ELSEVIER

Atherosclerosis 153 (2000) 433–443

ATHEROSCLEROSIS

www.elsevier.com/locate/atherosclerosis

Influence of leisure time physical activity and television watching on atherosclerosis risk factors in the NHLBI Family Heart Study

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Received 10 June 1999; received in revised form 25 January 2000; accepted 14 February 2000

Abstract

Physical activity favorably influences atherosclerosis risk factors but only a few studies in adults considered the time watching television (TV) as a measure of physical inactivity. We therefore determined in a population-based sample of 1778 subjects from the NHLBI Family Heart Study (FHS) whether leisure time physical activity and TV watching have independent or interactive associations with cardiovascular disease risk factors and carotid artery intima-media wall thickness (IMT). Subjects were free from diabetes mellitus and clinically-ascertained coronary artery disease and did not take lipid-lowering or antihypertensive drugs. Only 0.7 and 1.3% of the variance in leisure time physical activity in women and men, respectively, was explained by the amount of TV watching. Leisure time physical activity had a clearly favorable, and TV watching an unfavorable association with anthropometric measurements (BMI (body mass index), waist girth, waist-hip ratio, subscapular and triceps skinfold thickness). The odds ratio (95% CI) of being overweight was 0.41 (0.28–0.62) in women and 0.69 (0.46–1.04) in men in the highest quartile of leisure time physical activity compared to the lowest quartile. The odds ratio increased for increasing quartiles of TV watching to 2.12 (1.45–3.10) in women and 1.61 (1.07–2.43) in men. Watching TV only 1 h per day in women with a BMI of 30 kg/m^2 and doing about 75 min of moderate exercise per week was associated with a BMI 1.8 kg/m^2 lower than in women watching TV 3 h per day and doing the same amount of exercise. Those with twice the amount of moderate exercise and watching TV 1 h per day had a BMI 0.45 kg/m^2 lower. Furthermore, leisure time physical activity was negatively associated with concentrations of triglycerides and positively with HDL cholesterol in both genders. TV watching was significantly positively associated with triglycerides and slightly negatively with HDL cholesterol in men. The observed associations of leisure time physical activity and TV watching with atherosclerosis risk factors were independent from each other. Finally, we analyzed the relation between leisure time physical activity, TV watching and the degree of IMT of the carotid arteries. Neither of these two measures was significantly associated with IMT. In summary, TV watching, in addition to leisure time physical activity, shows an independent association with obesity-related anthropometric measurements, HDL and triglycerides. Decreasing the amount of TV watching might be effective as a first step in reducing atherosclerosis risk factors, especially overweight.

Keywords: Physical activity; TV watching; Atherosclerosis risk factors; Obesity; Lipids; Lipoproteins

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0021-9150/00/$ - see front matter
PII: S0021-9150(00)00426-3

1. Introduction

Although average daily energy and fat intake have decreased over the last decades in the United States and United Kingdom [1–4], the prevalence of overweight has increased [5]. Decreased physical activity during work and leisure time might have contributed to this negative development [1,6]. Physical activity is known to have a favorable influence on obesity and other cardiovascular risk factors such as lipoprotein and glucose metabolism and blood pressure [7–15]. Furthermore, prospective studies have shown an inverse association between the amount of self-reported physical activity and long-term cardiovascular and non-cardiovascular mortality [16–19].

In addition to physical activities such as sports and exercise, time spent in physical inactivity may be used to further define overall habitual activity. In fact, several physical activity questionnaires in the literature include questions about physical inactivity [20]. By definition, amount of inactivity should be inversely correlated with energy expended in such activities as household tasks and childcare that are typically not measured or not measured well by epidemiologic surveys. One measure of inactivity, hours of daily television (TV) watching, has been shown to correlate with atherosclerosis risk factors and obesity [21–23].

The purpose of the present study was to investigate whether leisure time physical activity and television watching have independent or interactive associations with obesity, cardiovascular disease risk factors, and carotid artery wall thickness in a cohort of middle-aged men and women.

2. Subjects and methods

2.1. Population

The FHS is a population-based, multicenter study designed to identify genetic and nongenetic determinants of cardiovascular disease. Probands were identified from three parent cohort studies, the Forsyth and Minneapolis cohorts of the Atherosclerosis Risk in Communities Study (ARIC), the Framingham Offspring Study, and the Utah Health Family Tree Study. Extended information and objectives of the FHS are given elsewhere [24]. The study was approved by the institutional review committee of each center and subjects gave written informed consent.

In phase I of the FHS, a random sample of ≈ 500 probands from each field center and another 500 probands with a high family risk score for coronary heart disease were recruited [24]. In phase II, a total of 5348 members from 592 randomly selected families and 661 high-risk families completed a detailed clinical and laboratory investigation including interviews by experienced interviewers. Data used for this investigation are based on phase II and include only families randomly ascertained.

Caucasian subjects who provided a fasting blood sample were included in the analysis. We excluded 666 of these 2572 randomly recruited subjects because of self-reported coronary heart disease and/or because of conditions which influence atherosclerosis risk factors. These conditions were the use of antihypertensive or lipid-lowering drugs as well as a history of diabetes mellitus according to the WHO criteria [25]. The use of a fasting glucose concentration of higher than 125 mg/dl according to the recent American Diabetes Association criteria for diabetes mellitus classification [26] would have resulted only in an exclusion of 14 additional subjects. An additional 128 subjects were excluded because of missing values of one or more covariates. The final analysis included a total of 1778 individuals (962 women and 816 men).

