Obesity

Cross-Sectional Associations of Objectively Measured Physical Activity, Cardiorespiratory Fitness and Anthropometry in European Adults

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Objective: To quantify the independent associations between objectively measured physical activity (PA), cardiorespiratory fitness (CRF), and anthropometry in European men and women.
Methods: 2,056 volunteers from 12 centers across Europe were fitted with a heart rate and movement sensor at 2 visits 4 months apart for a total of 8 days. CRF (ml/kg/min) was estimated from an 8 minute ramped step test. A cross-sectional analysis of the independent associations between objectively measured PA (m/s^2/d), moderate and vigorous physical activity (MVPA) (%time/d), sedentary time (%time/d), CRF, and anthropometry using sex stratified multiple linear regression was performed.
Results: In mutually adjusted models, CRF, PA, and MVPA were inversely associated with all anthropometric markers in women. In men, CRF, PA, and MVPA were inversely associated with BMI, whereas only CRF was significantly associated with the other anthropometric markers. Sedentary time was positively associated with all anthropometric markers, however, after adjustment for CRF significant in women only.
Conclusion: CRF, PA, MVPA, and sedentary time are differently associated with anthropometric markers in men and women. CRF appears to attenuate associations between PA, MVPA, and sedentary time. These observations may have implications for prevention of obesity.

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Introduction

Excessive body fat accumulation in the human body has reached ponderous dimensions and its prevalence worldwide has been steadily increasing since 1980 (1). In 2010, worldwide about 1.5 billion people were classified as overweight [Body Mass Index (BMI) > 25], and among them almost 0.5 billion were obese (BMI ≥ 30) (1,2).

Physical activity (PA) and different PA intensities like moderate and vigorous physical activity (MVPA) and sedentary time are strongly associated with obesity in cross-sectional analyses (3,4). However,

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Author contributions: UE designed the study, UE, PF, SB, HB, MJTD, JMHC, LA, KO, MAC, DP, KBB, WWV, AMM, and AT, were involved in data collection. AW did the literature research, analyzed the data, interpreted it, and generated the figures. All authors were involved in writing the paper and had final approval of the submitted and published versions.

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results from large-scale prospective studies using self-reported data have suggested a differential association between PA with overall (BMI) and central adiposity (waist circumference) (5). Unfortunately, self-reported PA is prone to measurement error, which may lead to either under- or overestimation of the true associations with outcomes (6,7). Alternatively, PA can be measured via accelerometry and heart rate recording which provide more valid and reliable measurements (8). However, results from studies using objective methods to assess PA have been inconsistent regarding the relationship between PA, different intensities of PA including sedentary time, and adiposity, partly explained by self-reported anthropometric measures (9-12).

In contrast to objectively measured PA, cardiorespiratory fitness (CRF) which refers to the circulatory and respiratory capacity to use and transport oxygen (13), has previously been associated with lower abdominal fat and a smaller waist circumference (14,15). Both PA and CRF are associated with each other, however, high intensity PA is most effective in improving CRF (16). The remaining variance is attributed to other factors, for example, genotype and environment (17). Identifying the independent associations between PA and CRF with different measures of adiposity may be important for preventive purposes because increasing population levels of PA may be more achievable than increasing CRF. Recent data in elderly showed that higher CRF and MVPA are independently associated with lower waist circumference (18). However, previous studies have mainly relied on CRF measures combined with self-reported data on PA and sedentary time when examining their independent relationships with BMI and waist circumference as measures of obesity (18-20).

We hypothesized that the associations between CRF, PA, MVPA, and sedentary time with anthropometric markers are independent of each other and differ in their magnitudes of association. Therefore, we quantified the independent associations between objectively measured total PA, MVPA sedentary time and CRF, and anthropometric markers in apparently healthy European men and women.

