg, diet, socioeconomic status, smoking). This warrants further studies examining the role of other co-variates on the associations between sedentary behaviors and emerging cardiometabolic biomarkers.

High TV viewing may play an important and independent role on cardiovascular and metabolic diseases through the cell adhesion molecules in adolescents. These results must be further examined in prospective and experimental studies, but they highlight the need of decreasing the time spent in sedentary behavior, mainly TV viewing time, in adolescence. ■

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Appendix

AFINOS Study Group members include:

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Table I. Bivariate associations between emerging cardiometabolic biomarkers in adolescents (n = 183)

	CRP*	IL-6†	C3†	C4†	Adiponectin*	Leptin*	ICAM-1*	VCAM-1*	L-selectin*	E-selectin*	PAI-1*
WBC, cel·10^3/mm^3	0.025 (.742)	0.062 (.406)	0.248 (.001)	0.220 (.003)	−0.051 (.497)	0.179 (.016)	0.155 (.038)	0.176 (.018)	0.239 (.001)	0.274 (<.001)	0.201 (.007)
CRP, mg/L*	–	0.205 (.006)	0.337 (<.001)	0.298 (<.001)	−0.115 (.123)	0.122 (.103)	−0.006 (.941)	0.046 (.540)	−0.121 (.105)	0.116 (.120)	0.212 (.004)
IL-6, pg/mL†		–	0.070 (.350)	−0.019 (.798)	−0.082 (.274)	0.119 (.111)	−0.030 (.685)	−0.128 (.087)	0.016 (.830)	−0.134 (.074)	−0.079 (.291)
C3, g/L†			–	0.628 (<.001)	−0.142 (.058)	0.457 (<.001)	0.260 (<.001)	0.129 (.084)	0.073 (.327)	0.257 (<.001)	0.263 (<.001)
C4, g/L†				–	−0.093 (.213)	0.269 (<.001)	0.266 (<.001)	0.211 (.005)	0.120 (.108)	0.237 (.001)	0.284 (<.001)
Adiponectin, μg/mL*					–	−0.047 (.533)	0.153 (.040)	0.252 (.001)	0.146 (.051)	0.260 (<.001)	0.123 (.101)
Leptin, ng/mL*						–	0.127 (.088)	0.052 (.489)	0.092 (.218)	0.123 (.099)	0.222 (.003)
ICAM-1, ng/mL*							–	0.592 (<.001)	0.384 (<.001)	0.578 (<.001)	0.332 (<.001)
VCAM-1, ng/mL*								–	0.349 (<.001)	0.513 (<.001)	0.413 (<.001)
L-selectin, μg/mL*									–	0.268 (<.001)	0.048 (.520)
E-selectin, ng/mL*										–	0.350 (<.001)
PAI-1, ng/mL											–

WBC, white blood cell; *CRP*, *C*-reactive protein; *C3*, complement factor 3; *C4*, complement factor 4; *IL-6*, interleukin-6; *PAI-1*, plasminogen activator inhibitor-1.
Data are r (*P* values) adjusted for age, sex, and pubertal status.
*Values were natural log-transformed before analysis.
†Values were square root transformed before analysis.

Table II. Bivariate associations between conventional and emerging cardiometabolic biomarkers in adolescents (n = 183)

	WBC	CRP*	IL-6†	C3†	C4†	Adiponectin*	Leptin*	ICAM-1*	VCAM-1*	L-selectin*	E-selectin*	PAI-1*
Systolic BP (mm Hg)	0.108 (.148)	0.208 (.005)	0.046 (.543)	0.242 (.001)	0.201 (.007)	−0.074 (.322)	0.178 (.017)	0.019 (.799)	0.033 (.660)	0.041 (.586)	−0.011 (.878)	−0.007 (.928)
Diastolic BP (mm Hg)	0.066 (.376)	0.081 (.278)	−0.045 (.547)	0.031 (.677)	−0.017 (.886)	−0.015 (.839)	0.028 (.711)	−0.032 (.670)	−0.095 (.202)	−0.097 (.193)	0.022 (.772)	0.022 (.770)
Total cholesterol (mg/dL)*	−0.015 (.842)	−0.015 (.845)	0.003 (.971)	0.404 (<.001)	0.197 (.008)	0.006 (.937)	0.088 (.243)	0.026 (.724)	−0.085 (.255)	−0.043 (.564)	0.118 (.113)	0.039 (.604)
HDL-cholesterol (mg/dL)*	−0.093 (.214)	−0.106 (.158)	−0.004 (.954)	−0.082 (.275)	−0.174 (.019)	0.351 (<.001)	−0.173 (.021)	0.033 (.664)	0.139 (.063)	0.079 (.285)	0.099 (.185)	−0.108 (.150)
LDL-cholesterol (mg/dL)*	−0.010 (.890)	0.011 (.885)	−0.012 (.873)	0.406 (<.001)	0.243 (.001)	−0.130 (.084)	0.153 (.041)	−0.036 (.627)	−0.206 (.006)	−0.139 (.063)	0.030 (.693)	0.027 (.717)
Apo-A1(mg/dL)	−0.024 (.748)	−0.084 (.266)	0.130 (.082)	0.035 (.638)	−0.005 (.944)	0.111 (.138)	−0.080 (.286)	0.169 (.023)	0.196 (.009)	0.267 (<.001)	0.136 (.070)	−0.093 (.215)
Apo-B100 (mg/dL)	0.042 (.577)	0.029 (.703)	0.088 (.241)	0.462 (<.001)	0.254 (.001)	−0.195 (.009)	0.227 (.002)	0.103 (.168)	−0.043 (.567)	−0.005 (.947)	0.100 (.185)	0.156 (.037)
Triglycerides (mg/dL)	0.132 (.077)	0.092 (.220)	0.055 (.463)	0.397 (<.001)	0.286 (<.001)	−0.196 (.009)	0.172 (.021)	0.150 (.045)	0.071 (.341)	0.125 (.096)	0.171 (.022)	0.238 (.001)
Glucose (mg/dL)*	−0.045 (.548)	0.069 (.357)	−0.042 (.578)	0.284 (<.001)	0.232 (.002)	0.048 (.521)	0.109 (.146)	0.073 (.328)	0.147 (.049)	0.071 (.345)	0.136 (.070)	0.083 (.265)
Insulin (pg/mL)*	−0.003 (.967)	−0.004 (.963)	0.041 (.588)	0.009 (.909)	0.026 (.731)	−0.020 (.790)	0.067 (.372)	−0.079 (.291)	0.074 (.327)	0.065 (.385)	−0.021 (.777)	0.160 (.032)

WBC, white blood cells; *CRP*, *C*-reactive protein; *IL-6*, interleukin-6; *C3*, complement factor 3; *C4*, complement factor 4; *PAI-1*, plasminogen activator inhibitor-1; *BP*, blood pressure; *HDL*, high-density lipoprotein; *LDL*, low-density lipoprotein; *Apo*, apolipoprotein.
Data are r (*P* values) adjusted for age, sex, and pubertal status.
*Values were natural log-transformed before analysis.
†Values were square root transformed before analysis.