American Journal of Epidemiology
Vol. 184, No. 4
DOI: 10.1093/aje/kwv338

Original Contribution

Is Sedentary Lifestyle Associated With Testicular Function? A Cross-Sectional Study of 1,210 Men

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Initially submitted August 25, 2015; accepted for publication December 2, 2015.

Based on cross-sectional data on 1,210 healthy young Danish men, we investigated whether sedentary lifestyle was associated with testicular function (semen quality and reproductive hormones) independent of physical activity. The men were invited to participate in the study between 2008 and 2012, when they attended a compulsory medical examination to determine their fitness for military service. Information on sedentary behavior (television watching and computer time) and physical activity was obtained by questionnaire. The men had a physical examination, delivered a semen sample, and had a blood sample drawn. Time spent watching television, but not time sitting in front of a computer, was associated with lower sperm counts. Men who watched television more than 5 hours/day had an adjusted sperm concentration of 37 million/mL (95% confidence interval (CI): 30, 44) versus 52 million/mL (95% CI: 43, 62) among men who did not watch television; total sperm counts in those 2 groups were 104 million (95% CI: 84, 126) and 158 million (95% CI: 130, 189), respectively. Furthermore, an increase in follicle-stimulating hormone and decreases in testosterone and the testosterone/luteinizing hormone ratio were detected in men watching many hours of television. Self-rated physical fitness, but not time spent on physical activity, was positively associated with sperm counts.

cross-sectional studies; male reproductive health; normal men; physical activity; reproductive hormones; sedentary lifestyle; semen quality

Abbreviations: BMI, body mass index; cFT, calculated free testosterone; CI, confidence interval; FSH, follicle-stimulating hormone; LH, luteinizing hormone; MET, metabolic equivalent; SHBG, sex hormone–binding globulin.

A large proportion of young men from various European countries have impaired semen quality (1–5). The causes are debated but may include lifestyle factors, such as smoking, alcohol, obesity, and diet (6–10). Recently, Gaskins et al. (11) reported an inverse association, which was modified by physical activity, between television watching and semen quality. This finding is interesting as sedentary behavior has become an increasing part of modern life, including transportation, work, and leisure time (12, 13). Other than working and sleeping, watching television and other "screen time" is the most common activity in many Western countries and accounts for many hours of sedentary behavior (12, 14). In Denmark, the average time spent watching television is 2 hours 53 minutes per day (15). While the suggestion of an association between television watching and semen quality is recent, sedentary behavior has been associated with other negative health outcomes—such as type 2 diabetes mellitus, development of cardiometabolic disease, and all-cause mortality—even among those who are physically active (14, 16). However, the biological mechanism by which sedentary behavior could affect male reproductive health is unknown.

To examine the hypothesis that sedentary behavior has adverse effects on testicular function, we investigated the association of television watching, computer time, and physical

activity with markers of testicular function, including semen parameters and reproductive hormones, in 1,210 young men from the general Danish population.

METHODS

Study population

Because of the military draft in Denmark, all 18-year-old men, except those suffering from severe chronic illness, are required to undergo a physical examination (within ages 18–25 years) to determine their fitness for military service. Thus, the draftees can be considered representative of the general population of young men in Denmark. We approached the draftees when they appeared for the compulsory physical examination and invited them to participate in a study of semen quality. All participants completed a questionnaire prior to the day of screening, at which they delivered a semen sample, had a blood sample drawn, and had a physical examination. Participants were compensated for their time (500 Danish kr, or approximately $85.00). A detailed description of the study has been published previously (1, 2).

A total of 1,243 men, examined from April 2008 to April 2012, were included in the present study. Data from 33 men were excluded: 4 with missing information on the primary exposures; 2 with missing semen analyses; 6 with ejaculatory duct obstruction; 3 who had previously received chemotherapy; 11 with previous or current use of anabolic steroids; and 7 with azoospermia. Results from the remaining 1,210 men are reported here. Ethical approval was obtained from the local ethics committee.

Semen analysis

All men provided a semen sample by masturbation in a room close to the semen laboratory, and the period of ejaculation abstinence was recorded. The men had been asked to abstain from ejaculation for at least 48 hours before sampling but were still included if abstinence time was shorter. The semen sample was kept at 37°C until analysis, as described by Jørgensen et al. (1, 2), in accordance with the most recent guideline from the World Health Organization (17). In short, semen volume was assessed by weighing, assuming 1 g of semen to be equal to 1 mL. Sperm concentration was determined in diluted samples using a Bürker-Türk hemocytometer (Paul Marienfeld GmbH and Co. KG, Lauda-Königshofen, Germany), and the total sperm count was calculated (semen volume × sperm concentration). For sperm motility, 2 drops of well-mixed semen were placed on a glass slide and examined under a microscope. The spermatozoa were classified as progressively motile, locally motile, or immotile. Fixed and Papanicolaou stained morphology slides were prepared and evaluated according to strict criteria (18). For all assessments, counts were done in duplicates, and the average was used.

Reproductive hormone analyses

Serum levels of follicle-stimulating hormone (FSH), luteinizing hormone (LH), and sex hormone–binding globulin (SHBG) were determined using a time-resolved immunofluorometric assay (DELFIA; Wallac Oy, Turku, Finland). Total testosterone and estradiol levels were determined using time-resolved fluoroimmunoassays (DELFIA; Wallac Oy). From June 2010 onward, estradiol was measured with radioimmune analysis (Pantex, Santa Monica, CA). Inhibin B was determined by a specific 2-sided enzyme-immunometric assay (Inhibin B Gen II; Beckman Coulter Ltd., High Wycombe, United Kingdom). The hormones were measured in thawed samples in June 2010 and December 2013/January 2014. A number of samples were measured at both time points to validate the comparison of the analyses over time. Calculated free testosterone (cFT) was based on the measured serum concentrations of total testosterone and SHBG, assuming a fixed albumin value as in the study by Vermeulen et al. (19). In addition, the ratios between relevant hormones were calculated.