Methods

Study design

In each participating country of the European Prospective Investigation into Cancer a sample of about 200 healthy participants of a center-specific age and gender distribution similar to that of the original EPIC-Europe cohort (21) was recruited: Aalborg (Denmark), Athens (Greece), Bilthoven, Utrecht (the Netherlands), Cambridge (United Kingdom), Florence (Italy), Murcia, San-Sebastian (Spain), Paris (France), Potsdam (Germany), Umeå (Sweden), and Tromsø (Norway). A training seminar was held to standardize the procedures and quality control cross-visits to each study center were conducted. Centers obtained ethical approval from the local ethics board prior to participant recruitment, and informed consent was obtained from all participants.

The study included two examinations 4 months apart in 2007 and 2008 to account for seasonal variation in PA. Exclusion criteria were severe cardiologic illness (i.e., recent myocardial infarction, heart failure, cardiomyopathy, stroke, and angina pectoris), the use of beta-blockers or physical disability preventing participants to walk unaided for a minimum of 10 minutes. A total of 2,056 participants agreed to participate in the study and retention of enrolled participants for the duration of the study was ≥87% irrespective of study center.

To determine eligibility to engage in a sub-maximal PA calibration test (step test), participants completed a general questionnaire on chest pain and safety of exercising that merged the Rose Angina Questionnaire (22) and the Physical Activity Readiness Questionnaire (23). Based on the questionnaire results, 60 participants were excluded from the step test.

Estimated cardiorespiratory fitness measurement (ml/kg/min)

An 8-minute sub-maximal ramped step test (200-mm step; Reebok, Lancaster, UK) was performed to estimate CRF (VO_{2max} [ml/kg/min]). Participants stepped up and down following a rhythmic voice that instructed participants to step "up, up, down, down" and which accelerated from 60 steps/minute to 132 steps/minute across the 8 minutes of the test. The exercise was immediately followed by a 2-minute recovery phase. Heart rate was recorded throughout the exercise test and recovery phase. When subjective symptoms occurred or a participant's heart rate reached >85% of his/her age-dependent maximal HR, the test was stopped (24). If at least 4 minutes of step test data were recorded, the individual relationship between heart rate and workload was used. Otherwise a group calibration model was applied as previously described (25).

Based on the step test data, VO_{2max} was estimated individually by extrapolating the relationship between work load and the age-dependent maximal HR (26). Finally, to achieve a more precise average CRF measure from both step tests, conducted during the two study visits, we weighted the estimated VO_{2max} for test duration (i.e., a 8-minute step test was weighted as 1, a 4-minute step test as 0.5) and then the obtained average CRF was used for the analysis.

Physical activity measurement

We used a validated combined heart rate and movement sensor (Actiheart, CamNtech, Cambridge, UK), which was attached to the chest via two standard ECG electrodes (26). This device measures vertical acceleration by a piezoelectric element included in the Actiheart with a frequency of 32 Hz.

Following the step test, the Actiheart sensor was initialized for long-term recording of PA summarized into 1-minute epochs. Participants were instructed to constantly wear the monitor for a minimum of 4 days.

Data collected by the Actiheart sensor were centrally cleaned and processed at the MRC Epidemiology Unit, Cambridge, UK. This included estimation of activity intensity (J/min/kg) for each time point by acceleration (27). Next, the identification of nonwear periods from the combination of nonphysiological heart rate and prolonged periods of inactivity was performed. We converted activity counts obtained by the movement sensor into units of acceleration ($m/s^2/d$) as recommended in the literature (28). We used vertical acceleration as the measure of PA in the analysis as it was shown to be a reliable indicator for body movement, especially walking, and increases steadily with increasing PA intensity (1 m/s^2 of

TABLE 1 Sex-specific study population characteristics (*n* =1,895)

