

Grøntved, A., Ried-Larsen, M., Froberg, K., Wedderkopp, N., Brage, S., Kristensen, P. L., Andersen, L. B., Møller, N. C. (2013). Screen time viewing behaviors and isometric trunk muscle strength in youth. *Medicine & Science in Sports & Exercise*, 45, 1975-1980.

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Title

Screen time viewing behaviors and isometric trunk muscle strength in youth

Authors

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Running title: Screen time viewing and trunk muscle strength

Conflicts of Interest and Source of Funding: None declared. This work was supported by The Danish Heart Foundation; the Danish Health Fund (Sygekassernes Helsefond).

Abstract

Purpose

To examine the association of screen time viewing behavior with isometric trunk muscle strength in youth.

Methods

A cross-sectional study was carried out including 606 adolescents (14-16-years old) participating in the Danish European Youth Heart Study; a population-based study with assessments conducted in either 1997/98 or 2003/04. Maximal voluntary contractions during isometric back extension and abdominal flexion were determined using a strain-gauge dynamometer, and cardiorespiratory fitness (CRF) was obtained using a maximal cycle ergometer test. Television (TV) viewing time, computer use, and other lifestyle behaviors were obtained by self-report. Analyses of association of screen use behaviors with isometric trunk muscle strength were carried out using multivariable adjusted linear regression.

Results

Mean (SD) isometric strength was 0.87 (0.16) N/kg. TV viewing, computer use, and total screen time use were inversely associated with isometric trunk muscle strength in analyses adjusted for lifestyle and socio-demographic factors. After further adjustment for CRF and waist circumference, associations remained significant for computer use and total screen time but TV viewing were only marginally associated with muscle strength after these additional adjustments (-0.05 (95% CI -0.11;0.005) SD difference in strength per 1 hours/day difference in TV viewing time, $p=0.08$). Each 1 hour/day difference in total screen time use was associated with -0.09 SD (95% CI -0.14;-0.04) lower isometric trunk muscle strength in the fully adjusted model ($p=0.001$). There were no indications that the association of screen time use with isometric trunk muscle strength was attenuated among highly fit individuals ($p=0.91$ for CRF by screen time interaction).

Conclusions

Screen time use was inversely associated with isometric trunk muscle strength independent of CRF and other confounding factors.

Keywords: Fitness, television, computer, adolescents, sedentary

Introduction

Paragraph Number 1 Television (TV) viewing and computer use - two very common sedentary behaviors among youth - are usually performed in a seated or lying posture for longer periods of time. The number of daily switches between seated/lying and standing/walking positions is likely to be affected by excessive time spent on these viewing behaviors. Thus, besides displacing time spent on physical activity, excessive screen time use may also influence posture allocation, which could explain part of the adverse health effects of screen time viewing reported on outcomes such as type 2 diabetes, cardiovascular diseases, premature mortality, and its biological risk factors (5, 8, 9, 24). A number of previous studies have shown that prolonged screen time viewing in childhood or youth may lead to poorer cardiorespiratory fitness (CRF) later in life independent of the level of physical activity and other determinants of CRF (12, 18). However, time spent in the seated or lying posture, a reduced number of posture transitions, and less time spent on physical activity as a result of excessive viewing time could also influence muscle strength, in particular trunk muscle strength. To further explore whether screen time viewing behaviors influence trunk muscle strength, we examined the association of screen time behaviors with abdominal and back isometric strength in a population sample of Danish youth with adjustment for potential confounding factors such as CRF.

Methods

Design

Paragraph Number 2 This study was cross-sectional and used data from the Danish EYHS, an international population-based multicenter study that addresses cardiovascular disease (CVD) risk factors in children and adolescents (21). For this particular investigation, the eligible participants were 429 adolescents from the assessment wave in 1997-98, and 444 adolescents from the 2003-04 wave. In 1997-98, a sub-group of 243 participants had isometric muscle strength assessed, and in 2003-04 n=441 had isometric muscle strength evaluated. The local scientific ethics committee approved the study and all participants gave informed consent to participate.