Physical examination

The men underwent a physical examination that included assessment for varicocele (grade 1–3) or hydrocele, enlargement of the epididymis, and the location, consistency, and size of the testes. Weight and height were measured, and body mass index (BMI) was calculated as weight (kg)/height $(m)^2$.

Questionnaire

All participants completed a questionnaire prior to the examination. At the examination, responses were reviewed with the participant to obtain missing data or clarify ambiguous information. The respondents were asked how many hours, on average, they had spent watching television, videos, or digital video disks on television (not computer) on weekdays and on weekends during the previous 3 months. Response categories were none or almost none, 1–3 hours/day, 4–6 hours/day, 7–9 hours/day, and 10 or more hours/day. A similar question was asked for hours spent in front of a computer (desktop and laptop combined). The median value for each response category was used to obtain daily television watching or computer time as the weighted average of time spent watching on weekdays and weekends, as in the study by Gaskins et al. (11). In the calculation, the response "none or almost none" was coded as 0 hours/day, and "10 or more hours" was coded as 10 hours/day. For analyses, the continuous weighted average of television watching was categorized into 0 hours/day, 0.1–2.5 hours/day, 2.6–5.0 hours/day, and more than 5.0 hours/day. The continuous variables for computer time and total screen time were categorized into quartiles.

The respondents were asked to rate their physical fitness as very good, good, fairly good, poor, or very poor. This was grouped into 3 categories: good (very good or good), fair, and poor (poor or very poor). In addition, the men provided information on hours per week spent in vigorous physical activity (causing shortness of breath), moderate physical activity (causing only slight shortness of breath), and light physical activity (not causing shortness of breath). This was coded into metabolic equivalent (MET)–hours in accordance with Craig et al. (20), multiplying hours of vigorous, moderate, and light activity by factors of 6, 4.5, and 2, respectively, to yield the average MET-hours, which were categorized into quartiles.

The questionnaire included questions on demographic factors and aspects of lifestyle (including sleep patterns, psychological stress, and dietary, smoking, and drinking habits) as well as mother's lifestyle during pregnancy (6–8, 21, 22).

Furthermore, information on previous and current diseases (including genital diseases) and use of medication was included. Participants were asked if they had been born with cryptorchidism and whether they had had a fever above 38°C (100.4°F) within the 3 months prior to the examination.

Statistical analyses

First, we calculated descriptive statistics on the variables from the questionnaire and physical examination for the total population and across categories of television watching. Distributions were compared by χ^2 test for categorical variables and Kruskal-Wallis test for continuous variables to identify potential confounders.

Next, unadjusted associations between the primary exposures (television watching, computer time, and total screen time) and outcomes (semen parameters and reproductive hormones) were investigated with linear regression. Data were then analyzed using multiple linear regression, including confounders, to investigate the adjusted association between sedentary behavior and reproductive function. To meet model assumptions of normally distributed residuals and homoscedasticity, outcome variables were transformed by square root (proportion of morphologically normal spermatozoa, testosterone, cFT, inhibin B, and estradiol), cubic root (sperm concentration, total sperm count, semen volume, SHBG, and sperm motility), or the natural logarithm (LH, FSH, and all hormone ratios). Sperm motility was added to the model as the ratio between the proportion of progressively motile spermatozoa and the proportion of nonprogressive spermatozoa.

In the linear regression analyses, potential confounders included factors shown in the literature to be associated with semen parameters, reproductive hormones, or sedentary behavior. An overview is given in Tables 1 and 2, which list all covariates that were tested. Directed acyclic graphs were drawn to explore different causal scenarios. Covariates were

Table 1. Basic Characteristics (Categorical Variables) for the Total Study Population and According to Hours of Daily Television Watching Among 1,210 Young Men, Denmark, 2008–2012

Characteristic	% of Men (*n* = 1,210)	% of Men by Television-Watching Time (hours/day)				*P* Value[a]
		0 (*n* = 116)	0.1–2.5 (*n* = 562)	2.6–5.0 (*n* = 400)	>5.0 (*n* = 132)	
General and reproductive health						
Used medication within the previous 3 months	16	17	16	18	14	0.5
Fever >38°C within the previous 3 months	7	6	7	4	11	0.02
Born with cryptorchidism	6	5	6	7	5	0.7
Past chlamydia and/or gonorrhea	10	8	9	11	10	0.8
Other inguinal-genital conditions[b]	6	8	6	5	9	0.4
Current varicocele (stage 2 or 3)	8	6	9	6	8	0.4
Characteristics and lifestyle						
Self-rated physical fitness						0.5
Good	60	59	62	59	53	
Fair	32	31	31	32	36	
Poor	8	10	7	9	11	
Current occupation[c]						<0.01
High school or higher education	70	75	72	69	64	
Craftsman training	8	2	8	9	12	
Full-time work	13	9	14	15	8	
Unemployed or other	9	14	7	7	16	
Nonsmoker	52	53	52	53	48	0.1
Exposure to smoking in utero	25	17	25	26	27	0.3
Maternal education, years						<0.01
>10	75	79	78	72	66	
9–10	22	14	19	25	29	
<9	3	7	3	2	5	

[a] *P* value from χ^2 test.
[b] Self-reported information about previous torsion of testes, epididymitis, or inguinal hernia.
[c] The variable refers to the men's current occupation. Thus, high school or higher education was not completed, and full-time work could be either skilled or unskilled.