	Women	Men	All
n	1317	578	1895
Age (years, SD)	53.45 ± 9.20	54.53 ± 9.69	53.78 ± 9.36
BMI (kg/m^2, SD)	25.34 ± 4.16	27.05 ± 3.57	25.79 ± 4.08
WHR (SD)	0.82 ± 0.07	0.94 ± 0.07	0.86 ± 0.09
Waist circumference (cm, SD)	83.77 ± 11.30	97.09 ± 12.11	87.83 ± 13.08
Hip circumference (cm, SD)	101.97 ± 8.74	102.76 ± 9.09	102.09 ± 8.86
PA (m/s^2/d, SD)	0.11 ± 0.05	0.12 ± 0.08	0.11 ± 0.06
CRF (ml/kg/min, SD)	30.71 ± 4.47	33.53 ± 5.28	31.57 ± 4.91
Sedentary time (%time/d, SD)	0.89 ± 0.04	0.88 ± 0.05	0.89 ± 0.04
MVPA (%time/d, SD)	0.05 ± 0.02	0.06 ± 0.03	0.05 ± 0.03

acceleration corresponds to approximately 0.89 m/s walking speed) (27). The intensity time-series were summarized into time spent in MVPA (%time/d) or sedentary time (%time/d). Different intensities were allocated to a respective activity intensity category according to predefined intensity cut-off limits (sedentary behavior <0.25 m/s^2/d; MVPA >5 m/s^2/d).

Finally, we excluded measurement periods with less than 48 hours of data and averaged daily estimates of time spent in different intensity categories from the two 4 day measurements. We also weighted PA, MVPA, and sedentary behavior outcomes to account for divergence from the optimum monitoring duration of two 4 day measurement periods (i.e., individuals with at least $4+4$ days were weighted 1.0, whereas those with fewer days, e.g., $4+3$ days, were weighted less, e.g., $^7/_8$). A final sample of 1,895 participants (92.1% of the recruited participants) was available for analysis.

Anthropometry

Anthropometric measures were recorded using standardized procedures by trained staff in all study centers. Weight, height, waist circumference, and hip circumference were measured by a standard scale, a rigid and portable stadiometer, and a measuring tape, respectively. Obesity-related anthropometry measures: BMI (weight [kg]/height^2 [m]) and waist-to-hip ratio (WHR) (waist circumference [cm]/hip circumference [cm]) were calculated (29). As anthropometry was assessed at both time points all measures used in the analysis were averaged.

Statistical methods

Main exposures were (1) CRF, expressed by estimated VO_{2max}, (2) total PA expressed by average acceleration per day; and (3) time spent in different intensity categories: MVPA and sedentary behavior. Outcome variables were BMI, WHR, and waist and hip circumference. Initial descriptive and univariate analyses were performed. Continuous variables of exposures and outcomes were characterized by mean and standard deviations. We used the Spearman correlation coefficient to examine the univariate relationships between the exposures and outcomes. All analyses were conducted separately for men and women because of a significant interaction between total PA and sex ($P>0.001$ for all anthropometry measures).

Further, we investigated the association between PA, CRF, and anthropometry using multiple linear regression analysis with adjustment for age and center. In the second and third model, we further adjusted for PA and CRF, respectively, in order to examine if the associations are independent of each other. We built *Z*-scores of all analyzed variables in order to facilitate the comparison of the strength of associations.

To better account for measurement precision, we performed a sensitivity analysis with beta-coefficient adjustment for measurement error (where we used the interclass correlation coefficients (ICC) of our two measurements: $PA_{ICC}=0.55$ and $CRF_{ICC}=0.84$) as the correction factor (30). For sedentary time and MVPA models PA_{ICC} was used.

All statistical analyses were performed with SAS Enterprise software release 9.2.

Results

The study population characteristics are summarized in Table 1. Overall, the mean age of participants was 53.8 (SD 9.4) years. Almost 70% of the study sample were women. In general, women had lower mean values of anthropometrical parameters (differences in BMI = 1.71 kg/m^2 ($P<0.001$) WHR = 0.12 ($P<0.001$) waist circumference = 5.67 cm ($P<0.001$) and hip circumference = 0.79 cm ($P<0.0288$) than men. Men were more physically active and had a 2.80 ml/kg/min higher CRF ($P<0.001$) than women (Table 1).

