Physically Active Adolescents Are More Likely to Have a Healthier Cardiovascular Fitness Level Independently of Their Adiposity Status. The European Youth Heart Study*

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Introduction and objectives. Cardiovascular fitness (CVF) has been considered a health marker at all ages. The main purpose of this study was to examine whether meeting the current physical activity (PA) recommendations is associated with a healthier CVF level in adolescents.

Methods. A total of 472 adolescents (14-16 years-old) were studied. CVF was estimated from a maximal bike test and PA was objectively assessed by accelerometry. Subjects were classed as high/low-CVF level, according to the Cooper Institute's cut-offs, and having a high/low-PA level depending on if the adolescents were engaged in at least 60 min per day at moderate-vigorous PA intensity level. Body fat was estimated from skinfold thicknesses.

Results. Binary logistic regression showed that adolescent girls meeting the current PA recommendations (≥60 min/day of moderate-vigorous PA) were 3 times more likely to have a high-CVF level than girls that did not meet the recommendations, after controlling for sexual maturation status (Tanner stages) and body fat. Likewise, adolescent boys meeting the PA recommendations were 8 times more likely to have a high-CVF level than boys that did not meet the recommendations.

Conclusions. The results suggest that devoting 60 min or more to moderate-vigorous PA daily is associated with a healthier CVF level in adolescents, independent of maturation status and adiposity. The patterns of the association were similar in girls and boys, but the fact that the associations were weaker in girls is of concern.

Key words: *Adolescents. Physical fitness. Physical activity. Accelerometry.*

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Los adolescentes físicamente activos presentan una mayor probabilidad de tener una capacidad cardiovascular saludable independientemente del grado de adiposidad. The European Youth Heart Study

Introducción y objetivos. Se considera que la capacidad cardiovascular (CCV) es un marcador de salud en todas las edades. La finalidad principal de este estudio fue examinar si las recomendaciones actuales de actividad física (AF) están relacionadas con un mejor CCV en los adolescentes.

Métodos. Se estudió a un total de 472 adolescentes (14-16 años de edad). La CCV se estimó a partir de una prueba máxima en cicloergómetro y la actividad física, mediante acelerometría. Se clasificó a los sujetos en las categorías de CCV alta o CCV baja según los valores de corte del Cooper Institute y en AF alta o baja, dependiendo de si los adolescentes practicaban un mínimo de 60 min diarios de AF moderada o intensa. La grasa corporal se estimó a partir de los pliegues cutáneos.

Resultados. La regresión logística binaria mostró que las adolescentes que satisfacen las recomendaciones de AF actuales (al menos 60 min/día de AF de moderada a intensa) presentaban 3 veces más probabilidad de tener un nivel de CCV alto que las que no satisfacían dichas recomendaciones, después de controlar por maduración sexual (según los estadios de Tanner) y de tejido graso. Asimismo, los varones adolescentes que cumplían las recomendaciones de AF presentaban 8 veces más probabilidad de tener un nivel de CCV alto que los que no las satisfacían.

Conclusiones. Los resultados indican que dedicar un mínimo de 60 min diarios a practicar una AF de moderada a intensa se relaciona con una CCV más saludable en los adolescentes, independientemente de su estado

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de maduración sexual y de adiposidad. Los patrones de esta relacion fueron similares en mujeres y varones, pero el hecho de que fuese más débil en ellas requiere más estudio.

Palabras clave: *Adolescentes. Capacidad cardiovascular. Actividad física. Acelerometría.*

ABBREVIATIONS

CI: confidence intervals
CVF: cardiovascular fitness
OR: odds ratio
PA: physical activity
VO_{2max}: maximal oxygen consumption

INTRODUCTION

Cardiovascular fitness (CVF) is a direct marker of physiological status and reflects the overall capacity of the cardiovascular and respiratory systems and the ability to carry out prolonged exercise. Cardiovascular fitness is inversely associated with cardiovascular risk factors for chronic disease such as high blood pressure,[1,2] hyperinsulinemia,[3] total fatness,[4] and abdominal adiposity,[5,6] an atherogenic lipid profile,[7,8] insulin resistance,[9] and clustering of metabolic risk factors.[10,11] Sex-specific cut-offs for a "healthy fitness zone" in childhood and adolescence has been proposed.[12,13] The upper-boundaries of this zone were designed to denote a "good" level of CVF associated with lower "risk" of disease than the lower boundaries. Sex-specific CVF cut-off values associated with a healthier metabolic risk score have also been reported for children aged 9-10 years.[11]