Table 2. Basic Characteristics (Continuous Variables) for the Total Study Population and According to Hours of Daily Television Watching Among 1,210 Young Men, Denmark, 2008–2012

Characteristic	Overall		By Television-Watching Time (hours/day)								*P* Value[a]
			0 (*n* = 116)		0.1–2.5 (*n* = 562)		2.6–5.0 (*n* = 400)		>5.0 (*n* = 132)		
	Median	5th to 95th Percentiles	Median	5th to 95th Percentiles	Median	5th to 95th Percentiles	Median	5th to 95th Percentiles	Median	5th to 95th Percentiles	
Age, years	19.1	18.4–22.9	19.1	18.5–24.8	19.1	18.4–23.5	19.1	18.5–22.2	19.1	18.5–21.4	0.4
Height, cm	181	170–192	181	170–191	181	170–192	181	171–193	182	171–193	0.6
Weight, kg	73	60–96	71	58–92	73	59–94	74	61–98	74	57–99	<0.01
Body mass index[b]	22.3	18.7–28.7	21.8	17.5–28.1	22.2	18.7–28.3	22.4	18.7–29.2	22.9	18.1–29.1	0.01
Period of abstinence prior to semen sampling, hours	62	36–135	64	35–142	61	36–130	65	37–134	63	38–158	0.09
Macronutrients[c]											
Total energy intake, MJ/day	8.8	4.7–16.5	7.8	4.6–16.5	8.7	4.8–16.5	9.0	4.5–15.9	9.0	4.8–16.8	0.4
Total fat, %E	32	22–40	31	14–39	32	22–39	32	22–42	31	23–42	0.2
Saturated fat, %E	13	9–18	13	6–17	13	9–17	13	9–18	13	8–19	0.2
Protein, %E	16	11–22	16	11–25	17	12–22	16	11–22	16	11–22	0.03
Carbohydrate, %E	56	44–69	57	46–75	56	44–68	56	43–68	57	43–68	0.09
Intake of soft drinks, L/week	1.5	0.0–6.0	1.0	0.0–6.0	1.0	0.0–5.0	1.5	0.0–6.0	2.0	0.0–6.0	<0.01
Alcohol, units/week[d]	10.5	0–41	10	0–40	10	0–41	11	0–42	12	0–41	0.4
Caffeine, mg/day	142	2–682	150	2–707	148	2–728	147	5–623	96	0–625	0.1
Physical activity (MET-hours)[e]	38	9–123	35	9–128	38	9–129	38	9–113	39	5–119	0.7
Computer time, hours/day	5.0	1.4–10.0	5.0	1.4–13.0	4.3	1.4–10.0	5.0	2.0–9.4	8.0	2.0–15.0	<0.01
Sleep score (0–100)[f]	17	0–50	17	0–58	17	0–50	17	0–50	17	0–58	<0.01
Stress score (0–100)[g]	25	0–58	33	0–67	25	0–58	25	0–58	25	0–67	0.5

Abbreviation: MET, metabolic equivalent; %E, % of total energy intake.

[a] *P* value from Kruskal-Wallis test. Because of unequal shapes of the distribution within the 4 television-watching categories for some variables, the *P* value for the Kruskal-Wallis test can be significant even though the given medians are the same.

[b] BMI was calculated as weight (kg)/height $(m)^2$.

[c] Intake of macronutrients, based on food frequency questionnaire data from a subset of the population (*n* = 673). Percentages are based on estimates and do not add up to 100.

[d] One unit = 12 g of alcohol. Alcohol intake is the sum of intake of beer, wine, and liquor during the week prior to participation in the study.

[e] Weekly moderate and vigorous physical activity in MET-hours.

[f] Sleep score was calculated from 4 questions on sleep patterns during the past 4 weeks. A score of 0 indicates no sleep disturbances.

[g] Stress score was calculated from 4 questions on perceived stress during the past 4 weeks. A score of 0 indicates no perceived stress.

included in the final model if they were associated with the outcome at the $P = 0.10$ level or changed the effect estimate more than 15%. Self-rated physical fitness was included in all analyses in an attempt to calculate the sole impact of sedentary behaviors regardless of the man's physical activity, which has been reported to have a positive impact on semen quality by Gaskins et al. (11). Groups of outcome variables were adjusted for the same confounders to assure comparability of effect estimates. Semen parameters were adjusted for cryptorchidism at birth, varicocele detected at the physical examination, fever during the previous 3 months, and self-rated physical fitness. Sperm concentration, total sperm count, and semen volume were additionally adjusted for duration of ejaculation abstinence (using splines for the slope: <48 hours, 48–96 hours, and >96 hours). Sperm morphology was additionally adjusted for BMI (<20, 20–25, or >25), and sperm motility was adjusted for both BMI and duration from ejaculation to analysis. Reproductive hormones and hormone ratios were adjusted for cryptorchidism, varicocele, fever, self-rated physical fitness, BMI, smoking (daily, occasionally, or never), alcohol intake (units/week; 1 unit = 12 g of alcohol), and the time of day when blood was sampled (hours and minutes).

Regression coefficients with 95% confidence intervals were calculated for associations between the sedentary behaviors and semen parameters and hormones. We evaluated the fit of the regression models by testing the residuals for normality (the Kolmogorov-Smirnov test) and by inspecting residual plots. Testing for trends was performed by inserting the categorical television-watching or computer-use variable into the model, on the assumption that the association was linear. Due to the transformations of the outcome variables, the regression coefficients are not directly interpretable. Thus, the results of the regression analyses are presented as adjusted and back-transformed mean values of the semen parameters and hormone levels.

To elucidate the role of physical activity, we investigated differences in the impact of reported physical activity level (MET-hours) and self-rated physical fitness on the association

between television watching and testicular function as well as the relationship between these 2 variables, which are presumed to be measures of physical activity. We also examined whether BMI, reported MET-hours, and self-rated physical fitness modified the association between television watching and semen parameters. This was done both by including a cross-product term in the final multivariate model and by stratifying the regression analyses by BMI (<20, 20–25, or >25), MET-hours (sum of the physical activity that was moderate or vigorous, <38 MET-hours vs. ≥38 MET-hours), and self-rated physical fitness (good, fair, or poor). We also explored the possible impact on the television–semen quality association if these variables were mediators instead of confounders by repeating the analyses with and without inclusion of these variables. Furthermore, we performed subanalyses investigating the impact of energy consumption (data were available for 673 men).