Table 2 shows the univariate Spearman correlation coefficients between anthropometry indices, PA, sedentary time, and CRF. CRF and PA were significantly correlated at a moderate level (in men: $r=0.32$ and women: $r=0.41$). MVPA was highly correlated with total PA (in men: $r=0.86$ and women: $r=0.85$).

To understand the relationship between PA-,CRF-, and obesity-related anthropometric measures, we compared the standardized regression coefficients of the PA and CRF variables in respect to anthropometry (Table 3). CRF was significantly and inversely associated with BMI [model 1: β (95% CI) $\beta=-0.28$ (-0.34; -0.22)], waist circumference $\beta=-0.24$ (-0.29; -0.18) and hip circumference $\beta=-0.28$ (-0.34; -0.22] in women; and with BMI $\beta=-0.24$ (-0.32; -0.17), WHR $\beta=-0.20$ (-0.27; -0.14), waist circumference $\beta=-0.27$ (-0.35, -0.19), and hip circumference $\beta=-0.20$ (-0.28; -0.11) in men. Adjusting for PA (model 2) did not significantly change the results.

TABLE 2 Sex-specific univariate Spearman correlation coefficients between anthropometry parameters), cardiorespiratory fitness (CRF), physical activity (PA), moderate and vigorous physical activity (MVPA), and time spent sedentary in 1895 European adults

	Spearman correlation coefficients								
		CRF (ml/kg/min)	PA ($m/s^2/d$)	Sedentary time (%time /d)	MVPA (%time/d)	BMI (kg/m^2)	WHR	Waist circumference (cm)	Hip circumference (cm)
CRF (ml/kg/min)	W		0.32[a]	−0.26[a]	0.34[a]	−0.32[a]	−0.22[a]	−0.33[a]	−0.30[a]
	M		0.41[a]	−0.35[a]	0.39[a]	−0.31[a]	−0.40[a]	−0.40[a]	−0.25[a]
PA ($m/s^2/d$)	W			−0.79[a]	0.85[a]	−0.18[a]	−0.21[a]	−0.28[a]	−0.21[a]
	M			−0.81[a]	0.86[a]	−0.27[a]	−0.27[a]	−0.32[a]	−0.27[a]
Sedentary time	W				−0.86[a]	0.13[a]	0.15[a]	0.18[a]	0.14**
(%time /d)	M				−0.90[a]	0.20[a]	0.20[a]	0.26[a]	0.23[a]
MVPA (%time /d)	W					−0.18[a]	−0.22[a]	−0.26[a]	−0.18[a]
	M					−0.24[a]	−0.24[a]	−0.29[a]	−0.24[a]
BMI (kg/m^2)	W						0.50[a]	0.81[a]	0.82[a]
	M						0.67[a]	0.87[a]	0.73[a]
WHR	W							0.81[a]	0.28[a]
	M							0.81[a]	0.32[a]
Waist circumference	W								0.76[a]
(cm)	M								0.78[a]
Hip circumference	W								
(cm)	M								

[a]$P < 0.001$.

Sex-specific and somewhat weaker magnitudes of associations were observed for PA compared with CRF. The associations between PA and anthropometry outcomes in women varied between $\beta = -0.12$ (−0.17; −0.07) (WHR) and $\beta = -0.22$ (−0.29; −0.15) (hip circumference). Similarly, in men, the regression coefficients were much smaller and varied between $\beta = -0.06$ (−0.10; −0.02) (WHR) and $\beta = -0.10$ (−0.15; −0.04) (BMI). After adjusting for CRF, the relationships were attenuated but remained statistically significant in women. In men all associations were attenuated towards the null except for BMI [$\beta = -0.06$ (−0.12; −0.01]. The regression coefficients between MVPA and anthropometric markers were of similar magnitude as the coefficients between total PA and anthropometric markers. This observation was consistent in both sexes. Sedentary time was weakly albeit significantly associated with anthropometry outcomes: β ranged from 0.07 to 0.13 in women and from 0.07 to 0.10 in men (Table 3). Although, the associations were attenuated after adjustment for CRF, these remained statistically significant in women, but not in men (Table 3).