Television, computer use, and total screen time viewing

Paragraph Number 3 TV viewing and computer use during leisure was obtained by self-report using a computer-based questionnaire (9). Two questions were asked about the amount of time viewing TV (before and after school). From these two questions a summary variable of daily TV viewing time variable was constructed (hours/day). Daily time spent using computer was asked in one question. A total screen time variable (hours/day) was created by summarizing TV and computer use.

Muscle strength

Paragraph Number 4 Isometric muscle strength was obtained during maximal voluntary contraction (MVC) of abdominal and back muscles using a strain-gauge dynamometer (1). The participants were standing upright and positioned with a strap around the shoulders connected to the dynamometer. Abdominal MVC was performed with the back against the dynamometer performing maximal forward flexion. For MVC of the lower back muscles, the participants were positioned with the front against the dynamometer performing maximal backward extension. We expressed total isometric trunk muscle strength (Newton (N)) as the mean of abdominal- and back strength relative to body weight (in N/kg). Previous studies have reported a high reliability of these particular isometric strength measures in adults (intraclass correlation coefficient > 0.9) (6).

Cardiorespiratory fitness

Paragraph Number 4 We assessed CRF during a progressive maximal ergometer bicycle test (Ergomedic 839; Monark, Varberg, Sweden) (21). Heart rate (HR) was recorded every 5 s during the test using a HR monitor (Polar Vantage, Finland). Criteria for a maximal effort were HR of 185 beats per minute or greater, and a subjective judgment by the observer that the participant could no longer continue, even after verbal encouragement. Maximal power output (wattmax) was used to estimate maximal oxygen uptake using the following equation $VO_2\text{-max (ml O}_2\text{/min/kg)} = 0.465 + (0.0112 * \text{wattmax}) + (0.172 * \text{gender}) / \text{kg body weight}$, where gender is boys=1 and girls=0 (15). The fitness measure is highly reproducible (coefficient of variation 2.5-4.8%) and a previous validation study among 15-year olds have shown that this measure is highly correlated with directly measured $VO_2\text{-max}$ ($r > 0.90$, $P < 0.001$) (2).

Other covariates

Paragraph Number 5 Height and weight were measured while the participants were wearing light clothing, without shoes, using standard anthropometric procedures. Waist circumference (WC) was measured to the nearest 1 mm at the midpoint between the lower ribs and the iliac crest with a flexible tape. Smoking status (yes/no), monthly frequency soft drinks, fruit, and vegetable intake were obtained by self-report in adolescence using a computer-based questionnaire as describes previously (21). Parental educational level was obtained by parental self-report. Parental

educational status was defined according to the International Standard Classification of Education (ISCED) (UNESCO 1997). However, as the details obtained of the description of education were insufficient, the ISCED seven-point scale was combined into 3 new groups (I=level 1-2; II=level 3-4; and III=level 5-7). Moderate and vigorous physical activity (MVPA) was assessed using accelerometry with data reduction as described previously (17). Specifically, an accelerometer output >2000 counts/min (equivalent to walking about 4 km/h) was defined as MVPA and expressed as percentage of total registered time.

Statistics

Paragraph Number 6 Associations of TV viewing, computer use, and total screen time use with isometric trunk muscle strength (standardized score (SD)) was analyzed using multivariable adjusted linear regression. Initially, we ran models adjusting for age, sex, recruitment wave, parental educational status, smoking status, intake of soft drinks, and fruit- and vegetable intake. We then ran analyses with additional adjustment for CRF and waist circumference. We also ran a multivariable adjusted model including both TV viewing and computer use in the same model to assess whether both types of screen-based behavior were associated with isometric trunk muscle strength, independent of each other.

Paragraph Number 7 We also examined the association of screen time use with isometric trunk muscle strength by CRF level, parental educational level, and sex. Interaction between screen time and these factors were examined by including interaction terms with main effects included in the multivariable models.

Paragraph Number 8 In sensitivity analyses, we additionally adjusted for accelerometry-measured MVPA to examine if any residual confounding by physical activity remained that CRF may not have captured. Because 37% of the participants with otherwise full data had missing information on accelerometer measured MVPA, we imputed missing values on MVPA using a multiple linear regression imputation approach ("mi impute" in STATA) including all covariates and the outcome. We obtained beta coefficients and standard errors (SE) based on 20 imputed datasets while the variability between imputations is adjusted for (22).