Last, we used logistic regression analysis to estimate odds ratios and 95% confidence intervals for a man having semen parameters below the World Health Organization's reference levels (17) based on his amount of television watching. The same confounders were included as were used in the linear regression analyses.

A P value of <0.05 was considered statistically significant, and <0.1 was considered borderline significant. All P values were 2-sided. Statistical analyses were performed using SAS, version 9.1 (SAS Institute, Inc., Cary, North Carolina), or PASW GradPack, version 19.0 (SPSS Inc., Chicago, Illinois).

RESULTS

A basic description of the study population, overall and according to time spent watching television, is shown in Tables 1 and 2. The men had a median age of 19.1 years and a median BMI of 22.3. More than half were nonsmokers, and the prevalence of relevant reproductive morbidity was low (6% with cryptorchidism). The participants watched television for a median of 2 hours/day. Median semen parameters and the proportion of men below the World Health Organization's reference levels are shown in Table 3. Most basic demographic and lifestyle characteristics did not differ significantly by level of television watching, but there was a slightly higher BMI and intake of soft drinks across categories of more television watching, and the proportion attending high school or higher education and having mothers with more than 10 years of education was lower across the same categories. Furthermore, men watching television more than 5 hours/day more often reported having had a fever and spending more time in front of the computer (Tables 1 and 2).

Television watching

Table 4 and Web Table 1 (available at http://aje.oxfordjournals.org/) show the unadjusted and adjusted calculated mean values for semen parameters and reproductive hormones according to daily hours of television watching. Hours of television watching per day was inversely associated with ejaculate volume, sperm concentration, and total sperm count (all adjusted P values for trend < 0.01). After adjustment for confounders, men who watched television more than 5 hours/day had a mean sperm concentration of 37 million/mL (95% confidence interval (CI): 30, 44), compared with 52 million/mL (95% CI: 43, 62) among men who did not watch any television, and total sperm counts were 104 million (95% CI: 84, 126) and 158 million (95% CI: 130, 189), respectively (Table 4 and Figure 1). Television watching was not associated with sperm motility or morphology (Table 4). The same conclusions were reached on the basis of logistic regression (Web Table 2). Television watching was associated with higher FSH levels (adjusted P-trend = 0.02) and unrelated to inhibin B levels. For the inhibin B/FSH ratio, men who watched television more than 5 hours/day had a borderline significantly lower ratio compared with men who did not watch television (adjusted P = 0.07). Furthermore, testosterone and cFT decreased with more hours of television watching (adjusted P-trend <0.01 for both), but no trends were observed in the levels of LH, SHBG, or estradiol. Thus, testosterone/LH and cFT/LH ratios were lower among men in the higher category of television watching (adjusted P-trend <0.01 for both) while estradiol/testosterone and estradiol/cFT ratios were higher (adjusted P-trend values were 0.07 and 0.03) (Web Table 1 and Figure 2). The effect estimates of television watching were similar regardless of whether results were adjusted for self-rated physical fitness or MET-hours.

Effect modification or mediation by BMI, MET-hours, and self-rated fitness. Neither BMI nor MET-hours modified the association between television watching and sperm counts. Nor did self-rated physical fitness when including a cross-product term (P-interaction was 0.3 for sperm concentration and 0.9 for total sperm count). However, based on stratified analyses, self-rated physical fitness slightly modified the association between television watching and sperm concentration. Overall, men with poor self-rated fitness who were in the highest television-watching category had the lowest semen quality (Figure 3). An analysis that treated these variables as mediators showed that their presence in or absence from the model did not change the estimates for the effect of television watching on sperm concentration.

Table 3. Median Values for Semen Variables in 1,210 Young Men, Denmark, 2008–2012

Semen Parameter	Median	5th to 95th Percentiles	% With Subnormal Fertility[a]
Semen volume, mL	3.3	1.3–6.3	7
Sperm concentration, million/mL	47	4–166	16
Total sperm count, millions	149	14–533	14
Progressively motile spermatozoa, %	58	24–79	9
Morphologically normal spermatozoa, %	7	1–16	23
One or more subnormal semen parameters			38

[a] Subnormal fertility was defined as having a value below the World Health Organization's reference levels (17): volume <1.5 mL, concentration <15 million/mL, total sperm count <39 million, motile spermatozoa <32%, and morphologically normal spermatozoa <4%.

Table 4. Distribution of Semen Variables According to Hours of Daily Television Watching in 1,210 Young Men, Denmark, 2008–2012

Television Watching, hours/day[a]	Volume, mL		Concentration, million/mL		Total Count, millions		Progressively Motile Spermatozoa (A+B[b]), %		Morphologically Normal Forms, %	
	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
Unadjusted										
0[c]	3.3	3.0, 3.6	54	46, 63	174	146, 205	59	56, 62	7.3	6.4, 7.5
0.1–2.5	3.4	3.3, 3.5	47	44, 51	155	143, 168	60	58, 61	6.8	6.4, 6.9
2.6–5.0	3.2	3.0, 3.3	46	42, 50	143[d]	130, 158	58	56, 59	6.4	6.0, 7.3
>5.0	3.0	2.8, 3.3	37[e]	31, 44	113[e]	93, 134	59	56, 62	6.7	5.8, 8.2
P-trend[f]	0.02		<0.01		<0.01		0.4		0.2	
Adjusted										
0[c]	3.1[g,h]	2.8, 3.4	52[g,h]	43, 62	158[g,h]	130, 189	59[g,i]	56, 62	7.3[g,j]	6.3, 8.3
0.1–2.5	3.2[g,h]	3.0, 3.4	47[g,h]	42, 53	149[g,h]	132, 167	60[g,i]	58, 62	6.9[g,j]	6.4, 7.4
2.6–5.0	3.0[g,h]	2.8, 3.1	45[g,h]	40, 51	13[g,h]	115, 149	58[g,i]	56, 60	6.4[g,j]	5.9, 7.0
>5.0	2.9[g,h]	2.6, 3.1	37[e,g,h]	30, 44	104[e,g,h]	84, 126	60[g,i]	57, 63	6.7[g,j]	5.8, 7.7
P-trend[f]	<0.01		<0.01		<0.01		0.4		0.1	