The sensitivity analysis, using exposure measurement error correction (i.e., beta coefficient adjustment for the ICC) suggested minor differences for the magnitude of association in men (Figure 2). However, following measurement error correction, the magnitude of associations between PA as well as MVPA and CRF with anthropometric outcomes in women was remarkably similar (Figure 1). Measurement error correction also improved the magnitude of association for sedentary time although the magnitude of associations remained smaller compared to that observed for PA, MVPA and CRF (Figures 1 and 2).

Discussion

The results from this cross-sectional study including 1,895 European adults suggested that CRF and PA are differentially associated with obesity measures in men and women. PA was only associated with BMI after adjustment for CRF in men whereas this adjustment did not materially change the associations between PA and anthropometric markers in women. Following measurement error correction, the magnitudes of associations were similar for PA and CRF in women but not in men.

The major strength of the present study was the use of a combined heart rate and movement sensor that objectively measured PA in a large study population from 10 different European countries. The study consisted of a repeated 4-day measurement of PA including weekends and weekdays. CRF was estimated on both occasions using a sub-maximal step test. The results from both occasions were averaged which provides data with a lower measurement error. This approach reflects more accurately the habitual PA and CRF status of an individual than a single measurement (31). Further, different anthropometry parameters were measured by trained personnel and included in the analyses allowing studying the impact of PA and CRF in detail. A potential limitation represents the way CRF was assessed. The validity of this specific step test is not yet determined against a gold standard. However, a similar step test, shorter in duration and administrated in less standardized conditions in the participants home (The Canadian Home fitness Test) correlates strongly ($r = 0.88$) with directly measured oxygen uptake (32). Also, the objective PA measurement method might have introduced some

TABLE 3 Sex-specific beta coefficients and confidence intervals of BMI, WHR, waist circumference, and hip circumference *Z*-scores, according to physical activity (PA), cardiorespiratory fitness (CRF), moderate and vigorous physical activity (MVPA), and time spent sedentary ($n = 1895$)

Women ($N = 1317$)	Model	BMI (kg/m^2)	WHR	Waist circumference (cm)	Hip circumference (cm)
CRF (ml/kg/ml)	1	−0.28 (−0.34;−0.22)[b]	−0.11 (−0.16;−0.06)[b]	−0.24 (−0.29;−0.18)[b]	−0.28 (−0.34;−0.22)[b]
	2	−0.24 (−0.30;−0.18)[b]	−0.09 (−0.13;−0.04)[a]	−0.19 (−0.25;−0.14)[b]	−0.24 (−0.31;−0.18)[b]
PA (m/s^2/d)	1	−0.22 (−0.29;−0.15)[b]	−0.12 (−0.17;−0.07)[b]	−0.22 (−0.27;−0.16)[b]	−0.22 (−0.29;−0.15)[b]
	3	−0.15 (−0.22;−0.08)[b]	−0.10 (−0.15;−0.05)[a]	−0.16 (−0.22;−0.11)[b]	−0.15 (−0.22;−0.08)[b]
MVPA (%time/d)	1	−0.18 (−0.25;−0.12)[b]	−0.11 (−0.16;−0.06)[b]	−0.18 (−0.24;−0.13)[b]	−0.17 (−0.24;−0.11)[b]
	3	−0.11 (−0.18;−0.05)[a]	−0.09 (−0.14;−0.04)[a]	−0.13 (−0.18;−0.07)[b]	−0.10 (−0.17;−0.04)[a]
Sedentary time (%time/d)	1	0.13 (0.07;0.18)[b]	0.07 (0.03;0.11)[a]	0.12 (0.08;0.18)[b]	0.12 (0.06;0.18)[b]
	3	0.07 (0.01;0.13)[a]	0.05 (0.01;0.10)[a]	0.08 (0.03;0.13)[a]	0.07 (0.01;0.13)[a]