2.2. Determination of physical activity and inactivity

Both questionnaires on physical activity and TV watching are based on those used in the CARDIA study [20] with minor modifications. The amount of exercise was assessed by trained interviewers using formal, rigid questionnaires so as not to bias the answer. Interviewers inquired how many months the subject had engaged in vigorous, moderate and light leisure-time activity on a regular basis (at least once a week) during the past year. Subjects were asked how often they engaged in each type of exercise per week and the length of each session. Subjects were given examples for each intensity category. Average weekly time spent in each of the three categories was multiplied by the average metabolic equivalent (MET) specific to each activity [27]. MET-minutes are a way of expressing activity intensity in comparison to resting energy expenditure (REE), with one MET equal to the standard for REE (roughly 3.5 ml of oxygen consumed per kilogram of body weight/min). For example, a five MET activity requires five times the energy of resting. For normal weight individuals, 1 MET is roughly equivalent to 1 kcal/kg per h. For individuals weighing 60 kg, 1 MET is equivalent to ≈ 1 kcal/min. MET-minutes is an index very much like kcals/week, in that both reflect duration and relative intensity of activity participation. However, the use of MET-minutes is preferred because converting MET-minutes to kcals/week requires assumptions which add an unfortunate bias to the results for those who are overweight [27]. This can be illustrated by the fact that 100 MET-minutes for a 80 kg person means burning of more kcals per min than for a 60 kg person. The use of MET-minutes is therefore more or less independent from body weight and makes

the interpretation of results easier. Weekly MET-minutes reflect the relative intensity and time spent in activities and was calculated by summing all MET-minutes for each exercise category. Each subject was further asked whether the usual occupational activity is light, moderate, or vigorous.

As a measure of physical inactivity, subjects were asked for the number of h spent watching television for both weekdays and weekend days. The average h watching TV per day was used for data analysis.

2.3. Scanning of carotid arteries

Trained technicians scanned the carotid arteries at three sites bilaterally according to the protocol of the ARIC study [28]: the distal 1 cm straight portion of the common carotid artery (CCA), the carotid bifurcation (BFR), and the proximal 1 cm of the internal carotid artery (ICA). Images were recorded on 3/4-high end cassettes, which were analyzed by trained readers at a central reading center according to a standardized protocol [29]. Eleven contiguous measurements (1 mm each) were derived in the far wall in each of the six segments. The overall average value of the mean intima-media wall thickness (IMT) of the six segments combined was calculated and used in the further analysis. Technicians scanning and reading the carotid arteries were blinded for the parameters in this analysis. IMT measurements of the carotid arteries was available in 897 women and 761 men.

2.4. Data collection and laboratory procedures

Alcohol consumption was assessed by interview asking for standardized drinks consumed per day. Smoking was defined as a categorical variable distinguishing present smokers and non-smokers. Former smokers were considered as non-smokers. Education was estimated by asking for the highest grade or year of school completed, including trade or vocational school or college. Subjects were asked about their combined family income for the past 12 months with six categories ranging from under US$12 000 to > US$100 000. In women, a reproductive history questionnaire was used to determine menopausal status and a medication inventory was used to ascertain current use of estrogens.

Technicians measured systolic and diastolic blood pressure three times in a sitting position after a resting period of at least 5 min [30] using a random zero sphygmomanometer. The mean of the second and third measurement was used in our analysis. Weight and height were measured to calculate body mass index (BMI). For calculation of waist-hip ratio, circumferences of the waist (umbilical level) and hip (maximum protrusion of the gluteal muscles) were measured to the nearest centimeter. Subscapular and triceps skinfolds were measured each twice with the 'Lange' caliper and the mean of the two measurements was used for calculations. Subscapular skinfold was measured by taking a fold on a diagonal line coming from the vertical border to 1 to 2 cm from the inferior angle of the scapula while the back of the subject's right hand was placed on the middle of the back. Triceps skinfold was measured by taking a vertical fold on the posterior midline of the upper arm (over triceps muscle) halfway between acromion and the olecranon processes with the elbow extended and relaxed.

Total and HDL cholesterol and triglyceride concentrations were measured by a Roche COBAS FARA high-speed centrifugal analyzer (Roche Diagnostic Systems, Montclair, NJ). HDL cholesterol was measured after precipitation of the other lipoprotein fractions by dextran sulfate [31]. LDL cholesterol was estimated either by the Friedewald formula in case of triglyceride concentrations below 400 mg/dl [32] or directly by ultracentrifugation. Glucose was measured by an enzymatic (glucose-oxidase) method (Kodak EKTCHEM 700 Analyzer, Rochester, NY).

2.5. Statistical analysis

Non-normally distributed continuous variables (triglycerides, BMI, amount of alcohol consumption, duration and MET-minutes of each exercise intensity group and h watching TV per day) were compared between women and men by Wilcoxon rank sum tests. Normally distributed variables were compared by unpaired t-test. Categorial variables were compared by Pearson's χ^2-test.