The apparently obvious association between CVF and physical activity (PA) still requires further research, mainly due to the complexity of assessing PA.[14] Furthermore, the differences between boys and girls in the relationships between PA and CVF are not fully understood.[15] Physical activity has been commonly assessed using questionnaires. Questionnaires have highly limited accuracy in the measurement of daily PA, especially in children and adolescents.[16] More objective methods such as accelerometry, have been shown to provide adequate measures for PA in children and adolescents.[17] The current recommendations for the amount of PA deemed appropriate to yield beneficial health and behavioral outcomes in youth are at least 60 minutes per day of moderate to vigorous PA.[18] Objectively measured PA data agree that PA is positively associated with CVF in young people.[4,19-22] However, the question of whether meeting the current PA recommendations is enough, in terms of amount and intensity, to achieve the CVF level considered healthy in adolescents, remains unanswered. From a health promotion perspective, it is of interest to determine if what researchers and international organizations are recommending to their adolescents in regard to PA (ie, 60 min or more of moderate to vigorous PA) is related or not to a healthier level of CVF. This study aimed to examine whether those adolescents who met the current PA recommendations were more likely to have a healthier CVF level, independently of their adiposity status.

METHODS

Study Sample and Design

The adolescents (n=472, 14-16 years) were participants in the Swedish part of the European Youth Heart Study.[23] Study design, sampling procedure, participation rates, and study protocol have been reported elsewhere.[24] The study was approved by the Research Ethics Committees of Örebro County Council and Huddinge University Hospital. Written informed consent was obtained from the parents of the children, and from both the parents of the adolescents and the adolescents themselves.

Physical Examination

Height and weight were measured by standardized procedures. Body mass index (BMI) was calculated as weight/height squared (kg/m^2). The BMI reference cut-offs, proposed by the International Obesity Task Force,[25] were used to categorize the subjects as non-overweight or overweight (including obese). Body fat percentage was estimated from skinfold thicknesses (triceps and subscapular) using Slaughter's equations.[26] These equations have been proposed as the most accurate equations for estimation of body fat percentage from skinfold thickness in the adolescent population.[27] Sexual maturation status was assigned by a trained researcher of the same sex as the child, after brief observation, according to Tanner and Whitehouse.[28] Breast development in girls, and genital development in boys, were used for pubertal classification. Given that very few of the subjects fell into Tanner stage 2, and none were at Tanner stage 1, they were regrouped into Tanner stage 3 for the analysis.

Cardiovascular Fitness Assessment

Cardiovascular fitness was determined by a maximal cycle-ergometer test, as described elsewhere.[29] The workload was pre-programmed on a computerized cycle ergometer (Monark 829E Ergomedic, Vansbro, Sweden) to increase every third minute until exhaustion as follows: In male adolescents the initial workload was set at 50 Watts, increasing by 50 Watts every 3 minutes, while in female adolescents the initial workload was set at 40 Watts, increasing by 40 Watts every 3 minutes. The individuals could choose the pedal frequency that is most comfortable for them (usually between 70-80 rpm), but a pedal frequency lower than 30 rpm was not allowed. Heart rate was registered continuously by telemetry (Polar Sport Tester, Kempele, Finland). The criteria for exhaustion were a heart rate ≥185 beats per minute (94% of the mean predicted maximum heart rate) and a subjective judgment by the test leader that the adolescent could no longer keep up, even after vocal encouragement. These maximal criteria have been reported to be equivalent to a respiratory quotient of ≥1.02, a rating of perceived exertion (RPE) of 18–20, and achievement of an oxygen plateau.[30] The power output (watt=W) was calculated as =W1+(W2×t/180), where W1 is a work rate at fully completed stage, W2 is the work rate increment at final incomplete stage, and t is the time in seconds at final incomplete stage. The "Hansen formula" for estimated maximal oxygen consumption (VO_{2max}) in mL/min was = 12×W+5×weight (kg) (W = power output calculated).[29] Subjects were classed as having a high-CVF level (those who met the minimum criteria for the "healthy fitness zone") or low-CVF level (those who did not), according to the criterion referenced standards for CVF proposed by the Cooper Institute.[12,13] The threshold for the "healthy fitness zone" for adolescent boys corresponds to a VO_{2max} of 42 mL/min/kg, and for girls 14 years or older to 35 mL/min/kg.[12,13] The test used to assess CVF has been previously validated in young people.[29,31]

