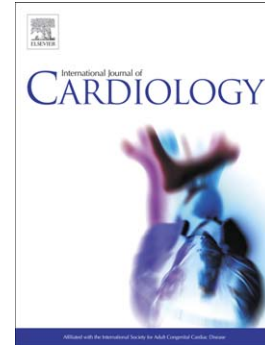# Accepted Manuscript

Physical activity, sedentary time, TV viewing, physical fitness and cardiovascular disease risk in adolescents: The HELENA study

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Physical activity, sedentary time, TV viewing, physical fitness and cardiovascular disease risk in adolescents: The HELENA study

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All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

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ABSTRACT

Background: To examine the independent associations between physical activity intensities (PA), sedentary time (ST), TV viewing, cardiorespiratory fitness (CRF) and muscular fitness (MF) with cardiovascular disease (CVD) risk in youth.

Methods: A cross-sectional study on 534 European adolescents (252 males, 282 females, 12.5-17.5 y). Minutes per day of light (LPA), moderate (MPA) and vigorous (VPA) PA and total ST were measured using accelerometers. TV viewing time was measured using a questionnaire. CRF and MF were measured using the 20 m shuttle run test and a hand dynamometer respectively. CVD outcomes included markers of body composition (body mass index (BMI), waist circumference (WC), WC/height(Ht) and sum of skinfolds (SumSF)), blood pressure, blood lipids and insulin resistance (HOMA-IR). Clustered CVD risk was calculated using SumSF, HOMA-IR, blood lipids and blood pressure.

Results: LPA had a significant positive independent relationship with all body composition outcomes ($P<0.001$) and clustered CVD risk ($P=0.046$). VPA was negatively related to SumSF ($P<0.001$), BMI ($P=0.018$), WC/Ht ($P=0.013$) and clustered CVD risk ($P=0.001$), but was non-significant for all when other exposures were considered ($P>0.10$). MPA had a negative independent relationship with only WC ($P=0.029$) and ST was not significantly related to CVD risk ($P>0.16$). TV viewing had a significant positive independent relationship with HOMA-IR ($P<0.001$) and clustered CVD risk ($P=0.019$). CRF (all $P<0.002$) and MF (all $P<0.009$) had a negative independent relationship with body composition outcomes and clustered CVD risk.

Conclusions: Public health guidelines should prioritize on increasing levels of CRF, MF and VPA, and reducing TV viewing time to lower CVD risk in youth.

INTRODUCTION

Current public health guidance recommends 5-18 y olds to undertake at least 60 min of moderate to vigorous physical activity (MVPA) daily and minimize time spent performing sedentary activities in order to modify their current and future cardiovascular disease (CVD) risk (1, 2). A recent study employing objective measures of PA and total sedentary time (ST) found MVPA to be more important for modifying CVD risk in youth than ST (3). However, higher daily screen time but not total ST is negatively related to CVD risk in children after adjusting for MVPA (4). This suggests targeting specific sedentary behaviors rather than total ST *per se* may be more important for improving CVD health in youth. The relationship between MVPA and CVD risk in youth may be attributable to the time spent performing vigorous physical activity (VPA) and not moderate PA (MPA) (5-8). However, few studies have examined the independent relationship between PA intensities, total ST and sedentary behaviour on CVD risk in youth.

High cardiorespiratory fitness (CRF) in youth has been shown to reduce the risk of myocardial infarction (9) and adverse CVD risk (10) in adulthood. CRF has a weak relationship with PA in youth (11) and CRF and PA are independently associated with clustered CVD risk in this population (12-14), suggesting that CRF may reduce CVD risk through a separate pathway compared to PA. Finally, low muscular fitness (MF) in youth is independently associated with elevated CVD risk (12) and predicts premature CVD related mortality in adulthood (15).

There is strong evidence that high levels of PA (especially VPA), CRF and MF and reduced time spent being sedentary and performing sedentary activities (e.g. TV viewing) are

associated with lower CVD risk in youth. However, a comprehensive evaluation of all these exposure variables on CVD risk in youth has not been performed within a single study. This approach would provide unique insight into which components of an 'active lifestyle' have the strongest relationship with CVD risk in youth; information that would enable modifications to current public health recommendations. Therefore, the aim of this study is to examine the independent associations between different intensities of PA, total ST, TV viewing, CRF and MF on individual and clustered markers of CVD risk in a contemporary sample of European adolescents.

METHODS

Study design and sample

This paper is based on data from the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) cross-sectional study (16) which received ethics approval by the Research Ethics Committees of each city involved as detailed elsewhere (17). Written informed consent was obtained from the adolescents involved in the study and their parents/guardians. For the current study, adolescents were selected based on having valid data for: 1) blood outcomes; 2) objectively measured PA and ST; 3) TV viewing data via questionnaire; 4) objective measures of CRF and MF; and 5) anthropometric measurements. From the original study sample (3,528), 534 adolescents (252 males, 282 females) aged 12.5-17.5 yr were included in the current study.