Paragraph Number 9 All statistical analyses were performed in STATA 12.1 with alpha=0.05 (two-sided).

Results

Paragraph Number 10 The present study included a total of 606 14-16 year old adolescents of whom 205 were recruited in 1997/98 and 401 in 2003/04. Table 1 shows selected characteristics of the included participants in the present study compared with participants excluded due to missing data (n=267). There were no difference between included participants and individuals with missing data in majority of characteristics, except for age, gender, and TV viewing time. Individuals with missing data were slightly older, viewed more TV and the percentage of boys compared to girls was lower (Table 1). The mean screen time was 2.8 hours/day among boys and 1.8 hours/day among girls participating in the study. The Spearman correlation coefficient between TV viewing and computer use was 0.10 (p=0.02).

Paragraph Number 11 The associations of television viewing, computer use, and total screen time with isometric trunk muscle strength in youth are shown in Table 2. In basic multivariable adjusted models without adjustment for CRF and waist circumference, all screen time behaviors were significantly associated with abdominal-, back-, and total isometric trunk muscle strength. After further adjustment for fitness and waist circumference, associations of computer use and total screen time use were moderately attenuated but were still associated with both abdominal, back, and total isometric trunk muscle strength (p<0.05). Each 1 hour/day difference in total screen time was associated with -0.09 (95%CI -0.14;-0.04) SD difference in isometric trunk muscle strength in fully adjusted analysis. TV viewing was marginally associated with total isometric trunk muscle strength in fully adjusted models (-0.05 (95%CI -0.11;0.005) SD difference in strength per 1 hours/day difference in viewing time, p=0.08). There was no indications that screen time was non-linearly associated with isometric trunk muscle strength, either based on visual inspection (Figure 1) or based on statistical evaluation by including a quadratic term of total screen time in the fully adjusted multivariable model (p=0.12). Results were unaltered when adjusting the analyses for waist-to-height ratio or BMI instead of waist circumference (data not shown). Additional adjustment for accelerometer measured MVPA did not alter the associations; each 1 hour/day difference in total screen time was associated with -0.08 (95%CI -0.13;-0.03) SD difference in isometric trunk muscle strength in fully adjusted analysis including waist circumference and CRF. When we included TV viewing and computer use in the model, the estimates of association with isometric trunk muscle strength was close to similar compared with the analyses of each viewing type analyzed separately ($\beta_{\text{computer}}=-0.18$ (95%CI -0.27;-0.08) SD, $\beta_{\text{TV}}=-0.05$ (95%CI -0.11;0.008) SD, p=0.09). We also examined if isometric trunk muscle strength was different according to achievement of youth recommendations for screen time (≤ 2 hours/day). Adolescents not exceeding the recommended levels for screen time (4, 25) had -0.18 (95%CI -0.32;-0.04) SD difference in isometric trunk muscle strength, compared with adolescents achieving recommendations (p=0.01).

Paragraph Number 12 We also analyzed the association of screen time with CRF adjusting for the same covariates including total isometric trunk muscle strength and waist circumference. Each 1 hour/day difference in total screen time was associated with -0.04 (95%CI -0.08;-0.01) SD difference in CRF in this analysis (p=0.02).

Paragraph Number 13 We then ran analyses of the association of total screen time with total isometric trunk muscle strength stratified by sex-specific quartiles of CRF, parental educational level, and sex (Figure 2). In these analyses, we did not see statistical evidence of interaction between these factors and screen time (p>0.3 for all interactions).

Discussion

Paragraph Number 14 In this cross-sectional study of a population sample of Danish youth excessive screen time behaviors were associated with lower isometric trunk muscle strength. Importantly, these inverse associations were independent of CRF, general or abdominal adiposity, and other lifestyle- and socio-demographic factors. Furthermore, we did not see any indication that the association of screen time use with muscle strength was attenuated among high-fit individuals, which suggests that limiting screen time use could be beneficial for improving or maintaining isometric trunk muscle strength even among cardiorespiratory fit individuals. Because daily excessive time spent in a seated or lying position is likely to reduce exposure to postures requiring greater muscle tone and potentially also posture transitions, this could explain these inverse associations. We adjusted our analyses for CRF to capture current- and long-term engagement in physical activity, which undoubtedly is an important confounder in the relation of screen time exposure with muscle strength. We cannot rule out that residual confounding remain for CRF and physical activity as excessive computer use and TV viewing are associated with other unhealthy behaviors including concomitant intake of unhealthy foods, as well as TV advertisements and TV/computer content may influence other unhealthy behaviors. Thus, it could be that the inverse associations of these viewing behaviors with isometric trunk muscle strength are explained by factors, which we have not fully adjusted for.