Physical Activity Assessment

Physical activity was measured with an activity monitor (MTI model WAM 7164, Manufacturing Technology Incorporated, Fort Walton Beach, Florida, USA, formerly known as Computer Science and Applications Inc.) worn on the lower back. Accelerometers provide chronological measure of frequency, intensity, and duration of movement, allowing data to be analyzed over user-defined intervals (epochs). In this study, epoch duration was set at 1 min. This epoch duration has been widely used in field-based studies, allowing data to be collected for long time with no download. Physical activity was measured over 4 consecutive days (2 weekdays and at least 1 weekend day). At least 3 days of recording with a minimum of 10 hours registration per day was set as an inclusion criterion.

The time spent in moderate to vigorous PA (>3 metabolic equivalents) was based upon the cut-off limits published elsewhere.[32] The validity of the equations used in this study have been reported to be useful for estimating participation in moderate and vigorous activity in children and adolescents.[17] The current PA recommendations for young people, ie, 60 minutes or more of moderate to vigorous PA daily, were used to classify the subjects into high-PA level (those who met the PA recommendations) and low-PA level (those who did not).[18]

Statistical Analysis

The physical characteristics of the adolescents are presented as means (standard deviations [SD]), unless otherwise stated. Continuous data were compared using analysis of variance (1-way ANOVA), with sex as a fixed factor. All the residuals showed a satisfactory pattern. Nominal data (PA level, sexual maturation status, etc) were analysed using χ^2 tests.

The dichotomized CVF variable (high vs low-CVF level) was analysed by logistic regression, and the odds ratios (OR) and 95% confidence intervals (CI) of having a high-CVF level were computed according to sex and PA recommendations (high vs low-PA level). We have previously reported that for CVF comparisons and interpretation in adolescent people, both sexual maturation status and body composition measurements are relevant modifying factors and should be taken into account.[33] Therefore, the analysis was controlled by sexual maturation status and body fat percentage. All calculations were performed using SPSS v.14.0 software for Windows. For all analyses, the significance level was 5%.

RESULTS

Cardiovascular Fitness and Physical Activity Levels

Table 1 shows the characteristics of the study population by sex. Cardiovascular fitness, weight, and height were higher in boys than in girls (P<.001). Percentage of overweight adolescents was similar in boys and girls, while the body fat percentage was lower in boys (P<.001). The prevalence of having a low-CVF level was 9% and 20% in adolescent boys and girls, respectively. The proportion of adolescen with a low-PA level was 30% and 39% in boys and girls, respectively.

Associations Between Cardiovascular Fitness and Physical Activity

Figure 1 shows the percentage of adolescents who had a low-CVF level by PA level. Results from the logistic regression analysis are shown in Table 2. Boys had 4-fold higher odds than girls of having a high-CVF level (Table 2) after controlling for sexual maturation status and body fat percentage. The adolescent girls meeting the current PA recommendations (≥60 min/day of moderate-vigorous PA; high-PA level group) were 3 times more likely to have a high-CVF level than girls that did

TABLE 1. Physical Characteristics, Cardiovascular Fitness, and Physical Activity Levels in Adolescent Boys (n=222) and Girls (n=250)