Anthropometric and maturity outcomes

Body mass, height, waist circumference (WC) and the sum of four skinfolds (sumSF; biceps, triceps, subscapular and suprailiac sites) were measured using previously reported standardized measurement procedures (18). Body mass index (BMI) was calculated in raw

units (kg·m^2) and converted to a z-score to classify the participants as non-overweight, overweight or obese (19). The ratio of WC to height (WC/Ht) was used as a marker of central adiposity (20). Pubertal status was assessed by a medical doctor using secondary sex characteristics (21).

Socioeconomic status

Socioeconomic status was measured using an adapted family affluence scale (FAS) (22) which focusses on material affluence (23). The FAS scale is composed of four questions: 1) do you have your own bedroom?; 2) How many cars are there in your family?; 3) how many computers are there in your home?; and 4) do you have internet access at home? The total FAS score ranged 0 to 8, with a higher score indicating greater affluence.

Blood pressure

Systolic (SBP) and diastolic blood pressure (DBP) were measured to the nearest mmHg using an automated device (OMRON M6) approved by the British Hypertension Society (24). The lowest SBP and DBP was recorded from two measurements taken 10 min apart.

Blood outcomes

A venous blood sample was obtained after a 10 hour overnight fast and sent to a central laboratory for analysis (25). Serum concentrations of triglycerides (TG), total cholesterol (TC), high density lipoprotein cholesterol (HDL-C) and glucose were determined using enzymatic methods. Lipid ratios were calculated be expressing HDL-C with TC (TC/HDL-C) and TG (TG/HDL-C) given their superior predictive ability in identifying metabolic complications compared to reporting in isolation (26, 27). Insulin was determined by an immunometric assay. Insulin resistance was estimated using the homeostasis model (HOMA-IR) (28).

Physical activity, sedentary time and TV viewing time

Uniaxial accelerometers (Actigraph GT1M, Manufacturing Technology Inc. Pensacola, FL, USA) assessed PA and total ST for seven consecutive days as previously described (29). Participants were permitted to remove the device for water-based activities. Data were considered valid if at least 3 days of wear time with 8 hours of recorded data was registered. Data were captured using a 15 s epoch and cut-points based on metabolic equivalents were used to determine time spent performing light PA (LPA) (100-1999 cpm), MPA (2000-3999 cpm) and VPA ($\geq$4000 cpm) (29). ST was defined as any registered activity < 100 cpm (30). A validated self-report sedentary behaviour questionnaire was administered during school hours to estimate TV viewing time in minutes per day (30).

Cardiorespiratory and muscular fitness

The 20 m shuttle run test was used to measure CRF, which has established validity and reliability (31). The number of stages completed was used to estimate maximal oxygen uptake (VO_{2max}) expressed relative to body weight (mL/kg/min) using a validated equation (32). A hand dynamometer (TKK 5101 Grip D, Takey, Tokyo Japan) adjusted for the participant's hand size was used to measure MF on two occasions with their left and right hands (33, 34). The average of the scores achieved by the left and right hands was used in the analysis and expressed relative to body mass.

Statistical analyses

Analyses were completed using IBM SPSS Statistics (version 22) with an alpha level of 0.05. Non-normally distributed data (BMI, WC, WC/Ht, SumSF, HOMA-IR, TG and TG/HDL-C) were log-transformed for analysis. Untransformed data are presented in the manuscript to

enhance readability. Independent samples t-tests and Pearson's chi-squared (maturity stage, BMI classification) were used to examine sex-differences for the descriptive variables.

Regression models examined the influence of the exposure variables, LPA (min/day), MPA (min/day), VPA (min/day), ST (min/day), TV viewing time (min/day), CRF ($mL·kg^{-1}·min^{-1}$) and MF (normalized for body mass), on individual CVD risk factors and a clustered CVD risk score. The clustered CVD risk score was calculated by summing the individual standardized z-scores for SumSF, HOMA-IR, TC/HDL-C, SBP and TG (12). SumSF was entered into the clustered CVD risk score as it has a stronger relationship with CVD risk factors in youth compared to BMI and WC (35).

Regression *model 1* consisted of separate regression models for each exposure variable to examine the relationship with CVD risk factors after adjustment for age, sex, Tanner stage and FAS. The SumSF was also entered as a covariate for all CVD risk factors except for BMI, WC and SumSF. Accelerometer wear time was not entered into the model due to multicollinearity. Regression *model 2* was used to examine the independent relationship of each separate exposure variable on CVD risk factors after including all other exposure variables as additional covariates in the model. Regression output is reported using the standardized beta regression coefficient and corresponding P-value. Regression model assumptions were tested and verified.

The nature of the relationship between the significant exposure variables highlighted in regression *model 2* and CVD risk factors was explored through quartile group analysis using analysis of covariance (ANCOVA) after adjustment for age, sex, pubertal status, FAS and all other exposure variables. Significant effects were followed-up using pairwise comparisons.