Abbreviation: CI, confidence interval.
[a] Numbers of participants in categories of television watching: 0 hours, $n = 116$; 0.1–2.5 hours, $n = 562$; 2.6–5.0 hours, $n = 400$; >5.0 hours, $n = 132$.
[b] A + B refers to the different speeds of progressively motile spermatozoa.
[c] 0 hours of television watching was the reference group in linear regression analyses.
[d] $P < 0.1$.
[e] $P < 0.05$.
[f] Test for trend was performed by inserting the categorical television variable into the linear regression model, on the assumption that the association was linear.
[g] Results are adjusted for physical fitness self-rated as fair and the absence of cryptorchidism, varicocele, and fever within the previous 3 months.
[h] Results are adjusted for variables listed in footnote g and median abstinence time (62 hours).
[i] Results are adjusted for variables listed in footnote g, body mass index of 20–25, and median time between time of ejaculation and analysis of the sample (35 minutes).
[j] Results are adjusted for variables listed in footnote g and body mass index of 20–25.

Subanalysis of diet. For 673 men, we had more detailed information on energy consumption. A subanalysis of these data showed that differences in total energy consumption and the proportions of macronutrients in the diet (total fat, saturated fat, protein, and carbohydrates) did not explain the differences in semen parameters for different categories of television watching. Intake of saturated fat did, however, remove some of the association (approximately 7%; data not shown).

Computer use

When television and computer time were combined into a single exposure variable (screen time), a significant trend of decreasing sperm count with increasing screen time was detected. However, the effect estimates were much lower than for the television variable alone. Computer time analyzed separately from television time showed no association, either with any semen variables or with reproductive hormones (Figure 1).

Physical activity

Self-rated physical fitness was associated with testicular function when adjusted for television time, but MET-hours was not. Men who rated their fitness as poor had significantly lower sperm concentrations (36 million/mL; 95% CI: 29, 44) and total sperm counts (117 million; 95% CI: 94, 143) than men with good self-rated fitness (50 million/mL (95% CI: 46, 55) and 160 million (95% CI: 146, 176), respectively; adjusted $P < 0.01$ for differences) (Table 5). After adjustments, compared with men who rated their fitness as good, men with poor self-rated fitness also had lower testosterone levels (adjusted $P = 0.049$), testosterone/LH ratios (adjusted $P < 0.01$), and SHBG levels (adjusted $P < 0.01$), and they had higher estradiol/testosterone ratios (adjusted $P = 0.04$) (Web Table 3).

The total of moderate and vigorous MET-hours was unrelated to both semen quality and reproductive hormones, except for SHBG (Web Tables 4 and 5), which was significantly higher in the fourth quartile compared with the first (adjusted $P = 0.03$) and showed a significant trend of increasing SHBG across the 4 quartiles of physical activity (adjusted *P*-trend = 0.03). Including light physical activity in the calculation of MET-hours did not alter the results.

DISCUSSION

In this large study of young men, we detected some negative associations between a sedentary lifestyle and testicular function. In particular, television watching was associated