	Boys	Girls
Age, mean (SD), y	15.6 (0.4)	15.5 (0.4)
Sexual maturation status		
Tanner stage 3	2.7	4.3
Tanner stage 4	13.6	41.4
Tanner stage 5	83.6	54.3
Weight, kg	64.2 (10.7)	57.8 (8.8)*
Height, cm	176 (8)	165 (6)*
Body mass index	20.7 (2.8)	21.2 (2.7)
Overweight/obesity, %	12.5	12.7
Body fat, %	14.0 (6.5)	23.4 (5.5)*
VO_{2max}, mL/min/kg	51.0 (6.7)	40.2 (5.9)*
Low-PA level, %	29.9	38.8*
Low-CVF level, %	8.6	19.6*

VO_{2max} indicates maximal oxygen consumption; PA, physical activity; CVF, cardiovascular fitness.
Data are shown as mean (SD), unless otherwise stated.
*Sex differences were found.

not meet the recommendations (<60 min/day of moderate-vigorous PA; low-PA level group), after controlling for sexual maturation status and body fat percentage. Likewise, the adolescent boys meeting the current PA recommendations (≥60 min/day of moderate-vigorous PA; high-PA level group) were 8 times more likely to have a high-CVF level than boys that did not meet the recommendations (<60 min/day of moderate-vigorous PA; low-PA level group).

TABLE 2. Odds of Having a High Cardiovascular Fitness Level for Sex and Physical Activity Level in Adolescents

	OR*	95% CI	*P*
Sex			
Boys	4.1	2.1-8.1	<.001
Girls	1	Reference	
PA			
Boys: high-PA level	8.0	1.6-30.7	.012
Boys: low-PA level	1	Reference	
Girls: high-PA level	3.0	1.2-7.7	.019
Girls: low-PA level	1	Reference	

OR indicates odds ratio; CI, confidence intervals; CVF, cardiovascular fitness; PA, physical activity.
*Controlling for sexual maturation and adiposity (tertiles).

DISCUSSION

The main contribution of this work respect to the previous literature published is that we examined, using objective methods, to what extent meeting the current PA recommendations was associated with a certain CVF level (here called high-CVF), considered healthy, and not only whether higher levels of PA are associated with higher CVF levels. The results suggest that those adolescents who met the current PA recommendations were between 3 and 8 times more likely to have a high-CVF level than those who did not, after controlling for sexual maturation status and body fat percentage. Studies using objectively measured PA have reported a positive association between PA and CVF, as measured by direct

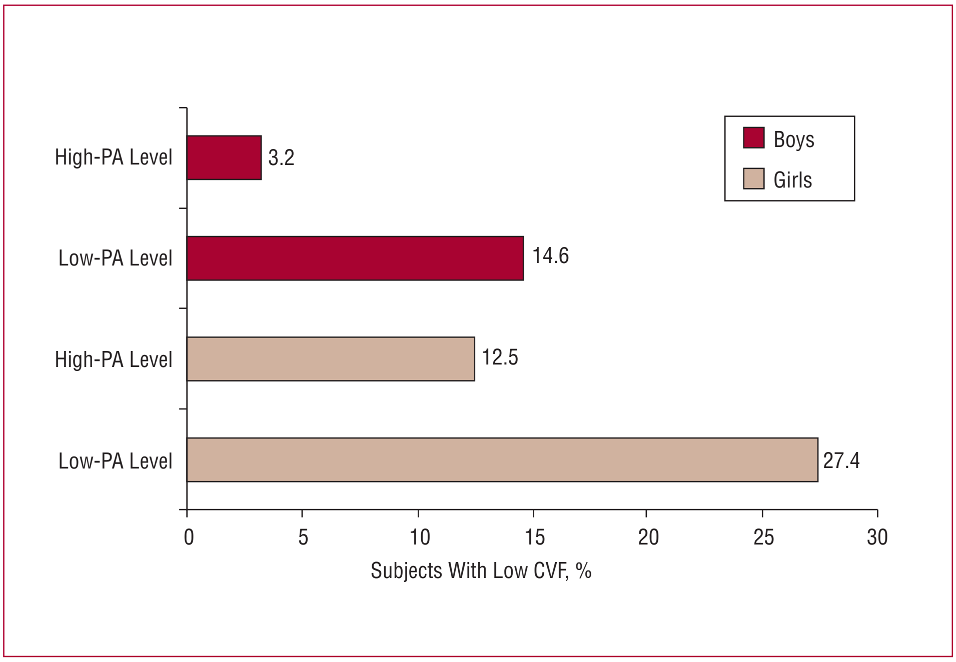

Figure 1. Percentage having a low cardiovascular fitness (CVF) level in boys and girls by sex and physical activity (PA) level.