Men ($N = 578$)	Model	BMI (kg/m^2)	WHR	Waist circumference (cm)	Hip circumference (cm)
CRF (ml/kg/ml)	1	−0.24 (−0.32;−0.17)[b]	−0.20 (−0.27;−0.14)[b]	−0.27 (−0.35;−0.19)[b]	−0.20 (−0.28;−0.11)[b]
	2	−0.22 (−0.30;−0.15)[b]	−0.19 (−0.26;−0.13)[b]	−0.25 (−−0.33;−0.18)[b]	−0.18 (−0.27;−0.09)[b]
PA (m/s^2/d)	1	−0.10 (−0.15;−0.04)[a]	−0.06 (−0.10;−0.02)[a]	−0.08 (−0.14;−0.03)[a]	−0.07 (−0.13;−0.004)[a]
	3	−0.06 (−0.12;−0.01)[a]	−0.03 (−0.08;0.01)	−0.05 (−0.10;0.01)	−0.04 (−0.10;0.03)
MVPA (%time/d)	1	−0.10 (−0.15;−0.04)[a]	−0.07 (−0.12;−0.02)[a]	−0.10 (−0.16;−0.04)[a]	−0.08 (−0.15;−0.01)[a]
	3	−0.06 (−0.11;−0.001)[a]	−0.03 (−0.08;0.01)	−0.05 (−0.11;0.01)	−0.04 (−0.11;0.02)
Sedentary time (%time/d)	1	0.10 (0.04;0.16)[a]	0.07 (0.02;0.12)[a]	0.11 (0.04;0.17)[a]	0.10 (0.02;0.17)[a]
	3	0.05 (−0.01;0.12)	0.03 (−0.02;0.08)	0.05 (−0.01;0.12)	0.06 (−0.02;0.13)

Model 1: Adjusted for age and center.
Model 2: Adjusted for age, center, and PA.
Model 3: Adjusted for age, center, and CRF.
[a]$P < 0.05$.
[b]$P < 0.001$.