RESULTS

The descriptive characteristics of the study sample are presented in Table 1 with significant sex differences highlighted in bold. There were no significant differences between males and females for the classification of pubertal stage ($P=0.06$). Although BMI expressed kg/m^2 was significantly higher in females, this disappeared when expressed as a z-score or categorized into underweight, normal weight, overweight and obese ($P=0.28$).

Regression model 1 output (Table 2)

LPA was significantly and positively related to BMI, WC, WC/Ht and SumSF. MPA did not display any significant relationships with the CVD risk factors. VPA was significantly and inversely related to BMI, WC/Ht, SumSF, TG, TG/HDL-C and clustered CVD risk. A significant positive relationship was observed for VPA and SBP. ST had no significant relationship with the health outcomes. TV viewing time had a significant positive relationship with DBP, TG, TG/HDL-C, HOMA-IR and clustered CVD risk. Significant negative relationships were observed for CRF and MF with BMI, WC, WC/Ht, SumSF and clustered CVD risk score. CRF and MF had a significant positive relationship with SBP. Finally, CRF had a significant negative relationship with TC/HDL-C and TG/HDL-C.

Regression model 2 output (Table 3)

LPA had a significant positive relationship with BMI, WC, WC/Ht, SumSF and clustered CVD risk. MPA only had a significant negative relationship with WC. VPA had a significant positive relationship with SBP and DBP and a negative relationship with TG and TG/HDL-C. ST was not significantly related to any of the health outcomes. TV viewing time had a significant positive relationship with TG, TG/HDL-C, HOMA-IR and clustered CVD risk

score. CRF and MF had a significant negative relationship with BMI, WC, WC/Ht, SumSF and clustered CVD risk score and a positive relationship with SBP. Finally, CRF had a significant negative relationship with TC/HDL-C.

ANCOVA quartile analyses (Figure 1)

SumSF (Figure 1A) was significantly higher across the quartile groups for LPA (trend $P=0.005$) and lower across quartile groups for CRF (trend $P<0.001$) and MF (trend $P<0.001$). SumSF was significantly higher in LPA quartiles 2 ($P=0.025$;+4.5 mm), 3 ($P=0.002$;+7.2 mm) and 4 ($P=0.002$;+8.0 mm) compared to quartile 1. SumSF was significantly lower in CRF quartile 4 compared to quartile 1 ($P<0.001$;-14.2 mm). A lower SumSF was observed between consecutive CRF quartiles 2 to 3 ($P=0.008$;-8.5 mm) and 3 to 4 ($P=0.007$;-4.4 mm). For MF, SumSF was lower in quartile 2 ($P<0.001$;-16.2 mm), 3 ($P<0.001$;-28.1 mm) and 4 ($P<0.001$;-33.4 mm) compared to quartile 1. A significantly lower SumSF was overserved between consecutive MF quartile groups from 2 to 4 (all $P<0.039$;-12.0 mm and -5.2 mm respectively).

BMI was significantly higher across the LPA quartile groups (trend $P=0.013$; Figure 1B). Compared to quartile 1, BMI was significantly higher in quartiles 2 ($P=0.036$;+0.5 kg/m^2), 3 ($P=0.008$;+1.4 kg/m^2) and 4 ($P=0.002$;+1.7 kg/m^2). BMI was significantly lower across the CRF (trend $P=0.012$) and MF (trend $P<0.001$) quartile groups. BMI was significantly lower in CRF quartiles 3 ($P=0.018$;-1.4 kg/m^2) and 4 ($P=0.006$;-1.8 kg/m^2) compared to quartile 1. For MF, in contrast to quartile 1, BMI was significantly lower in quartiles 2 ($P<0.001$;-2.5 kg/m^2), 3 ($P<0.001$;-3.8 kg/m^2) and 4 ($P<0.001$;-4.1 kg/m^2). BMI was also significantly lower in quartile 3 compared to 2 ($P<0.001$;-1.3 kg/m^2).

WC (Figure 1C) was significantly higher across the quartile groups for LPA (trend $P=0.012$) and lower for the quartile groups for MF (trend $P<0.001$). However, there was no significant effect for WC across the quartile groups for MPA ($P=0.15$) or CRF ($P=0.08$) (data not shown). For LPA, WC was higher in quartiles 3 ($P=0.011$;+2.4 cm) and 4 ($P=0.002$;+2.9 cm) compared to quartile 1. For MF, quartiles 2 ($P<0.001$;-5.2 cm), 3 ($P<0.001$;-8.1 cm) and 4 ($P<0.001$; -9.5 cm) had a significantly lower WC compared to quartile 1. A lower WC was also found in quartile 3 compared to quartile 2 ($P=0.001$;-3.0 cm).