The associations of total leisure time physical activity and TV watching with atherosclerosis risk factors were adjusted for each other and for activity level at work, age, center, drinking and smoking habit, degree of education, income, and postmenopausal status and estrogen use in women by multiple regression analysis. Since the data included in this analysis are based on families and a correlation of the variables within the families can be expected, we used a mixed linear model for adjustment of the different variables which accommodates this intrafamilial correlation by using an identification number for each family as a random effect in the model. Non-normally distributed dependent variables (triglycerides and BMI) were used in the model after logarithmic transformation to achieve a Gaussian-like distribution. Derived coefficients can therefore not be applied on a linear scale. We tested for interactions between leisure time physical activity and TV watching by inclusion of an interaction term. To graphically display the information, we cross-tabulated thirds of physical activity (cutpoints of the three tertiles were 150 and 750 MET-minutes in women and 250 and 900 MET-minutes in men) by about thirds of television

watching (cutpoints ≤ 1 and > 2 h in both genders). We examined the trends in BMI and subscapular and triceps skinfolds (adjusted for age, center, drinking and smoking habit, and in women additionally for menopausal status and estrogen use) by analysis of variance (ANOVA). An interaction term of leisure time physical activity and TV watching h was included in the analysis to investigate the relationship of these two variables on BMI and skinfolds.

Associations of both total leisure time physical activity and TV watching with IMT were investigated by a mixed linear model.

The 85th percentile of BMI from the NHANES II survey (BMI > 27.3 kg/m^2 for women and > 27.8 kg/m^2 for men) was used to classify a subject as overweight [33]. Odds ratios (OR) for being overweight were calculated for each of the top three quartiles of total leisure time physical activity and TV watching groups. Both total leisure time physical activity and TV watching were adjusted for each other before grouping into quartiles. The Mantel–Haenszel χ^2-test was used to test for significance between the quartiles.

All analyses were performed using the Statistical Analysis System (SAS) version 7.0 [34].

Table 1
Characteristics of the study population[a]

Variable	Women ($n = 962$)	Men ($n = 816$)
Age (years)	49 ± 13	48 ± 14*
Total cholesterol (mg/dl)	201 ± 39	198 ± 36
HDL cholesterol (mg/dl)	58 ± 16	46 ± 12***
LDL cholesterol (mg/dl)	119 ± 34	124 ± 33***
Triglycerides (mg/dl)	123 ± 76 [106]	145 ± 98 [121]***
Glucose (mg/dl)	91 ± 9	95 ± 9***
Systolic blood pressure (mmHg)**	111 ± 16	116 ± 14***
Diastolic blood pressure (mmHg)**	66 ± 9	70 ± 9***
BMI (kg/m^2)	26.2 ± 5.3	27.4 ± 4.3***
Waist circumference (cm)	91 ± 15	99 ± 13***
Waist-hip ratio	0.86 ± 0.09	0.95 ± 0.07***
Subscapular skinfold (mm)	18.8 ± 9.1	18.1 ± 7.4
Triceps skinfold (mm)	23.8 ± 8.3	16.4 ± 7.4***
Alcohol consumption (drinks/24 h)	0.16 ± 0.51 (0–4)	0.37 ± 0.96 (0–9)
Current smoker (n (%))	113 (11.8)	123 (15.1)
Years of education	16.1 ± 3.6	17.0 ± 3.8***
Family income scale[b]	3.5 ± 1.1	3.7 ± 1.2**
Postmenopausal status (n (%))	503 (52.3)	–
Estrogen use (n (%))	281 (29.2)	–

[a] Values are presented as unadjusted mean ± SD and as [median] or (minimum-maximum) where appropriate.

[b] Family income scale: 1 = under $12 000; 2 = $12 000–24,999; 3 = $25 000–49,999; 4 = $50 000–74 999; 5 = $75 000–100 000; 6 = over $100–000

* $P < 0.05$ for comparison of women and men.

** $P < 0.01$ for comparison of women and men.

*** $P < 0.0001$ for comparison of women and men.

3. Results

3.1. Univariate analysis

Table 1 shows the gender-stratified characteristics of the 1778 study participants who were free of coronary heart disease and diabetes mellitus and who were not treated with antihypertensive and/or lipid-lowering drugs. Because men had, in general, a higher atherosclerosis risk factor profile and because we aimed to investigate the influence of leisure time physical activity and TV watching on these risk factors, we performed the remaining analyses stratified by gender. This is supported by the different physical activity profile in women and men (Table 2) and by significant statistical interactions between leisure time physical activity and gender on HDL and LDL cholesterol, triglycerides, glucose, blood pressure, BMI, waist circumference, waist-hip ratio, subscapular and triceps skinfolds (data not shown).

Leisure time physical activity in Table 2 is presented in terms of MET-minutes which are an index of the duration and relative intensity of activity participation (see Section 2). Men reported that they were much more involved in light and especially vigorous exercise during the recent year than women. Both genders reported a similar amount of moderate exercise. Together, this resulted in an $\approx 70\%$ higher total weekly leisure time MET-minutes in men than in women. The differences between the two genders were less pronounced for the time watching television. Men spent on average about 8.4 min per day longer watching TV than women which was mainly because of more TV watching during the weekend. Additionally, the activity level at work was considered as a possible confounder of an association between leisure time physical activity and TV watching with atherosclerosis risk factors. This level was different between genders with a significantly higher frequency of men considering themselves to have a moderate or vigorous activity level at work (Table 2).

Next we analyzed whether the amount of total leisure time physical activity correlated with television watching and whether the latter was an indicator for total leisure time physical activity. Correlation analysis revealed that only a very small amount (0.7–1.3%) of the variance of the total leisure time physical activity can be explained by TV viewing: Spearman $r = -0.084$ ($P = 0.009$) for women and $r = -0.115$ ($P = 0.001$) for men. This small overlap in variance pointed us to investigate a further association of watching TV beyond leisure time physical activity on cardiovascular risk factors.