oxygen consumption.[22] It has been also reported that vigorous PA, rather than light or moderate PA, is associated with an enhanced CVF level in children and adolescents.[4,19] Pate et al[34] reported that US adolescents who had high levels of PA and lower levels of sedentary behavior were also more likely to have higher levels of CVF. On the other hand, a study following children from 11 to 16 years reported that being more physically active was not associated with increased fitness, as measured by several physical fitness qualities (ie, flexibility, strength, speed/agility, and CVF).[35] In these two last studies PA was not objectively measured, hence an accurate comparison can not be made.

Nearly 20% of the studied adolescent girls were classed into the low-CVF level group, which means that 1 in 5 adolescent girls has a CVF level that may represent an increased cardiovascular risk later in life. The prevalence of having a low-CVF level in the studied adolescent girls is similar to that reported for Spanish adolescent girls (20% vs 17%, respectively).[36] In contrast, the prevalence of having a low CVF level in Swedish adolescent boys is much lower than in Spanish adolescent boys (9% vs 19%, respectively). Data from Portuguese children aged 8-9 years, also using the Cooper Institute's cut-offs showed that 19% of boys and 28% of girls had a low-CVF level.[37] In US adolescents, Pate et al,[34] reported that approximately one third of both boys and girls failed to meet the recommended standards for cardiorespiratory fitness; a percentage much higher than for the Swedish adolescents, especially in boys.

Of note also is that the studied adolescent boys were 4 times more likely to have a high-CVF level than their female counterparts, after adjustment for sexual maturation status and body fat percentage. Since the CVF cut-offs are sex-specific, ie, the thresholds for girls are already lower than for boys, and sex-differences have not been found in adolescents from other countries, we hypothesized that socio-cultural factors, rather than physiological factors might explain the sex-differences here observed. Further research is needed in order to clarify the differences on PA and CVF between adolescent boys and girls, and the main causes of those differences.

The proportions of adolescents who met the current PA recommendations were between 61% and 70%, for boys and girls respectively. Similar percentages have been observed in Portuguese, Danish, Estonian, and Norwegian adolescent girls (62%), while the percentage in the studied boys was lower than in these countries (82%).[38]

The limitations of this study should be recognized. No adolescent fell into Tanner stage 1 and few of them were at stage 2, therefore only information about late adolescence is provided. It has been reported that running tests (particularly treadmill tests) give a higher VO_{2max} value than bike tests,[39-41] so comparisons of people with a high/low CVF level in studies involving running or bike tests discussed in this or other reports should be interpreted with caution. The current PA recommendations are supported by a thorough review of the literature,[18] as well as by several governmental agencies and professional organizations, yet its value has been questioned. Andersen et al,[42] suggested that 60 min per day of at least moderate PA might not be enough to prevent the clustering of cardiovascular disease risk factors in young populations. Moreover, a critical issue in any study involving accelerometers is how to select cut-off points to define different activity intensities. There is no consensus on which cut-off points to use.[43] The equations used in this study have been reported to be useful and valid for estimating participation in moderate and vigorous activity in children and adolescents.[17]

Genetic factors were not examined in this study, and they may play an important role in the association between PA and CVF. The present cross-sectional study only provides suggestive evidence concerning the causal relationship between PA and CVF. The objective measurement of PA, the individual assessment of CVF under well-controlled conditions and the substantial number of subjects included are notable strengths of this study.

CONCLUSIONS

The data suggest that those adolescents who spent 60 minutes or more in moderate to vigorous PA daily are more likely to have a healthier CVF level independently of their sexual maturation and adiposity status, according to the "healthy fitness zone" proposed by the Cooper Institute. The patterns of the association were similar in girls and boys, but the fact that the associations were weaker in girls is of concern. Longitudinal and randomized controlled trials will be able to determine how increases in PA levels may affect CVF during the life span and impact on health later in life.

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