The ratio of the WC/Ht (Figure 1D) was significantly higher across LPA quartile groups (trend $P=0.002$). Compared to LPA quartile 1, WC/Ht was significantly elevated in quartiles 3 ($P=0.006$, 0.014) and 4 ($P<0.001$; 0.021). There was a trend for a significant linear-like decrease in WC/Ht across quartile groups for CRF (trend $P=0.026$) and MF (trend $P<0.001$). For CRF, quartiles 3 ($P=0.033$; -0.016) and 4 ($P=0.004$; -0.023) had a significantly lower WC/Ht compared to quartile 1. A lower WC/Ht was observed in MF quartile groups 2 ($P<0.001$; -0.029), 3 ($P<0.001$; -0.047) and 4 ($P<0.001$; -0.055) compared to quartile 1. Consecutive decreases in WC/Ht were also observed between MF quartiles 2 and 3 ($P<0.001$; -0.018).

HOMA-IR was significantly higher across TV viewing quartile groups (trend $P=0.004$; Figure 1E). Compared to quartile 1, HOMA-IR was significantly higher in quartile 2 ($P=0.038$;+ 0.38) and 4 ($P<0.001$;+ 0.99).

TG was not significantly different across quartile groups for TV viewing (trend $P=0.20$; data not shown), but a significantly lower TG was observed across the VPA quartile groups ($P=0.012$; Figure 1F). TG peaked in the 2nd and 3rd quartiles for VPA suggesting an 'inverted

U' relationship. TG was lower in quartile 4 compared to quartiles 2 (P=0.006;- 8.9 mg/dl) and 3 (P=0.004;- 9.3 mg/dl) but not quartile 1 (P=0.17).

The ratio of TG/HDL-C was significantly different across VPA quartiles (trend P=0.007; Figure 1G). Similar to TG, the TG/HDL-C ratio peaked across the 2nd and 3rd VPA quartiles and was significantly lower in quartile 4 compared to quartiles 1 (P=0.044; -0.19), 2 (P=0.001; -0.21) and 3 (P=0.003; -0.22). For TV viewing, TG-HDL-C significantly increased across quartile groups (trend P=0.012). Compared to quartile 1, TG/HDL-C was significantly higher in TV viewing quartile 4 (P=0.02; -0.40). A significant increase in TG-HDL-C was also observed between TV viewing quartile 3 and 4 (P=0.010; 0.31).

Significantly lower clustered CVD risk score (Figure 1H) was observed across quartile groups for CRF (trend P=0.003) and MF (trend P<0.001). However, no significant effect was observed for quartiles of LPA (trend P=0.41) and TV viewing (P=0.063) on clustered CVD risk. Clustered CVD risk score was lower in CRF quartile 4 compared to quartile 1 (P=0.004;-1.28). A lower clustered CVD risk score was found between consecutive CRF quartiles 2 to 3 (P=0.020;-0.81). Clustered CVD risk was lower in MF quartiles 2 (P<0.001;-1.33), 3 (P<0.001;-1.71) and 4 (P=0.001;-1.50) compared to quartile 1.

DISCUSSION

The novel findings from the current study are: 1) time spent performing LPA and VPA were strong predictors of CVD risk, but the effect of VPA diminished with the inclusion of other exposure variables; 2) MPA did not consistently demonstrate a strong significant relationship with CVD risk factors; 3) ST was not significantly related to any CVD risk factors, whereas TV viewing time was an independent predictor of elevated TG, TG-HDL-C, HOMA-IR and

clustered CVD risk score; and 4) both CRF and MF were strong independent predictors of all body composition indices and clustered CVD risk. Although these findings derive from a cross-sectional analysis and preclude causality, a key strength is the scrutiny of the independent relationship of PA intensity, ST, TV viewing and physical fitness with both single and clustered CVD risk factors in youth. Furthermore, objective measures of PA and ST were obtained and established protocols were used to determine CRF and MF. Thus, these findings hold practical relevance in terms of informing public health policy for lowering CVD risk in youth.

Physical activity intensity

Current PA guidelines stipulate that targeting MVPA is important for improving health outcomes in children and adolescents (2). Such guidelines are based on an established dose-response relationship between time spent performing MVPA and a reduction in CVD risk in European children (3, 36). In the current study, VPA and not MPA was consistently related to CVD outcomes in adolescents. Higher VPA was associated with lower BMI, SumSF, WC/Ht, TG and clustered CVD risk, whereas MPA was not a significant predictor of any of the health outcomes when no adjustment was made for other exposure variables (Table 2). These findings corroborate with a 2-y longitudinal study in 315 9-15 y olds where time spent performing more VPA and not MPA was associated with improved BMI, SBP, WC and CRF after adjusting for age, sex, diet quality, accelerometer wear time and other intensities of PA (5). The superior effect for VPA modifying CVD risk factors in youth compared to MPA is also consistent with previous cross-sectional observations (6, 7, 37). Collectively, these findings underscore the importance of performing VPA and suggest it is the VPA component of MVPA that should be targeted to improve the health status of youth. However, the dose response of the VPA-CVD risk relationship is largely unknown in youth. The 2-y prospective

study by Carson and colleagues (5) suggest that <8 min of VPA per day may be needed, whereas cross-sectional evidence indicates that either >17 min (8) or >26 min (37) of VPA per day may be required. Clearly, further work is needed to identify the dose response characteristics for VPA and how this may differ between different age and sex groups and CVD health outcomes.