3.2. Multivariate analysis

Using a multiple regression analysis, we estimated independent associations of total leisure time physical activity and TV watching with atherosclerosis risk fac-

Table 2
Leisure time physical activity and TV watching in the study population

Variable	Women ($n = 962$)	Men ($n = 816$)
Light Exercise[a]		
Average duration of each exercise session, min	36.6 [0, 30, 60]*	69.2 [0, 30, 120]*
Average min of activity per week, min	73 [0, 30, 89]	126 [0, 50, 159]*
Weekly moderate activity MET-min[b]	102 [0, 42,125]	176 [0, 69, 222]*
Moderate exercise[a]		
Average duration of each exercise session, min	32.6 [0, 30, 45]	39.7 [0, 30, 60]
Average min of activity per week, min	77 [0, 37, 112]	81 [0, 30, 119]
Weekly moderate activity MET-minute[b]	285 [0, 137, 415]	300 [0, 111, 443]
Vigorous exercise[a]		
Average duration of each exercise session, min	11.2 [0, 0, 0]	27.1 [0, 0, 45]
Average min of activity per week, min	20 [0, 0, 0]	58 [0, 0, 67]*
Weekly moderate activity MET-minute[b]	151 [0, 0, 0]	435 [0, 0, 498]*
Total weekly leisure time MET-minute[ab]	538 [83, 314, 706]	911 [125, 498, 1213]*
TV watching[a]		
TV (h/week day)	1.75 [1, 2, 2][a]	1.82 [1, 2, 3]*
TV (h/weekend day)	2.05 [1, 2, 3]	2.40 [1, 2, 3]*
Total TV (h/day)	1.84 [1.0; 1.7; 2.6]	1.98 [1.0; 1.7; 2.7]**
Currently employed *n* (%)	631(66)	679 (83)*
Activity level at work[a]*		
Light *n* (%)	434 (69)	387 (57)
Moderate *n* (%)	168 (27)	217 (32)
Vigorous *n* (%)	29 (5)	75 (11)

[a] Values are presented as mean and [cutpoints of the four quartiles].
[b] MET-minute are an index of the duration and relative intensity of activity participation. For normal weight individuals, 1 MET is roughly equivalent to 1 kcal/kg h. For individuals weighing 60 kg, 1 MET is equivalent to ≈ 1 kcal/min. Therefore, weekly activity MET-min can also be interpreted as kcals/week with restrictions as discussed in the methods section.
* $P < 0.0001$ for comparison of women and men.
** $P < 0.05$ for comparison of women and men.

tors. Both variables were adjusted for each other (included in the same model) and for activity level at work, age, center, drinking and smoking habits, degree of education and income, and postmenopausal status and estrogen use in women. The results for total leisure time physical activity and TV watching are presented in Table 3.

Leisure time physical activity and TV watching had significant negative and positive associations, respectively, with BMI, waist circumference, waist-hip ratio, subscapular and triceps skin thickness. The associations of leisure time physical activity and TV watching with these measurements were independent of each other and more pronounced in women than in men. We assured this independence further by dividing leisure time physical activity and TV watching in quartiles and testing for statistical trends in increasing anthropometric measures from the highest to the lowest quartiles of TV watching in each quartile of leisure time physical activity ($P < 0.05$ four-degree of freedom test for trend in each anthropometric measurement across quartiles of leisure time physical activity; data not shown). Figs. 1–3 illustrate the mostly additive association between three classes of TV watching h and tertiles of leisure time physical activity with BMI and subscapular and triceps skinfold. An interaction term of the classes of TV watching and leisure time physical activity was not significantly associated with these variables.

In calculations based on the regression coefficients from Table 3 we compared women having a BMI of 30 kg/m^2 and doing 300 MET-minutes of total leisure time physical activity (corresponds, for example, to a combination of roughly 90 min of light and 40 min of moderate exercise or 75 min of moderate exercise per week) and 1 h TV watching per day (reference group) to those watching TV 3 h per day and the same amount of physical exercise as the reference group. The higher TV watching time was associated with a BMI 1.8 kg/m^2 higher than in the reference group. Women watching the same amount of TV as the reference group but twice as physically active (600 MET-minutes) had a BMI 0.45 kg/m^2 lower than the reference group. The association of TV watching and total leisure time physical activity with BMI in men was less pronounced than in women.

Table 4 represents an example of the association of total leisure time physical activity and TV watching with the prevalence and odds ratio for overweight. Each of the two variables are adjusted for the other variable as well as for the activity level at work, age and center. The association was markedly more pronounced in women and the odds ratio for being overweight decreased significantly in the upper two quartiles of leisure time physical activity. The odds ratio increased independently of the total leisure time physical activity level in the highest quartile of TV watching. A less pronounced trend was observed for total leisure time physical activity in men, although the odds ratio of overweight did appear to be increased in the second to fourth quartile.

Blood pressure showed a positive association with the amount of TV watching in women but not in men. Leisure time physical activity was not significantly associated with blood pressure in either gender (Table 3).

The association of lipids with TV watching was less pronounced than with leisure time physical activity

(Table 3). Triglycerides and HDL cholesterol showed significant negative and positive associations, respectively, with leisure time physical activity in both genders. Triglycerides were positively associated with TV watching in men and women but the negative association between HDL cholesterol and TV watching was statistically significant only in men. Leisure time physical activity was negatively associated with total and LDL cholesterol in women.