Paragraph Number 15 We are aware of only one other study examining the association of screen time and isometric trunk muscle strength. Our study is in agreement with a cross sectional study among Finnish young adults that reported an inverse association of TV viewing with isometric trunk muscle strength assessed using similar procedures (19). These associations were reported being independent of self-reported “brisk” physical activity and smoking status but were not adjusted for CRF and other lifestyle- and socio-demographic factors. Furthermore, the evaluation did not include computer use nor make sequential adjustment for adiposity, so it is not unlikely that reported associations have a larger degree of confounding by adiposity and other unmeasured factors associated with young adult lifestyle. The observations from our study are also supported by findings from a prospective study of Canadian toddlers followed until 2nd grade (7). In that study, increases in parentally reported TV viewing time between the age of 2.5 and 4.5 years predicted shorter long jump performance at 8 years of age independent of parentally reported physical activity, and other characteristics including child weight status at follow-up. Finally, two cross-sectional studies carried out in the 1970s and early 1980s have reported inverse associations of TV viewing time with components of muscle strength and fitness (14, 26).

Paragraph Number 16 We are not aware of randomized trials examining the effect of reducing any type of sedentary behavior including screen-based behaviors on muscle strength. However, a small scale randomized trial have examined the effect of changing school furniture to adjustable desks and chairs with sitting trunk–thigh angle adjusted to 135° compared with traditional school desks and chairs with sitting trunk–thigh angle of 90° for a period of 2 years among high school student. This study found that the intervention increased abdominal- and back muscle strength (16). These results supports the notion that specific postures while sitting are important for development or maintaining of trunk muscle strength. We have previously reported that low isometric MVC of the trunk and prolonged screen time use in youth are associated with greater adiposity, insulin resistance, and raised levels of other cardiovascular risk factors in young adulthood independent of CRF (10, 11). Thus, limiting screen time use or introducing more standing while engaging in screen time could be important targets for maintaining isometric trunk muscle strength and subsequently in preventive measures against development of insulin resistance and other metabolic abnormalities later in life. Clearly more evidence from experimental studies is needed on this topic to infer, with

greater confidence, that these associations are causal and to test the effectiveness of interventions such as standing desks on physical fitness and other health outcomes.

Paragraph Number 17 The major strength of the study was that we were able to adjust our analyses for a range of important confounding factors including CRF. Furthermore, we assessed isometric trunk muscle strength using a highly reliable method. We were also able to examine both TV viewing time and computer use separately, which are two analogous behaviors in the sense that both behaviors are usually performed seated or in a lying position and likely to reduce exposure to posture requiring greater muscle tone. Since associations with isometric trunk muscle strength for both type of viewing behavior were unaffected by mutual adjustment, this strengthens the inference that posture allocation or sitting/lying time explains the associations. Besides the possibility that residual and unknown confounding could explain the results, there are some additional limitations to the study. The inverse associations of screen time use and muscle strength could also be a result of reverse-causality, i.e. screen time use increases as a result of poor strength. As our study was cross sectional we could not tease out the extent of this possible reverse causation bias. Although we did not see a sex-by-screen time use interaction on muscle strength, sex stratified analyses indicated that associations were less strong for girls and larger studies are needed to further examine this. Furthermore, the assessments of screen time viewing behaviors were based on self-report, and we cannot rule out the possibility of recall bias (i.e. that screen time use is over- or underestimated dependent on the level of isometric trunk muscle strength). Reliability of self-reported screen use among adolescents has been reported moderate to excellent (13, 20, 23, 27), and validity against diary as the criterion measure has been reported moderate (23, 27). Evaluations have also been carried out against accelerometer assessed total sedentary time among youth, and these studies suggest that self-reported TV viewing is a poor measure of total sedentary time, although some method disagreement would stem from inability of the accelerometer to correctly classify all sedentary time (3). In addition, while the isometric muscle strength assessment procedures are very reliable in adults, we did not evaluate reliability of the tests in youth, which remains to be determined.