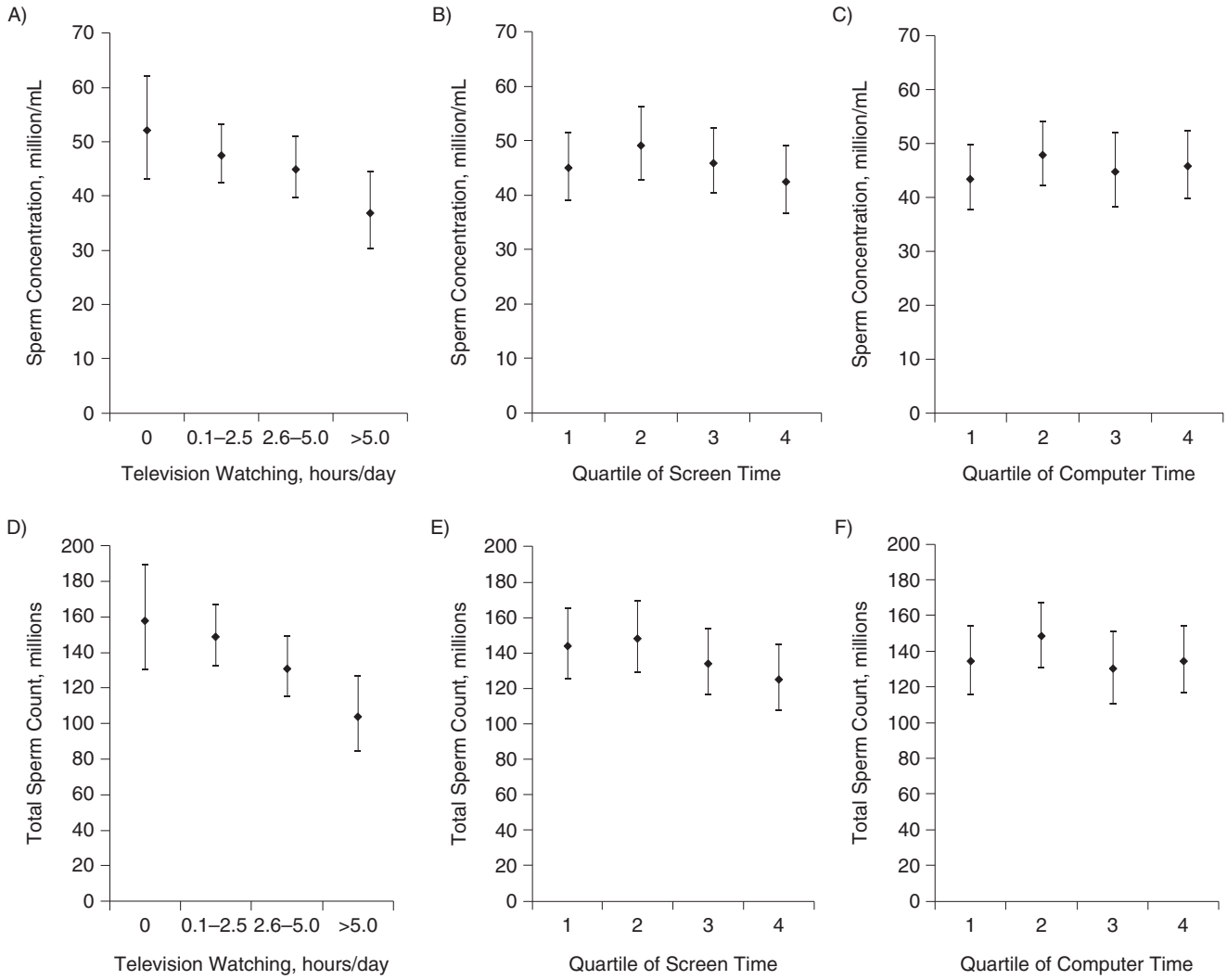

Figure 1. Association between television watching alone (left panels), total screen time (television watching and computer time combined; middle panels), and computer time alone (right panels) and sperm concentration (upper row) and total sperm count (lower row) in 1,210 young men, Denmark, 2008–2012. Numbers of participants in categories of television watching: 0 hours, $n = 116$; 0.1–2.5 hours, $n = 562$; 2.6–5.0 hours, $n = 400$; >5.0 hours, $n = 132$. Results are presented as means adjusted for physical fitness self-rated as fair, median abstinence time (62 hours), and the absence of cryptorchidism, varicocele, and fever during the previous 3 months. A) P-trend < 0.01; B) P-trend = 0.4; C) P-trend = 0.8; D) P-trend < 0.01; E) P-trend < 0.01; F) P-trend = 0.6. Bars, 95% confidence intervals.

with reduced sperm counts. The higher FSH level observed with more television watching was consistent with our finding of adversely affected spermatogenesis, and lower testosterone levels suggested reduced Leydig cell function. It is noteworthy that we detected a positive association between television watching and several indicators of unhealthy lifestyle. Thus, it is possible that the observed association between television watching and semen quality was due to residual confounding by uncovered lifestyle factors, although there is substantial evidence that sedentary behavior per se is unhealthy. Nevertheless, the mechanisms relating television watching to impaired spermatogenesis are unknown. Sitting may increase scrotal temperature, thereby disrupting spermatogenesis (23), but this is unlikely to be the cause; we did not observe the same associations with use of computers as with television time. In the literature on sedentary behavior, it has been increasingly recognized that the domain of sitting is complex and related to different health effects. Therefore, viewing sedentary behavior as a single exposure may not be appropriate (24–27), and this seems to be the case for associations with testicular function as well. Studies focusing on other health effects, such as cardiometabolic risk and muscle strength, have found the same trend of detrimental effects of television watching as opposed to computer use (13, 28, 29), and some studies even showed a positive effect of the latter (30).

The finding of a positive impact of moderate levels of physical activity on semen quality, reported in other studies (11, 31,