The relationship between VPA and health outcomes in the current study was mitigated once other exposure variables, especially physical fitness, were included in the model. Only a significant negative relationship was observed for TG and TG/HDL-C, with quartile analysis suggesting that > 26 min of VPA per day may be needed to accrue these health benefits as they occurred in the 4th quartile (see Figures 1F-G). Also, increasing levels of VPA were associated with a higher resting SBP and DBP after adjustment for confounders including other exposure variables. This relationship is difficult to explain and is not consistent with other observational (5, 6) or experimental (38) data.

In the current study LPA had a positive independent relationship with body composition outcomes and clustered CVD risk in youth. The nature of this relationship was explored though quartile analysis, showing that >143 min of LPA per day (≥quartile 2) was consistent with a higher BMI, WC, WC/Ht and SumSF. Previous research has not consistently found a relationship between LPA and health outcomes in youth (7, 29), but data were not adjusted for other PA intensities. Our findings are in agreement with prospective data showing increased LPA over a 2-y period is positively associated with adverse changes in BMI and WC in children and adolescents after adjustment for other PA intensities (5). Elevated BMI and WC was identified through quartile analysis with a dose of 190 min/day of LPA (5), corroborating with the current study. These findings suggest that interventions designed to

increase LPA in youth are likely to lead to increased CVD risk, and underscores the importance of current PA guidelines focusing on increasing daily levels of MVPA.

Sedentary time and TV viewing

A key finding in the current paper was that ST was not a significant predictor of any of the CVD health outcomes. Although previous work has suggested a significant relationship between ST and CVD risk in youth (39), data were not adjusted for PA. Our data are consistent with a recent observational study on 20,871 4-18 y olds that once MVPA status is considered, ST is not a significant independent predictor of CVD risk (3). In contrast, we found TV viewing time to significantly predict CVD risk even after adjustment for other exposure variables including PA intensities, ST and fitness. In particular, TV viewing time had a positive independent relationship with metabolic outcomes including TG, TG/HDL-C, HOMA-IR and clustered CVD risk. Interestingly, TV viewing was the only significant predictor of HOMA-IR in the current study, suggesting that this metabolic outcome may be particularly sensitive to sedentary behaviours in youth rather than PA or physical fitness. These data suggest that while total sedentary time *per se* is not a predictor of CVD health in youth, specific sedentary activities, such as TV viewing and playing video games are, and should be the focus of public health interventions. Specifically, the current study suggests HOMA-IR may be increased after >58 minutes (>quartile 1) of TV viewing per day. However, TV viewing may act as a proxy variable for other health-related behaviors, such as an increased consumption of sweetened beverages and lower consumption of fruits and vegetables (40).

Physical fitness

A novel finding in the current study was that both CRF and MF were significantly related to all body composition indices (BMI, WC, WC/Ht and SumSF) and clustered CVD risk even after adjustment for other exposure variables. The magnitude of the standardized beta coefficients also indicate that the strength of the associations were greater than all other exposure variables. These data therefore agree with previous cross-sectional evidence showing CRF to be a strong independent predictor of CVD risk factors in youth when compared to total PA and PA of different intensities (41). Although previous work has shown MF to be an independent predictor of CVD risk in youth (42), even after adjustment for CRF (12), the current study is, to our knowledge, the first to show this relationship independent of PA intensities and sedentary exposures. In the current study, MF demonstrated a stronger relationship than CRF for all body composition outcomes, which disagrees with a systematic review suggesting CRF may be more important for health in youth (14). However, CRF did have a marginally stronger relationship with clustered CVD risk in the current study, which contradicts a previous report (12), and may be explained by the inclusion of PA intensities, ST and TV viewing as covariates in the current study. Irrespective of the strength of the associations, our data suggest that both CRF and MF have independent pathways for modifying CVD risk in youth, and should be a priority for public health recommendations. However, it is pertinent to note that improvements in body composition outcomes and clustered CVD risk were observed in the second quartile group on a consistent basis for MF, whereas for CRF, improvements were not seen until the third of fourth quartile group. This suggests that smaller improvements in MF may confer benefits to CVD risk compared to CRF in youth.

Previous research has shown that, when adjusting for CRF, both MPA and VPA retain significant relationships with CVD risk factors in European youth (39). Nevertheless, in the current study when all exposure variables were considered, the significant associations for CRF and MF appeared to diminish the effect of VPA such that the relationship became non-significant for BMI, WC/Ht, SumSF and clustered CVD risk. Thus it appears that the influence of CRF and MF on CVD risk may hold a similar mechanistic pathway to VPA. This may be related to the observation that only VPA intensity is associated with CRF in cross-sectional (37) and longitudinal (5) studies in youth.