Paragraph Number 18 In summary, in a population sample of Danish youth screen time use was inversely associated with isometric trunk muscle strength independent of CRF, lifestyle behaviors, adiposity, and socio-demographic factors. Further studies are needed to disentangle whether the prolonged time spent in a seated or lying position and possibly fewer posture allocations are driving this association, which would therefore be important behavioral intervention targets for maintaining trunk muscle strength.

Acknowledgements

This work was supported by The Danish Heart Foundation; the Danish Health Fund (Sygekassernes Helsefond). The results of the present study do not constitute endorsement by American College of Sports Medicine. The authors declare no conflicts of interest.

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Table 1. Characteristics of the study population by gender and attrition analyses.

Characteristics	Boys (n=292)	Girls (n=314)	Total participants (n=606)	Individuals with missing data (n=200-267)	P*
Sex (% boys)	-	-	48.2	40.1 (n=267)	<0.01
Age (years)	15.6 (0.4)	15.6 (0.4)	15.6 (0.4)	15.7 (0.4) (n=267)	<0.01
BMI (kg/m ²)	21.0 (2.7)	21.1 (2.9)	21.0 (2.8)	21.0 (2.9) (n=267)	0.51
Waist circumference (cm)	74.5 (7.7)	71.1 (6.7)	72.8 (7.4)	70.0 (6.9) (n=266)	0.59
Abdominal strength (N/kg)	0.91 (0.18)	0.71 (0.14)	-	-	-
Back strength (N/kg)	0.98 (0.17)	0.88 (0.17)	-	-	-
Cardiorespiratory fitness (ml O ₂ /min/kg)	50.3 (6.8)	41.7 (5.6)	45.8 (7.5)	46.2 (8.2) (n=200)	0.10
Television viewing (hours/day)	1.8 (1.2)	1.5 (1.1)	1.6 (1.1)	1.8 (1.2) (n=255)	0.02
Computer use (hours/day)	1.1 (0.8)	0.3 (0.5)	0.6 (0.8)	0.5 (0.6) (n=255)	0.17
Soft drinks intake (servings/month)	13.1 (9.6)	7.4 (7.8)	10.1 (9.1)	10.9 (9.3) (n=255)	0.65
Fruit and vegetable intake (servings/month)	33.3 (17.4)	42.4 (16.6)	38.0 (17.6)	37.0 (16.8) (n=255)	0.64
Parental education level (% 1 / 2 / 3)**	12.7 / 32.2 / 55.1	10.8 / 28.0 / 61.2	11.7 / 30.0 / 58.3	14.7 / 31.2 / 54.1 (n=231)	0.49
Smoking status (%)	22.6	17.5	20.1	27.5 (n=255)	0.17

Data are means (SD) or numbers (%). N=Newton.

*p-value for difference between participants and individuals with missing data adjusted for sex (except for analysis of sex-difference) and recruitment period.

**Based on educational level (International Standard Classification of Education (ISCED, UNESCO 1997), I=basic education; II=secondary or post-secondary education; and III=tertiary education).

Table 2. Association of television viewing, computer use, and total screen time viewing (hours/day) with isometric trunk muscle strength (SD) in youth.