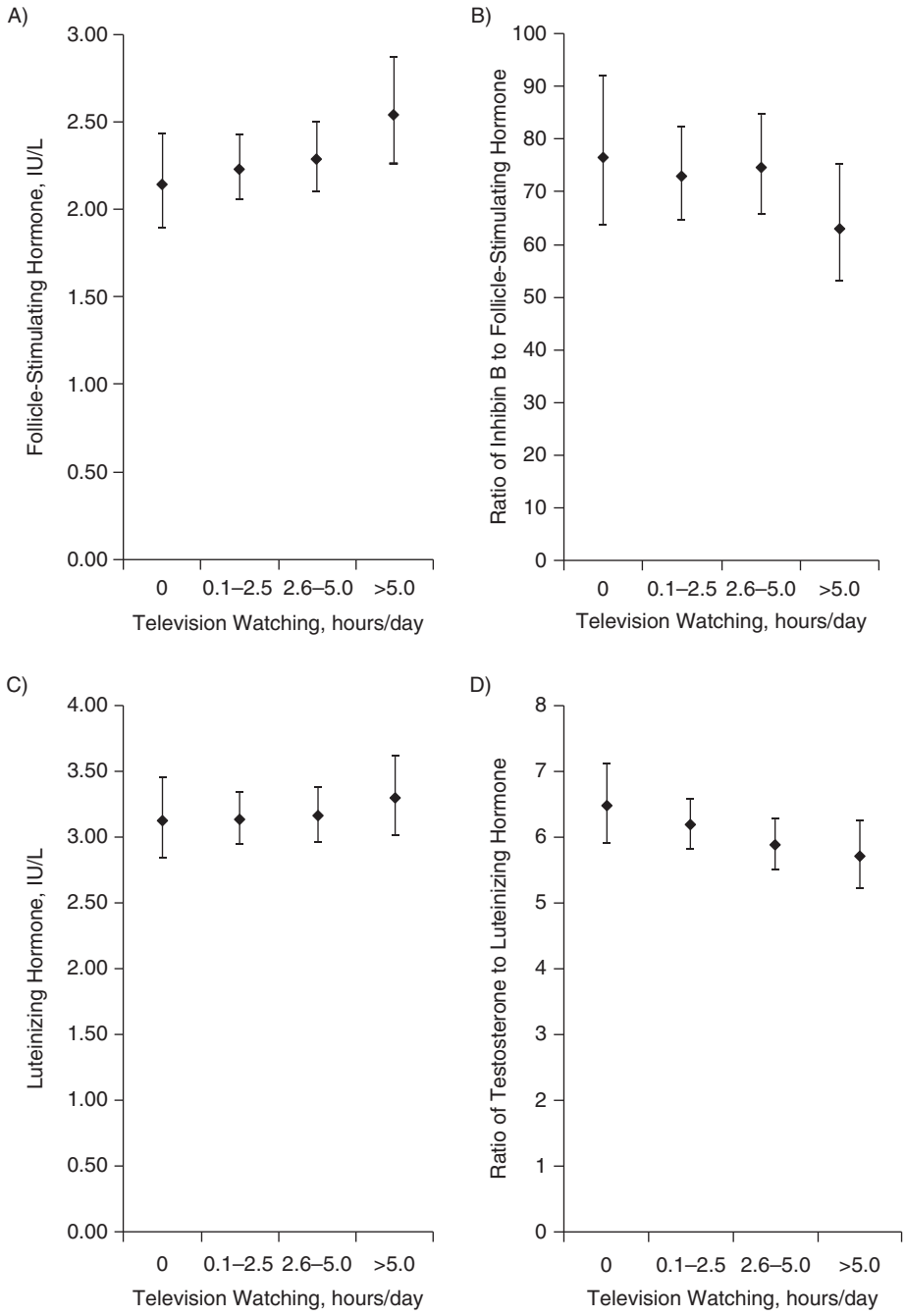

Figure 2. Association between television watching and levels of selected hormones and hormone ratios in 1,183 young men, Denmark, 2008–2012. Numbers of participants in categories of television watching: 0 hours, $n = 112$; 0.1–2.5 hours, $n = 552$; 2.6–5.0 hours, $n = 393$; >5.0 hours, $n = 126$. Results are presented as means adjusted for physical fitness self-rated as fair, BMI of 20–25, nonsmoking status, median alcohol intake (10.5 units/week), median blood sampling time (9:55 AM), and the absence of cryptorchidism, varicocele, and fever during the previous 3 months. A) P-trend = 0.02; B) P-trend = 0.2; C) P-trend = 0.3; D) P-trend < 0.01. Bars, 95% confidence intervals.

32), was only partially replicated in our study, which showed an association with self-rated physical fitness but not with calculated MET-hours. The range of the variable measuring moderate and vigorous physical activity in our study was quite similar to that reported for a US population (cutpoints for MET-hours quartiles in our study vs. the US study: 23 vs. 25, 38 vs. 45, and 60 vs. 71 (11)). A recent study in a comparable population of young Spanish men also did not find level of physical activity to be related to parameters of semen quality (33). We did not have information on the type

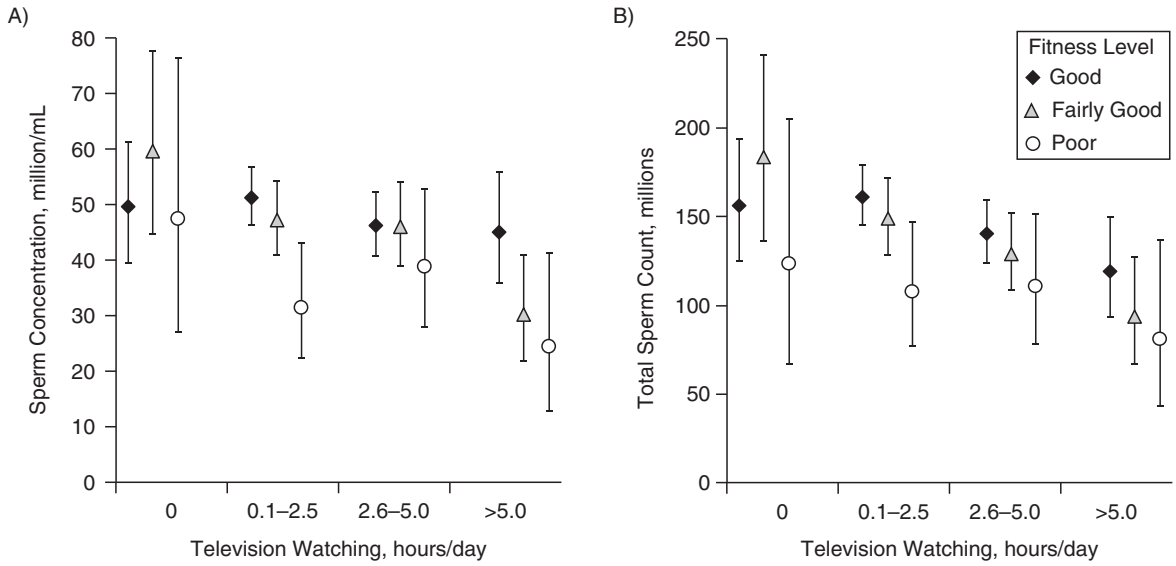

Figure 3. Effect of modification of self-rated physical fitness on the association between television watching and both sperm concentration and total sperm count in 1,204 young men, Denmark, 2008–2012. Numbers of participants in categories: good fitness combined with television watching of 0 hours/day, $n = 68$; 0.1–2.5 hours/day, $n = 346$; 2.6–5.0 hours/day, $n = 233$; >5.0 hours/day, $n = 70$; fair fitness combined with television watching of 0 hours/day, $n = 36$; 0.1–2.5 hours/day, $n = 173$; 2.6–5.0 hours/day, $n = 129$; >5.0 hours/day, $n = 47$; poor fitness combined with television watching of 0 hours/day, $n = 12$; 0.1–2.5 hours/day, $n = 39$; 2.6–5.0 hours/day, $n = 36$; >5.0 hours/day, $n = 15$. Results are presented as means adjusted for nonsmoking status, median abstinence time (62 hours), and the absence of varicocele, cryptorchidism, and fever in the previous 3 months. A) Among participants with good self-rated fitness: *P*-trend = 0.2; with fair self-rated fitness: *P*-trend < 0.01; with poor self-rated fitness: *P*-trend = 0.2. B) Among participants with good self-rated fitness: *P*-trend = 0.2; with fair self-rated fitness: *P*-trend < 0.01; with poor self-rated fitness: *P*-trend = 0.2. Bars, 95% confidence intervals.