Blood glucose concentrations were negatively correlated with leisure time physical activity in women and positively with TV watching in both genders.

The inclusion of an interaction term between leisure time physical activity and TV watching h did not contribute to the model for any of the atherosclerosis risk factors.

3.3. Association with carotid intima-media thickness

Finally, we analyzed the association of total leisure time physical activity and TV watching as well as various atherosclerosis risk factors with preclinical atherosclerosis in the carotid arteries calculated as overall mean IMT of six carotid segments (common, internal and bifurcation of both sides). Neither leisure time physical activity nor TV watching nor an interaction term of both correlated significantly with IMT (minimal model, Table 5). Leisure time physical activity showed only a trend to be associated with IMT in women. In an extended model leisure time physical activity was no longer related to IMT in women after inclusion of atherosclerosis risk factors (Table 5). We repeated the analysis by inclusion of weekly MET-minutes for light, moderate and vigorous exercise separately into the minimal and extended model instead of total leisure time physical activity. None of these exercise classes was associated with IMT (data not shown).

4. Discussion

This population-based study investigated TV watching as a parameter for physical inactivity in addition to leisure time physical activity and its influence on cardio-

Table 3
Influence of leisure time physical activity and TV watching on atherosclerosis risk factors investigated by multiple regression analysis[a]

		Leisure time physical activity			TV watching h		
Dependent variable	Gender	Coefficient[b]	SE[b]	P	Coefficient	SE	P
BMI[c]	Women	−0.0050	0.0008	0.0001	0.0291	0.0046	0.0001
	Men	−0.0006	0.0004	0.11	0.0146	0.0036	0.0001
Waist circumference	Women	−0.4110	0.0649	0.0001	2.0185	0.3568	0.0001
	Men	−0.1150	0.0353	0.0013	1.2795	0.2970	0.0001
Waist-hip ratio	Women	−0.0020	0.0004	0.0001	0.0076	0.0021	0.0003
	Men	−0.0006	0.0002	0.0013	0.0058	0.0016	0.0002
Subscapular skinfold	Women	−0.2000	0.0380	0.0001	1.0253	0.2121	0.0001
	Men	−0.0530	0.0207	0.0103	0.4570	0.1746	0.0092
Triceps skinfold	Women	−0.1260	0.0330	0.0002	0.6587	0.1846	0.0004
	Men	−0.0500	0.0203	0.0142	0.3258	0.1706	0.057
Systolic blood pressure	Women	−0.1060	0.0639	0.10	1.0976	0.3528	0.002
	Men	0.0090	0.0389	0.82	0.1862	0.3279	0.57
Diastolic blood pressure	Women	−0.0600	0.0412	0.15	0.4827	0.2301	0.037
	Men	−0.0260	0.0279	0.36	0.2996	0.2336	0.20
Total cholesterol	Women	−0.3890	0.1502	0.0099	0.8608	0.8370	0.30
	Men	−0.1210	0.1011	0.23	0.7763	0.8556	0.36
HDL cholesterol	Women	0.2541	0.0681	0.0002	−0.4364	0.3800	0.25
	Men	0.0640	0.0321	0.047	−0.6475	0.2719	0.018
LDL cholesterol	Women	−0.4190	0.1375	0.0024	0.7512	0.7681	0.33
	Men	−0.0480	0.0942	0.61	0.0162	0.7945	0.98
Triglycerides[c]	Women	−0.0090	0.0022	0.0001	0.0259	0.0123	0.036
	Men	−0.0050	0.0017	0.0042	0.0473	0.0141	0.0009
Glucose	Women	−0.0980	0.0383	0.0113	0.6382	0.2111	0.0026
	Men	−0.0380	0.0262	0.15	0.9598	0.2200	0.0001

[a] The associations of leisure time physical activity and TV watching with atherosclerosis risk factors are adjusted by each other and for activity level at work, age, center, drinking and smoking habit, degree of education and income as well as postmenopausal status and estrogen use in women. The inclusion of an interaction term between leisure time physical activity and TV watching h did not contribute to the model for any of the risk factors.

[b] Coefficient and standard error (SE) are based on a 100 weekly MET-minute increment of total leisure time physical activity.

[c] Triglycerides and BMI were logarithmically transformed before inclusion into the model. Coefficients and SE are based on the transformed values and can therefore not be applied on a linear scale.

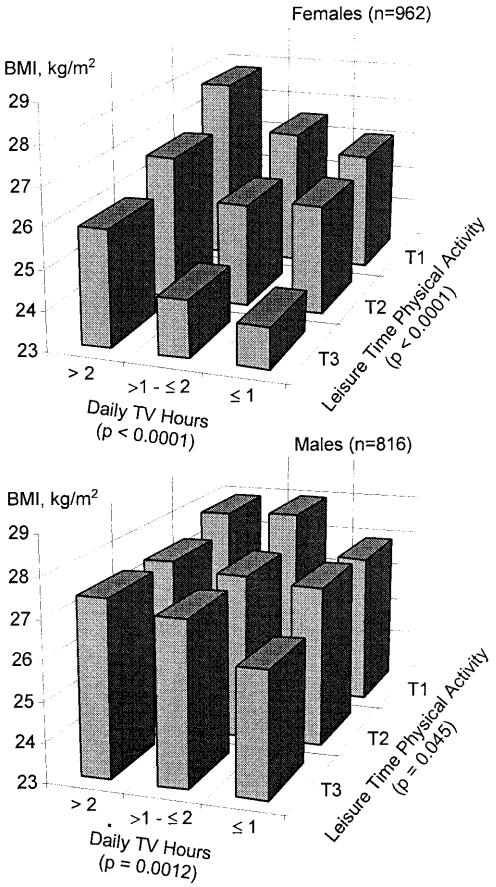

Fig. 1. Influence of total physical activity (in tertiles T1–T3) and amount of daily h watching television (TV) on body mass index (BMI) in females and males. BMI is adjusted for age, center, drinking and smoking habit and in women additionally for menopausal status and estrogen use. *P* values report the main effects for each variable. An interaction term of leisure time physical activity and TV watching h did not significantly contribute to BMI.