	Model 1		Model 2		Model 3	
	Beta (95% CI)	p	Beta (95% CI)	p	Beta (95% CI)	p
Screen time variables						
Abdominal muscle strength						
Television viewing (hours/day)	-0.09 (-0.15;-0.03)	0.004	-0.05 (-0.11;0.004)	0.07	-0.06 (-0.11;0.002)	0.06
Computer use (hours/day)	-0.20 (-0.30;-0.11)	<0.001	-0.19 (-0.28;-0.10)	<0.001	-0.19 (-0.29;-0.10)	<0.001
Total screen time use (hours/day)	-0.12 (-0.17;-0.07)	<0.001	-0.09 (-0.14;-0.04)	<0.001	-0.10 (-0.14;-0.04)	<0.001
Back muscle strength						
Television viewing (hours/day)	-0.09 (-0.16;-0.02)	0.01	-0.04 (-0.10;0.03)	0.25	-0.04 (-0.10;0.02)	0.22
Computer use (hours/day)	-0.14 (-0.25;-0.03)	0.01	-0.12 (-0.22;-0.02)	0.02	-0.13 (-0.23;-0.03)	0.01
Total screen time use (hours/day)	-0.10 (-0.16;-0.04)	0.001	-0.06 (-0.11;-0.007)	0.03	-0.06 (-0.12;-0.01)	0.02
Total trunk muscle strength						
Television viewing (hours/day)	-0.10 (-0.16;-0.03)	0.003	-0.05 (-0.11;-0.008)	0.09	-0.05 (-0.11; 0.005)	0.08
Computer use (hours/day)	-0.19 (-0.30;-0.09)	<0.001	-0.18 (-0.27;-0.08)	<0.001	-0.18 (-0.27;-0.08)	<0.001
Total screen time use (hours/day)	-0.12 (-0.17;-0.07)	<0.001	-0.08 (-0.13;-0.03)	0.001	-0.09 (-0.14;-0.04)	0.001

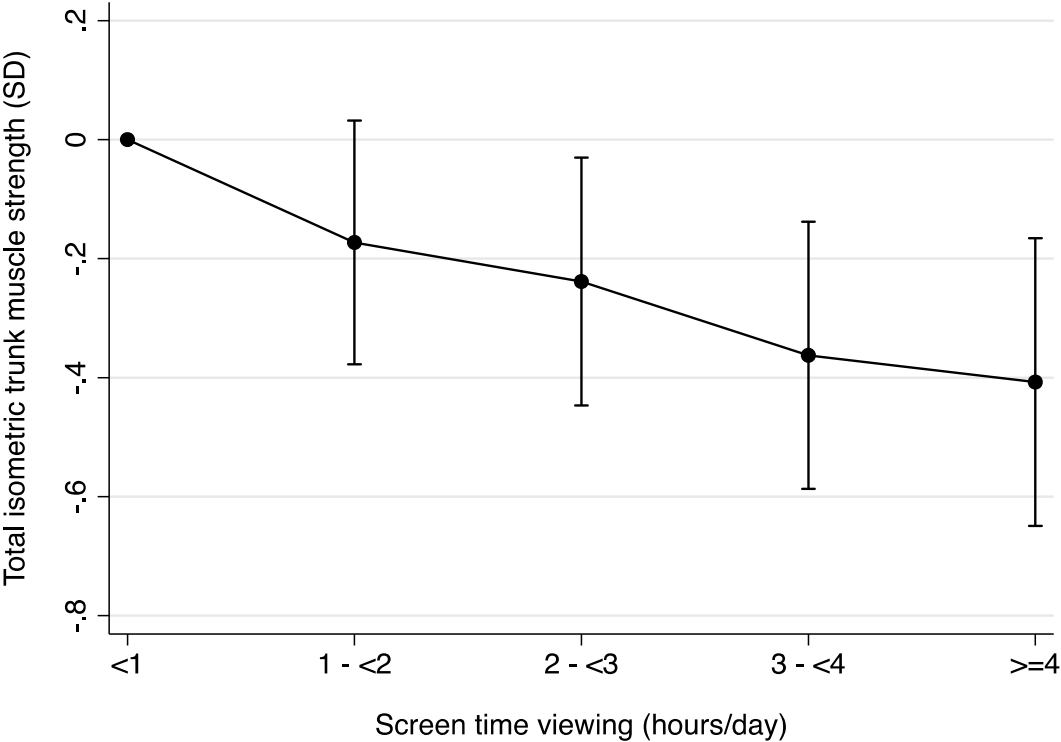
Beta coefficient (95% CI) represents change in youth isometric muscle strength (SD, 0.16 Newton/kg) per 1 hours/day difference in screen time viewing.

Model 1 was adjusted for age, sex, recruitment period, parental education level, smoking status, intake of soft drinks, fruit- and vegetable intake.

Model 2 was additionally adjusted for cardiorespiratory fitness.