CONCLUSIONS

The current study provides unique insight into which components of an 'active lifestyle' has the strongest relationship with CVD risk in youth and has implications for primary prevention strategies. Our findings suggest that public health recommendations should promote increasing levels of VPA, CRF and MF and reducing time spent performing specific sedentary behaviors, such as TV viewing, to minimize the development of CVD risk factors in youth. However, these findings require elaboration using a prospective design.

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Table 1. Descriptive characteristics of the study participants by sex

Variable	Male n=252	Female n=282	P value
Age (y)	14.7±1.3	14.5±1.1	0.18
Sexual maturity	3.9±1.0	4.0±0.9	0.26
Stage 1 n (%)	4 (1.6)	0 (0)	-
Stage 2 n (%)	23 (9.1)	14 (5.0)	-
Stage 3 n (%)	56 (22.2)	69 (24.5)	-
Stage 4 n (%)	90 (35.7)	115 (40.8)	-
Stage 5 n (%)	79 (31.3)	84 (29.8)	-
FAS	4.7±1.8	4.2±1.9	**0.005**
Height (cm)	169.3±10.1	161.5±7.5	**<0.001**
Body mass (kg)	59.5±13.5	55.8±11.3	**0.001**
WC (cm)	72.5±8.1	70.3±8.4	**0.004**
WC/Hth	0.43±0.04	0.44±0.05	**0.048**
SumSF (mm)	41.5±23.9	59.6±24.9	**<0.001**
BMI (kg/m^2)	20.6±3.5	21.3±3.6	**0.019**
BMI (z-score)	0.38±1.10	0.40±1.10	0.81
Underweight n (%)	17 (6.7)	16 (5.7)	-
Normal weight n (%)	191 (75.8)	200 (70.9)	-
Overweight n (%)	29 (11.5)	51 (18.1)	-
Obese n (%)	15 (6.0)	15 (5.3)	-
SBP (mmHg)	120±13	112±11	**<0.001**
DBP (mmHg)	64±9	64±8	0.84
TG (mg/dL)	63.2±30.8	75.2±37.9	**<0.001**
TC/HDL-C	2.9±0.7	3.0±0.6	0.18
TG/HDL-C	1.3±0.8	1.4±0.9	0.08
HOMA-IR	2.3±2.4	2.5±1.7	0.45
ST (min/day)	542.1±90.0	548.1±78.6	0.41
LPA (min/day)	178.3±43.5	172.4±41.3	0.11
MPA (min/day)	44.2±15.8	37.9±12.5	**<0.001**
VPA (min/day)	25.4±14.9	13.9±10.5	**<0.001**
MVPA (min/day)	69.6±25.3	51.8±19.4	**<0.001**
TV viewing (min/day)	121.8±69.9	111.0±66.1	0.07
CRF (mL/kg/min)	46.2±7.2	37.1±5.7	**<0.001**
MF	0.60±0.11	0.47±0.09	**<0.001**

Data are presented as mean ± SD, unless stated otherwise. A significant difference is indicated in bold.

FAS, family affluence scale; WC, waist circumference; WC/Ht, ratio of waist circumference to height; BMI, body mass index; SumSF, sum of skinfolds; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; TC/HDL-C, ratio of total cholesterol to high-density lipoprotein cholesterol; TG/HDL-C, ratio of triglyceride to high-density lipoprotein cholesterol; HOMA-IR, HOMA insulin resistance; ST, sedentary time; LPA, light physical activity; MPA, moderate physical activity; VPA, vigorous physical activity; MVPA, moderate to vigorous physical activity; CRF, cardiorespiratory fitness; MF, muscular fitness.

Table 2. Associations between physical activity, sedentary time, TV viewing and physical fitness with cardiometabolic risk factors derived from separate model (*regression model 1*)