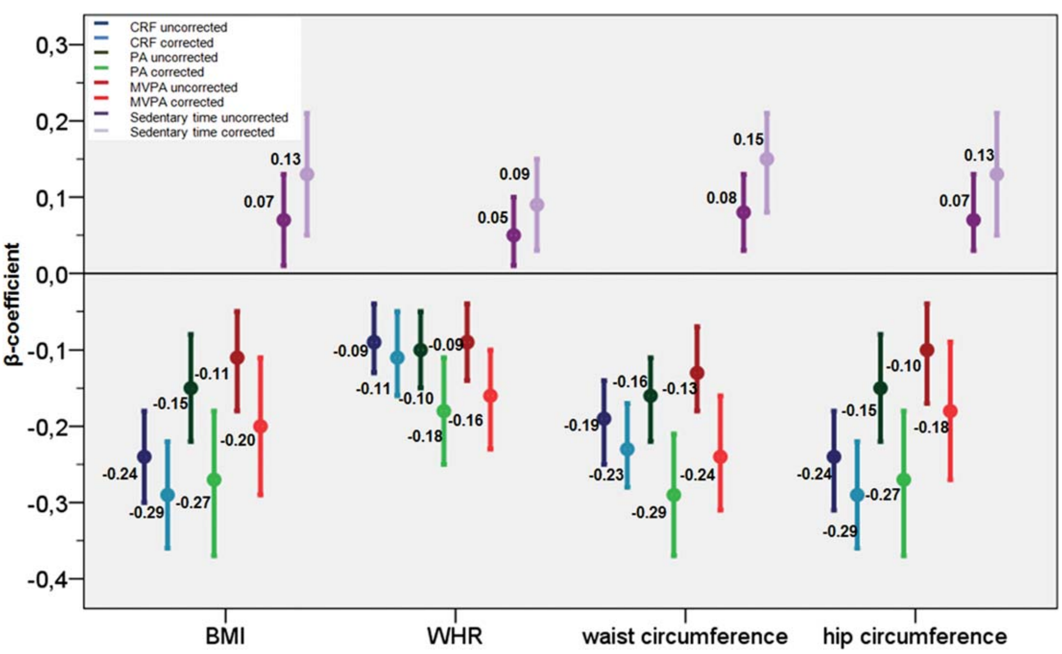

FIGURE 1 Adjusted for age, center, and mutually adjusted (CRF for PA; PA, MVPA and sedentary time for CRF).

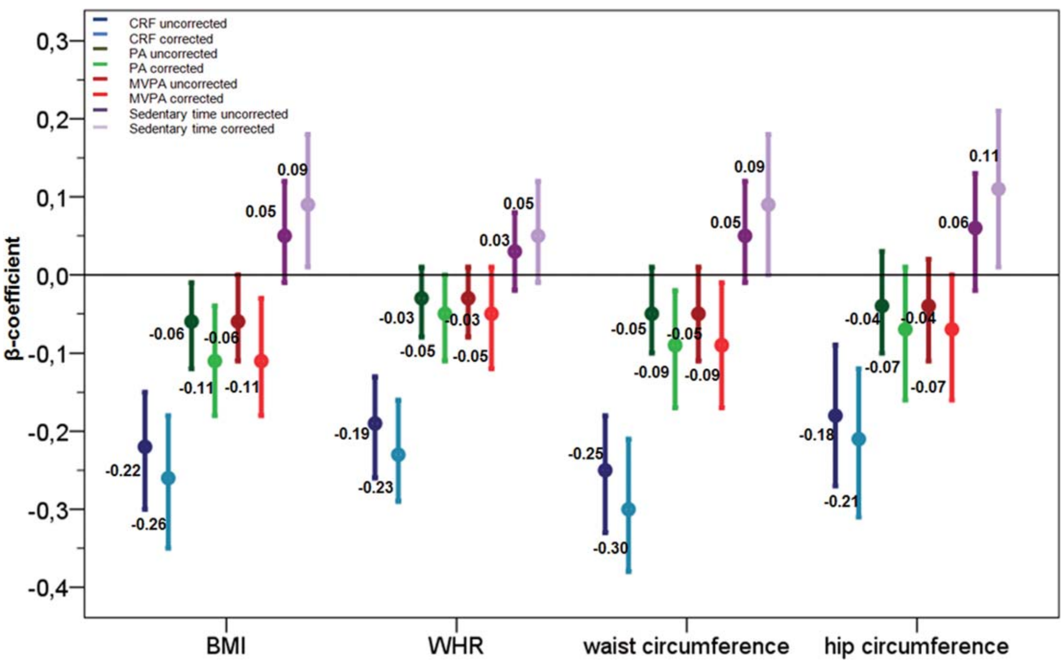

FIGURE 2 Adjusted for age, center, and mutually adjusted (CRF for PA; PA, MVPA and sedentary time for CRF).

inaccuracy because of the Hawthorne effect (33) which implies that participants are more likely to change their activity during the measurement. Acceleration was measured in the vertical plane, therefore some activities could not be quantified and the overall level of PA may be underestimated. Daily and seasonal variability of PA may also impact the reliability of the individual PA estimates and may be a source of error. A 7-day measurement would better quantify the different weekend and weekday patterns and more than two time points would contribute to assessing the seasonal variability (34). Finally, because of the cross-sectional study design, it is not possible to assess causality and rule out reverse causality (whether less obese people tend to have higher CRF instead of the contrary).