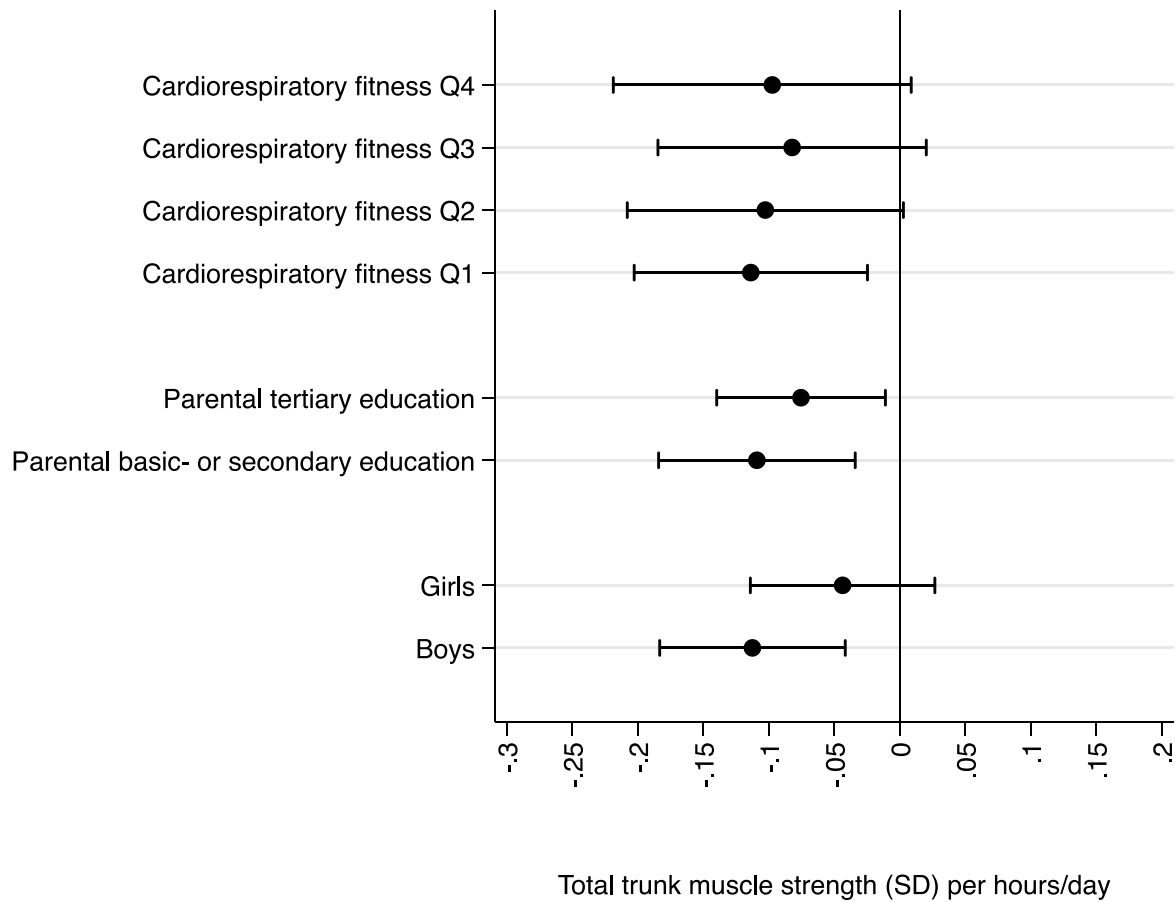
Model 3 was additionally adjusted for waist circumference.

Figure 1. Screen time viewing and total isometric muscle strength in a population sample of Danish youth



Legend: Estimates with 95% CI are from fully adjusted multiple regression analysis (as model 3 in Table 2).

Figure 2. Association of total screen time viewing (hours/day) with isometric trunk muscle strength (SD) in youth stratified by fitness (sex-specific quartiles), parental educational level (basic- or secondary education / tertiary education), and sex.



Legend: Estimates with 95% CI are from fully adjusted multiple regression analysis (as model 3 in Table 2). $P=0.91$ for fitness by screen time interaction, $p=0.97$ for educational level by screen time interaction, and $p=0.36$ for sex by screen time interaction on trunk muscle strength.