vascular risk factors and preclinical atherosclerosis of the carotid arteries. It shows that leisure time physical activity and inactivity are inversely correlated. However, one variable can only explain a very small amount of about 0.7 and 1.3% of the variance of the other variable in women and men, respectively. Since several studies have shown an influence of physical activity on cardiovascular risk factors [7–15], we expected that the amount of TV watching would explain further variance in these risk factors. Indeed, TV watching showed besides leisure time physical activity a pronounced additive but not an interactive association mainly with anthropometric measurements such as BMI, waist circumference, waist-hip ratio and subscapular and triceps skinfolds. The association with lipids was less pronounced and was seen mainly for triglycerides and HDL cholesterol. The association of leisure time physical activity and TV watching with anthropometric measures becomes more important in light of recent results from the Framingham Offspring Study [35]. This study considered six metabolically related risk factors defined as the lowest sex-specific quintile of HDL cholesterol and the highest quintiles of BMI, systolic blood pressure, triglycerides, glucose and serum total cholesterol (for the analysis extreme quintile levels were coded as 1, all other quintiles as 0 and the overall risk factor sums were represented as integers and ranged from 0 to 6). A 2.25 kg weight increase over 16 years was associated with a 20 and 37% increase in the risk factor sum in men and women, respectively. A 2.25 kg weight loss was associated with a decrease in the risk factor sum of 48 and 40%, respectively [35]. This underlines the importance of weight changes on atherosclerosis risk factor development.

The influence of TV watching on obesity in children was intensively investigated in several cross-sectional studies from US national samples [36–39]. They demonstrated a significant correlation between TV watching and adiposity. Similar observations were

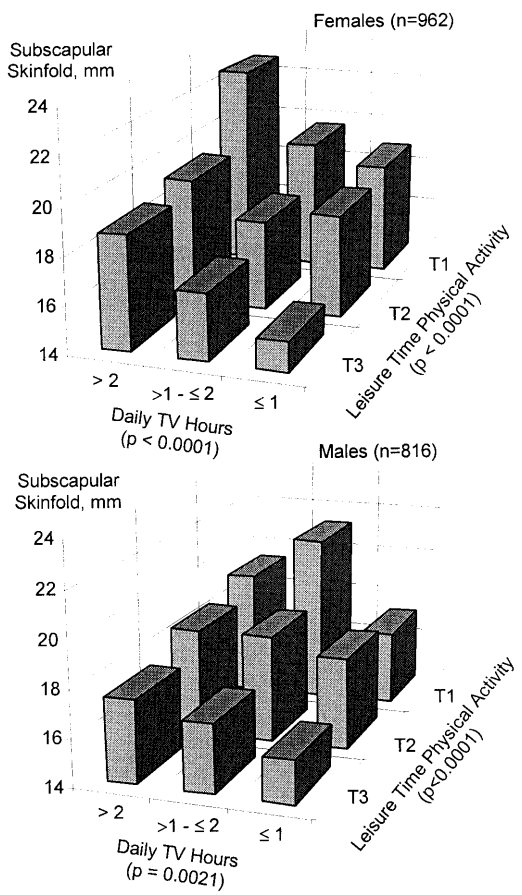

Fig. 2. Influence of total physical activity (in tertiles T1–T3) and amount of daily h watching television (TV) on subscapular skinfold in females and males. Subscapular skinfold is adjusted for age, center, drinking and smoking habit and in women additionally for menopausal status and estrogen use. *P* values report the main effects for each variable. An interaction term of leisure time physical activity and TV watching h did not significantly contribute to subscapular skinfold.