As our study compares two separate exposures measured with different degrees of precision, it is also important to account for measurement precision differences. Averaging measurements from two time points increases the precision in both exposure variables. However, we also used the ICC to correct measurement error in the exposure variables, which strengthened the observed associations between PA and anthropometric outcomes in women but not in men.

We are not aware of any previous studies in adults suggesting that CRF attenuates the association between PA or MVPA and adiposity or that the associations between PA and anthropometric markers are more pronounced in women compared to men. Santos et al. (18) examined these associations in a group of 296 elderly participants (mean age 74.4) and concluded that MVPA was inversely associated with waist circumference independently of CRF in both sexes. Differences between studies may be because of differences in age between our participants and those in the study by Santos et al. It is likely that men in our study participated in more vigorous intensity activity, which may influence their CRF and thereby attenuated the association between total PA, MVPA, and adiposity towards the null. Additionally, sex differences in exercise behavior may contribute to the observed differences for the associations between CRF, PA, and obesity outcomes (35). Exercise participation in men may be more focused on strength conditioning exercises compare with women who are more likely to participate in exercises aimed at maintaining or reducing body weight (35). There are also sexual dimorphisms in energy metabolism during exercise, which may partially explain the fact that in women the PA anthropometry relationship was stronger than in men. Women preferentially burn a higher glucose-fat mixture during exercise compared to men and in sedentary times store fat more efficiently (36).

Other studies have examined the independent associations between PA and CRF with metabolic outcomes and suggested that PA is associated with clustered metabolic risk and insulin resistance independent of CRF (37,38). Additionally Franks et al. found that CRF modifies the association between physical activity energy expenditure (PAEE) and metabolic syndrome in which the association between PAEE and metabolic syndrome was much stronger in unfit individuals (38).

We observed a positive association between sedentary time with obesity outcomes. Our measure of sedentary time included sleep which has previously been shown to be inversely related to anthropometry (39). However, excluding sleeping time between 12 pm and 6 am did not materially change the magnitude of associations between sedentary time and the outcomes (data not shown). Particular sedentary activities like leisure time computer use or television viewing are considered as activities consistently associated with obesity (9,20). A previous study with simultaneous measurement of sedentary behavior by accelerometry and self-report showed that sedentary behavior assessed objectively was significantly positively associated with waist circumference only $\beta = 0.63$ cm (95% CI, 0.17, 1.09 cm). However TV-viewing time estimated through self-report was significantly positively associated with waist circumference $\beta = 0.23$ cm (95% CI, 0.13, 0.34), BMI $\beta = 0.09$ kg/m^2 (95% CI, 0.05, 0.13) and also other known cardio-metabolic risk factors such as cholesterol levels (9). Taken together, this suggests that accelerometry-measured sedentary time and self-reported TV-viewing are differently associated with health outcomes and the stronger associations observed for TV-viewing than for accelerometry may be explained by other behaviors associated with TV-viewing.

CRF was moderately correlated with PA measures. It is known that an increase in CRF requires high intensity activity (16). Nevertheless, CRF is a much more stable trait than PA and also influenced by previous exercise habits. Previous studies indicated that even a high CRF level remains stable over years and is only slowly decreased by low levels of exercise (40). Further, CRF is strongly genetically determined (17). Therefore, this might contribute to the greater magnitude of associations between CRF and anthropometry in men.

This study, revealed that CRF, PA, MVPA, and sedentary time are differently associated with anthropometric markers in European men and women. CRF appears to attenuate associations between PA, MVPA, and sedentary time. Increasing high intensity PA that leads to CRF improvement in a population may be important to counteract overweight and obesity. Future prospective studies employing precise measures of both CRF and PA are needed to examine the temporality of these relationships. O

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