Table 5. Distribution of Semen Variables According to Self-Rated Physical Fitness in 1,204 Young Men, Denmark, 2008–2012

Self-Rated Physical Fitness[a]	Semen Volume, mL		Sperm Concentration, million/mL		Total Sperm Count, millions		Progressively Motile Spermatozoa (A + B[b]), %		Morphologically Normal Forms, %	
	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
Unadjusted										
Poor	3.3	3.0, 3.6	35[c]	29, 43	115[c]	93, 140	57	53, 60	6.9	6.0, 7.9
Fair	3.2	3.1, 3.4	46	41, 50	144	131, 159	60	58, 61	6.9	6.4, 7.4
Good[d]	3.3	3.2, 3.4	48	45, 52	155	145, 167	59	56, 60	6.6	6.3, 7.0
P-trend[e]	0.8		0.007[c]		0.007[c]		0.7		0.3	
Adjusted										
Poor	3.3[f,g]	3.0, 3.6	36[c,f,g]	29, 44	117[c,f,g]	94, 143	59[f,h]	56, 62	6.9[f,i]	5.9, 8.1
Fair	3.2[f,g]	3.0, 3.4	47[f,g]	42, 53	149[f,g]	132, 167	58[f,h]	56, 60	7.1[f,i]	6.5, 7.8
Good[d]	3.2[f,g]	3.1, 3.4	50[f,g]	46, 55	160[f,g]	146, 176	60[f,h]	57, 63	6.9[f,i]	6.4, 7.4
P-trend[e]	0.9		0.002[c]		0.003[c]		0.5		0.7	

Abbreviation: CI, confidence interval.

[a] Numbers of participants in categories of self-rated physical fitness: poor, $n = 102$; fair, $n = 385$; and good, $n = 717$.

[b] A + B refers to the different speeds of progressively motile spermatozoa.

[c] Differences at significance level $P < 0.05$.

[d] Fitness self-rated as good was the reference group in linear regression analyses.

[e] Test for trend was performed by inserting the categorical self-rated physical fitness variable into the linear regression model, on the assumption that the association was linear.

[f] Results are adjusted for 0.1–2.5 hours/day of television watching and the absence of cryptorchidism, varicocele, and fever within the previous 3 months.

[g] Results are adjusted for variables in footnote f and median abstinence time (62 hours).

[h] Results are adjusted for variables in footnote f, body mass index of 20–25, and median time between time of ejaculation and analysis of the sample (35 minutes).

[i] Results are adjusted for variables in footnote f and body mass index of 20–25.

of physical activity, which would be relevant—physical activity overall might obscure type-specific associations (32).

The reason for the discrepancy between our results according to calculated physical activity score and those according to self-rated fitness is unknown; the MET-hours increased with higher categories of self-rated physical fitness, and this was also true within the categories of television watching. Furthermore, the association between MET-hours and SHBG indicates higher insulin sensitivity among the men with higher MET levels, consistent with their being more physically active.

Although the results of the present study seem robust and partly in accordance with previous literature, some limitations warrant mention. The cross-sectional design leaves open the possibility of reverse causation; men with poorer testicular function might be lacking energy due to lower testosterone levels and thus be more inclined to engage in sedentary behaviors, including television watching. However, from a clinical perspective the men were not testosterone-deficient. In addition, the exposure information was obtained by self-report, leaving a chance of misclassification. Because the men were not aware of their semen quality, this is unlikely to have introduced systematic bias. Although it is unlikely to have been a major problem in our data, which date back to 2008–2012, distinguishing between television watching and computer use is becoming more difficult, because access to streaming services is increasing, and in our study watching television on the computer would have been classified as computer time. How this could have affected our results is not clear. Computer time included both work-related and leisure-time computer use and might therefore have been less accurately recalled than television time, which is more limited to leisure time, and that might explain the lack of association with testicular function. In addition, residual confounding by factors related to television time may be present. BMI was used as a marker of body fat. However, this might not be sufficient in a population of young men with a wide variation in body composition. Overall, the results are likely generalizable to the general population of men in Denmark, but clinical implications with regards to fertility were not addressed by the present study.

A strength of the study is that it was based on a large sample of healthy volunteers who, for the most part, had no knowledge of their fertility potential. In addition, we had detailed information on a variety of lifestyle risk factors and thus could distinguish between two sedentary behaviors, television watching and computer time—both exposures covering a wide range from none to many hours per day.

In conclusion, we detected some evidence that sedentary behavior, particularly many hours of television watching, was associated with poorer testicular function, even among men who were physically active. The findings should be of public concern, because it is common among young men to spend many hours watching television.

ACKNOWLEDGMENTS

Author affiliations: University Department of Growth and Reproduction, Rigshospitalet, Faculty of Medical and Health Sciences, University of Copenhagen, Copenhagen, Denmark (Lærke Priskorn, Tina Kold Jensen, Anne Kirstine Bang, Loa Nordkap, Ulla Nordström Joensen, Tina Harmer Lassen, Inge Ahlmann Olesen, Niels E. Skakkebaek, Niels Jørgensen); Environmental Medicine Unit, Department of Public Health, University of Southern Denmark, Odense, Denmark (Tina Kold Jensen); and Department of Preventive Medicine, Icahn School of Medicine at Mount Sinai, New York, New York (Shanna H. Swan).

This study was supported by the Research Fund of Rigshospitalet (grant R42-A1326 to N. J.). The background studies of young men have been supported economically by several grants, from the European Union (FP7/2007–2013, DEER grant 212844), the Danish Ministry of Health, and the Danish Environmental Protection Agency.

None of the sponsors had any involvement in the study design or data analysis.

Conflict of interest: none declared.

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