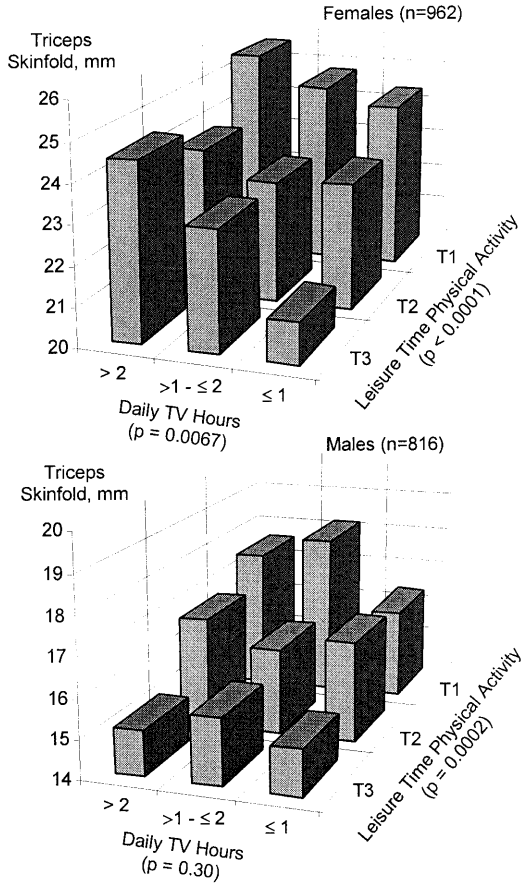

Fig. 3. Influence of total physical activity (in tertiles T1–T3) and amount of daily h watching television (TV) on triceps skinfold in females and males. Triceps skinfold is adjusted for age, center, drinking and smoking habit and in women additionally for menopausal status and estrogen use. *P* values report the main effects for each variable. An interaction term of leisure time physical activity and TV watching h did not significantly contribute to triceps skinfold.

made in the few cross-sectional studies in adults [21,22,40–44], two of them including a prospective observation period [42–44]. Tucker and colleagues investigated 6138 adult male [40] and 4771 adult female employees [41] of over 50 different US companies. They found that men who watched TV >3 h per day and women who watched >4 h per day were at least twice as likely to be obese compared with those watching <1 h per day. Faculty, staff and students at the Harvard School of Public Health who reported watching 3 or more h of TV per day had a four times higher prevalence of obesity than those reporting up to 1 h (19.2 vs. 4.5%) [45]. Young participants in the CARDIA study aged 23 to 35 years had a higher prevalence of obesity with increased TV companionship [22]. A cohort study including 1137 women found that both a high BMI and high waist-hip ratio were associated with little physical activity and increased TV watching [46]. Heavy watchers (≥ 41 h/week) in the Health Professionals Follow-Up Study experienced an odds ratio of being overweight of more than four [42]. During the prospective 4-year follow-up, increasing physical activity and decreasing TV watching were associated with maintaining the weight or modest weight loss [23]. Another prospective study found as association between TV watching and body weight change over 1 year [43] which was, however, no longer observed after 3 years of observation [44].

Besides an association with obesity, TV watching in our study was positively related to triglyceride concentrations in both genders. A negative association was also observed with HDL cholesterol with significant differences in men. Correlations were seen between leisure time physical activity and both triglycerides and HDL cholesterol. To our knowledge, only the CARDIA study correlated TV watching with lipid abnormalities and did not detect any association [22]. This may be explained by the selection of only young adults aged 23 to 35 years. The correlations with leisure time physical activity are in agreement with the finding of other studies that changes in physical activity score are correlated with changes in lipids and lipoproteins [13,47,48]. The correlations of fasting glucose levels with leisure time physical activity and TV watching are in accordance with the observed associations of exercise with glucose tolerance [49,50].

The observed associations between leisure time physical activity and atherosclerosis risk factors might be underestimated for three reasons. First, we excluded in our study all subjects with coronary artery disease, diabetes mellitus, as well as those subjects treated with antihypertensive and lipid-lowering drugs. These exclusions are clearly affecting the evaluation of atherosclerosis risk factors by narrowing the variance. Such subjects, on the other hand, are mostly undergoing interventions with diet and medical drugs which affect the atherosclerosis risk factors in different ways and which would have markedly confounded the analysis. Since these interventions are heterogeneous we were also not able to include these subjects and to perform a stratified analysis because this would result in a high number of strata (subjects treated with lipid-lowering drugs alone, anti-hypertensive drugs alone, lipid-lowering and antihypertensive drugs combined, diet, etc.) and lack of statistical power. Even an adjustment for the use of antihypertensive drugs would be inadequate since different types of these drugs act heterogeneously on lipoprotein metabolism with either neutral, negative or positive influences. Furthermore, cutting out the upper spectrum of blood pressure by excluding hypertensive and antihypertensive-treated subjects might be the reason why we did not observe associations between leisure time physical activity and blood pressure. Second, the estimated leisure time physical activity given in MET-minutes does not consider body weight in the calculation. Recent studies, however, showed that this

approach might result in a bias for overweight subjects. The amount of bias increases with increasing overweight and it seems that overweight people do less physical activity than they may actually do (KH Schmitz et al., unpublished results). This falsely high activity levels in overweight subjects might have resulted in an attenuation of the inverse association between physical activity and measurements of body size. Third, physical activity is measured much less accurately than most other risk factors. If carotid artery

Table 4
Prevalence and odds ratios for overweight (BMI > 27.3 kg/m^2 for women and > 27.8 kg/m^2 for men)[a] among women and men, by quartiles of leisure time physical activity and TV watching.

	Women		Men	
Group	Prevalence of overweight (%)	OR (95% CI)	Prevalence of overweight (%)	OR (95% CI)
Leisure time physical activity[b]				
Quartile 1[c]	40.0	1.0	39.2	1.0
Quartile 2	40.3	1.01 (0.70–1.46)	40.7	1.06 (0.72–1.58)
Quartile 3	28.3	0.59 (0.41–0.87)	34.3	0.81 (0.54–1.21)
Quartile 4	21.6	0.41 (0.28–0.62)	30.9	0.69 (0.46–1.04)
Test for trend in ORs		$P < 0.0001$		$P = 0.037$
TV watching[b]				
Quartile 1[c]	27.4	1.0	29.4	1.0
Quartile 2	28.3	1.05 (0.70–1.56)	38.2	1.49 (0.98–2.25)
Quartile 3	30.0	1.14 (0.77–1.69)	37.3	1.43 (0.94–2.16)
Quartile 4	44.4	2.12 (1.45–3.10)	40.2	1.61 (1.07–2.43)
Test for trend in ORs		$P < 0.0001$		$P = 0.037$