	LPA (min/day)	MPA (min/day)	VPA (min/day)	ST (min/day)	TV viewing (min/day)	CRF (mL/kg/min)	MF
BMI (kg/m^2)	**0.120** $P=0.007$	-0.019 $P=0.67$	**-0.110** $P=0.018$	-0.043 $P=0.31$	0.080 $P=0.064$	**-0.408** $P<0.001$	**-0.537** $P<0.001$
WC (cm)	**0.139** $P=0.001$	-0.032 $P=0.47$	-0.089 $P=0.055$	-0.009 $P=0.83$	0.058 $P=0.17$	**-0.330** $P<0.001$	**-0.507** $P<0.001$
WC/Ht	**0.190** $P<0.001$	0.049 $P=0.28$	**-0.119** $P=0.013$	-0.042 $P=0.33$	0.085 $P=0.053$	**-0.393** $P<0.001$	**-0.560** $P<0.001$
SumSF (mm)	**0.109** $P=0.008$	-0.030 $P=0.46$	**-0.159** $P<0.001$	0.009 $P=0.82$	0.048 $P=0.23$	**-0.444** $P<0.001$	**-0.592** $P<0.001$
SBP (mmHg)	0.055 $P=0.18$	0.001 $P=0.98$	**0.111** $P=0.011$	0.045 $P=0.26$	0.015 $P=0.70$	**0.128** $P=0.022$	**0.173** $P=0.002$
DBP (mmHg)	-0.037 $P=0.40$	-0.073 $P=0.09$	0.054 $P=0.25$	0.071 $P=0.09$	**0.085** $P=0.045$	-0.020 $P=0.75$	0.057 $P=0.35$
TG (mg/dL)	-0.055 $P=0.22$	-0.022 $P=0.62$	**-0.141** $P=0.003$	0.030 $P=0.49$	**0.102** $P=0.018$	-0.114 $P=0.06$	0.039 $P=0.53$
TC/HDL-C	-0.036 $P=0.42$	-0.055 $P=0.22$	-0.087 $P=0.069$	0.037 $P=0.39$	0.027 $P=0.53$	**-0.135** $P=0.030$	0.093 $P=0.13$
TG/HDL-C	-0.046 $P=0.30$	-0.021 $P=0.63$	**-0.150** $P=0.001$	0.018 $P=0.67$	**0.124** $P=0.004$	**-0.130** $P=0.032$	0.062 $P=0.31$
HOMA – IR	-0.014 $P=0.74$	-0.027 $P=0.52$	-0.062 $P=0.17$	0.009 $P=0.83$	**0.173** $P<0.001$	-0.096 $P=0.10$	0.015 $P=0.80$
Clustered CVD	0.064 $P=0.16$	-0.050 $P=0.27$	**-0.159** $P=0.001$	0.019 $P=0.67$	**0.141** $P=0.001$	**-0.388** $P<0.001$	**-0.340** $P<0.001$

Regression model 1 consisted of separate regression models for each exposure variable to examine the relationship with CVD risk factors after adjustment for age, sex, Tanner stage and family affluence scale.

Data are reported as the standardized regression coefficient point estimate with the associated P value. Bold numbers are used to highlight a significant result. See Table 1 for abbreviations.

Table 3. Independent associations between physical activity, sedentary time, TV viewing and physical fitness with cardiometabolic risk factors (*regression model 2*)

	LPA (min/day)	MPA (min/day)	VPA (min/day)	ST (min/day)	TV viewing (min/day)	CRF (mL/kg/min)	MF
BMI (kg/m^2)	**0.163** *P*<0.001	-0.073 *P*=0.13	-0.017 *P*=0.72	-0.037 *P*=0.34	0.028 *P*=0.46	**-0.236** *P*<0.001	**-0.455** *P*<0.001
WC (cm)	**0.190** *P*<0.001	**-0.106** *P*=0.029	0.004 *P*=0.94	-0.014 *P*=0.72	0.014 *P*=0.72	**-0.169** *P*=0.002	**-0.452** *P*<0.001
WC/Ht	**0.208** *P*<0.001	-0.006 *P*=0.90	-0.063 *P*=0.17	-0.029 *P*=0.47	0.040 *P*=0.30	**-0.214** *P*<0.001	**-0.481** *P*<0.001
SumSF (mm)	**0.145** *P*<0.001	-0.046 *P*=0.26	-0.064 *P*=0.10	0.021 *P*=0.54	-0.005 *P*=0.89	**-0.254** *P*<0.001	**-0.507** *P*<0.001
SBP (mmHg)	0.050 *P*=0.28	-0.061 *P*=0.23	**0.125** *P*=0.009	0.030 *P*=0.46	0.023 *P*=0.56	0.074 *P*=0.20	**0.149** *P*=0.009
DBP (mmHg)	-0.020 *P*=0.69	-0.082 *P*=0.13	**0.112** *P*=0.030	0.063 *P*=0.16	0.083 *P*=0.052	-0.040 *P*=0.52	0.057 *P*=0.35
TG (mg/dL)	-0.073 *P*=0.15	0.091 *P*=0.10	**-0.149** *P*=0.004	0.036 *P*=0.41	**0.099** *P*=0.022	-0.089 *P*=0.16	0.070 *P*=0.26
TC/HDL-C	-0.021 *P*=0.68	-0.001 *P*=0.98	-0.062 *P*=0.24	0.034 *P*=0.45	0.020 *P*=0.65	**-0.141** *P*=0.028	0.118 *P*=0.06
TG/HDL-C	-0.062 *P*=0.21	0.091 *P*=0.10	**-0.158** *P*=0.002	0.023 *P*=0.61	**0.121** *P*=0.005	-0.106 *P*=0.09	0.097 *P*=0.11
HOMA – IR	-0.014 *P*=0.77	0.017 *P*=0.74	-0.048 *P*=0.34	0.006 *P*=0.89	**0.170** *P*<0.001	-0.077 *P*=0.20	0.041 *P*=0.48
Clustered CVD	**0.096** *P*=0.046	-0.032 *P*=0.54	-0.082 *P*=0.10	0.019 *P*=0.66	**0.098** *P*=0.019	**-0.281** *P*<0.001	**-0.240** *P*<0.001

Regression *model 2* was used to examine the independent relationship of each exposure variable on CVD risk factors with adjustment for age, sex, Tanner stage, family affluence scale and all other exposure variables.