[a] BMI for classification of overweight status was adjusted for age, activity level at work, center, drinking and smoking habit and income.
[b] Leisure time physical activity was adjusted for age, activity level at work, center and amount of TV watching. TV watching was adjusted for age, activity level at work, center and leisure time physical activity.
[c] Quartile cutoffs for adjusted weekly total leisure time physical activity levels in women were 100, 310 and 677 MET-minutes and in men 137, 506 and 1162 MET-minutes. Quartile cutoffs for adjusted TV watching h in women were 1.0, 1.6 and 2.3 h/day and in men 1.1, 1.7 and 2.5 h/day.

Table 5
Associations of leisure time physical activity (MET-min) and TV watching h with carotid intima-media thickness (IMT) investigated by multiple regression analysis[a]

	Women			Men		
	Coefficient	SE	P	Coeffecient	SE	P
Minimal model						
Age	0.0105	0.0005	0.0001	0.0129	0.0006	0.0001
Activity level at work	[b]	[b]	0.95	[b]	[b]	0.11
Leisure time physical activity[‡]	-0.001	0.0009	0.11	−0.00006	0.0007	0.93
TV watching h	0.0019	0.0048	0.69	0.0006	0.0053	0.91
Extended model						
Age	0.0091	0.0006	0.0001	0.0125	0.0007	0.0001
Activity level at work	[b]	[b]	0.87	[b]	[b]	0.11
Leisure time physical activity[c]	0.0002	0.0008	0.81	0.0002	0.0006	0.80
TV watching h	−0.0025	0.0048	0.61	−0.0038	0.0052	0.47
BMI[a]	−0.1259	0.0623	0.0439	0.2718	0.1076	0.0120
Waist circumference	0.0026	0.0008	0.0013	−0.0024	0.0013	0.0703
HDL cholesterol	−0.0013	0.0004	0.0024	−0.0020	0.0007	0.0040
LDL cholesterol	0.0004	0.0002	0.0609	0.0006	0.0002	0.0167
Blood glucose	0.0001	0.0008	0.90	0.0022	0.0009	0.0103
Alcoholic drinks/day	−0.0012	0.0021	0.57	0.0065	0.0021	0.0019
Systolic blood pressure	0.0020	0.0004	0.0001	0.0003	0.0006	0.59
Current smoking	0.0450	0.0191	0.0191	0.0305	0.0211	0.15

[a] Carotid intima-media thickness (IMT) and BMI were logarithimically transformed before inclusion into the model. Therefore coefficients can not be applied on a linear basis.
[b] No estimates are given because activity level at work has more than two classes.
[c] Coefficient and standard error (SE) are based on a 100 weekly MET-minutes increment of total leisure time physical activity.

wall thickness is also measured less accurately than the other risk factors this might explain why we found robust associations between activity and inactivity with risk factors but not with carotid artery wall thickness.

Consumption of fast food or snacks during TV watching is common and might add to the dyslipidemic state and contribute to obesity, as was shown recently for women [43]. In that study, TV viewing was positively related to energy intake in both high- and low income women and to the relative amount of energy intake coming from fat in low-income women. This is not surprising when 58% of foods advertised on TV during 'soap opera' time are high in fat [51].

Because of the cross-sectional design of our study, we cannot exclude the possibility that the relationship between leisure time physical activity and/or TV watching with overweight acts the other way around, meaning that obesity results in reduced activity. Although it was shown in a longitudinal observation that less physically active people and more intensive TV watchers have an increased incidence of overweight [23], it is highly conceivable that all three components have a ratcheting effect: less activity and more TV watching results in overweight which leads to greater physical discomfort and the beginning of orthopedic problems. This might result in a more sedentary lifestyle which again aggravates overweight.

Although leisure time physical activity and TV watching showed an additive association on several atherosclerosis risk factors, we were not able to find a direct correlation of each of these two variables with IMT of the carotid arteries. A correlation of borderline significance for leisure time physical activity and IMT was observed in women but not in men. However, since this correlation disappeared after inclusion of other atherosclerosis risk factors, it can be assumed that leisure time physical activity does not act directly and independently of other atherosclerosis risk factors on carotid IMT but by its influence on these risk factors. This is in accordance with a recent study reporting an association of leisure time physical activity with several parameters which correlated with IMT of the common carotid artery. Leisure time physical activity itself, however, did not correlate with IMT but showed an association with arterial stiffness [52].

Increasing physical activity is often a 'painful' process, especially for those who are obese and who are starting from a very low physical activity level. Physical inactivity caused by TV watching has an additional association with atherosclerosis risk factors and obesity. Decreasing the amount of TV watching as a first step might be an advantageous alternative and a rewarding concomitant phenomenon along with increasing physical activity. This is in accordance with the finding that a reduction in TV watching time was more effective as a weight loss strategy, at least in children, than the direct enforcement of an increase in physical activity [53].

Acknowledgements

F. Kronenberg is supported by the 'Austrian Programme for Advanced Research and Technology' (APART) of the Austrian Academy of Science and by the 'Hans und Blanca Moser Stiftung'. This study was supported by cooperative agreements UO1-HL-56563, -56564, -56565, -56566, -56567, -56568, and -56569.

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