Data are reported as the standardized regression coefficient point estimate with the associated P value. Bold numbers are used to highlight a significant result. See Table 1 for abbreviations.
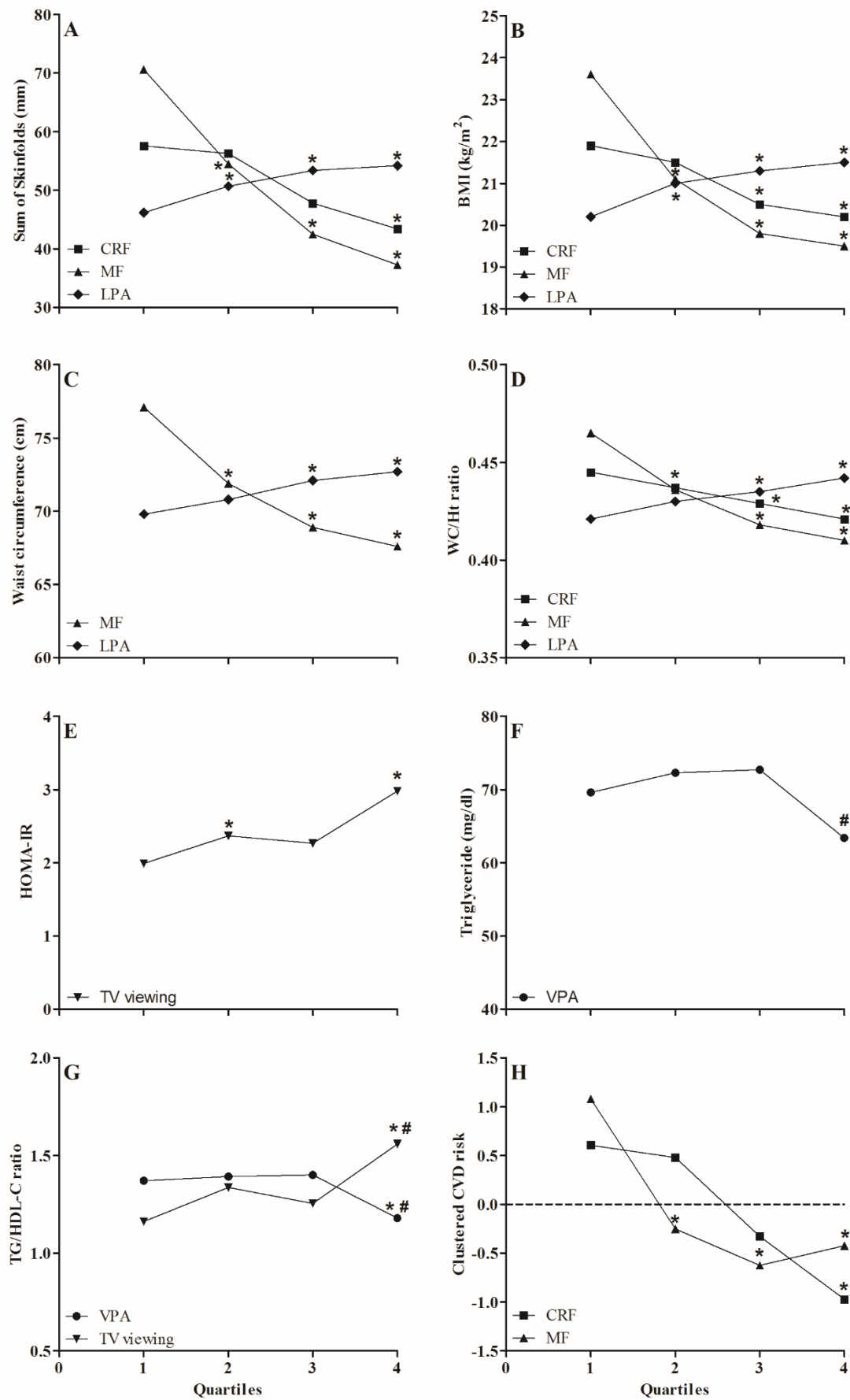
Figure 1. ANCOVA adjusted SumSF (A), BMI (B), WC (C), WC/Ht (D), HOMA-IR (E), TG (F), TG-HDL-C (G) and clustered CVD risk (H) across quartile groups for LPA (♦), VPA (●), TV viewing (▼), CRF (■) and MF (▲). Selection of the exposure variables for the CVD risk factors was based on making a significant independent contrition in linear regression model 2 as outlined in Table 3. Each data point represents the mean adjusted for age, sex, pubertal status, family affluence scale and all other exposure variables.

* denotes a significant difference compared to quartile 1.

\# denotes a significant difference in TG compared to quartiles 2 and 3 for VPA and quartile 3 for TV viewing. See text for other significant differences.