Published in final edited form as:

J Phys Act Health. 2014 March ; 11(3): 596–603. doi:10.1123/jpah.2011-0280.

Participation in Vigorous Sports, Not Moderate Sports, Is Positively Associated With Cardiorespiratory Fitness Among Adolescent Girls

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Abstract

Background—There is controversy regarding whether moderately-intense sports can improve physical fitness, which declines throughout adolescence among girls. The objective was to estimate the association between moderate and vigorous sports participation and cardiorespiratory fitness in a racially diverse sample of adolescent girls.

Methods—Cardiorespiratory fitness was measured using a modified physical work capacity test in 1029 eighth-grade girls participating in the Trial of Activity for Adolescent Girls. Girls reported sports in which they participated in the last year on an organized activity questionnaire. Using general linear mixed models, the study regressed absolute and relative fitness on the number of vigorous and moderate sports in which girls participated, race/ethnicity, age, treatment group, fat mass, fat-free mass, and an interaction between race and fat-free mass.

Results—The number of vigorous sports in which girls participated was positively associated with absolute fitness ($\beta = 10.20$, $P = .04$) and relative fitness ($\beta = 0.17$, $P = .04$). Associations were reduced, but not eliminated, after controlling for MET-weighted MVPA. Participation in moderate sports was not associated with either fitness measure.

Conclusions—Vigorous sports participation is positively associated with cardiorespiratory fitness. Future longitudinal research should analyze whether promoting vigorous sports at an early age can prevent age-related declines in cardiorespiratory fitness among adolescent girls.

Keywords

vigorous activity; moderate activity; intervention

Physical fitness can be defined as a set of attributes that a person possesses in terms of that person's ability to perform physical activities which require cardiorespiratory endurance, speed, flexibility or balance, and body composition.¹ It is an integrated measure of a majority of the body's functions (eg, musculoskeletal, cardiorespiratory, hematocirculatory, endocrine-metabolic, and psycho-neurological) that are involved in the performance of physical activity.²

The complex nature of physical fitness is reflected in the broad health risks associated with poor fitness. Among adolescents, lower fitness is associated with high levels of abdominal adiposity, poor cardiovascular health profile, low bone mineral content, depression, low-self esteem, and poor academic achievement.² Childhood physical activity patterns also tend to track throughout adulthood,³ and longitudinal studies of adults have shown that low physical fitness is a strong predictor of adverse health outcomes such as cardiovascular disease,^{4,5} hypertension,⁶ type 2 diabetes mellitus,⁷ cancer mortality,^{8,9} cardiovascular mortality,^{10,11} and all-cause mortality.^{10–13}

Physical fitness levels relative to body mass tend to decline throughout adolescence among girls,^{14,15} underscoring the need to identify and promote activities that improve fitness levels at an early age.² Organized sports are a popular activity among adolescent girls—56.6% of ninth-grade girls participated in at least 1 sport in the past 12 months in 2009¹⁶—yet the association between sports participation and physical fitness has not been studied extensively in the general population. Research on the topic has largely been restricted to studies of athletes in specific sports, often only elite athletes, limiting the generalizability of any findings.¹⁷

The importance of physical activity intensity is also a controversial topic. Many experts have put forth physical activity recommendations that emphasize the health benefits of moderate physical activity,^{18–20} but several studies have reported that the association between moderate physical activity and cardiorespiratory fitness is not as strong as the association between vigorous physical activity and cardiorespiratory fitness among youth.^{21–23} Several intervention studies likewise reported that fitness levels were increased only by incorporating vigorous activity.^{2,20,24} A recent review by Janssen and LeBlanc recommended that children incorporate activities of vigorous intensity, but the authors acknowledged that the evidence supporting vigorous activity was relatively weak.¹⁸ The impact of sports intensity on fitness levels is particularly salient because longitudinal patterns of sports participation depend on intensity level; from seventh through tenth grade, girls are more likely to discontinue participating in vigorous sports, and less likely to begin playing vigorous sports, compared with moderate or light sports.²⁵

The purpose of this study was to estimate the association between moderate and vigorous sports participation and cardiorespiratory fitness among adolescent girls. This study hypothesized that participation in vigorous sports is associated with higher cardiorespiratory

fitness levels, independent of race/ethnicity and body composition. This study analyzed data from a racially diverse sample of adolescent girls in 36 school communities across the United States, enhancing the generalizability of the findings.

Methods

Data Source

Data were collected as part of the Trial of Activity for Adolescent Girls (TAAG)—a multicenter randomized trial that tested an intervention to reduce the age-related decline in physical activity among middle school girls.²⁶ Six universities and a Coordinating Center were involved in the study. Participating universities include: the University of Maryland (College Park, MD), the University of South Carolina (Columbia, SC), Tulane University (New Orleans, LA), the University of Arizona (Tucson, AZ), San Diego State University (San Diego, CA), and the University of Minnesota (Minneapolis, MN). Study coordination was provided by the University of North Carolina at Chapel Hill. The National Heart, Lung, and Blood Institute (NHLBI) sponsored the trial, which was monitored by a data and safety monitoring board appointed by the NHLBI.

Participants

Six schools were recruited at each of the 6 field centers. Eligible schools were public middle schools, where the majority of the enrolled students resided in the community served by the school. Schools were also required to agree to a memorandum of understanding, have a class of at least 90 girls enrolled in eighth grade and average class size of 120 girls, offer a course of physical education each semester, and not anticipate closing or merging for at least 3 years.

Forty eighth-grade girls per school were randomly selected to participate in cardiorespiratory fitness tests in Spring 2005, following the 2-year intervention period. Girls were recruited through required classes in their respective schools. Girls who were not able to participate in regular physical education class or were taking contraindicated medications were excluded from the fitness tests. Girls who did not speak or read in English were also excluded. Of the 1440 girls who were selected, 1226 (85%) provided both assent and parental/guardian consent. Informed consent, assent forms, recruitment materials, and any other information were reviewed by Institutional Review Boards at each institution and by the Coordinating Center.

Data Collection and Measurements

Physical Fitness—Cardiorespiratory fitness (CRF) was assessed on a Monark cycle ergometer using a modified physical working capacity test that predicted the workload at a heart rate of 170 beats per min (PWC_{170}). All cycle ergometers were calibrated before each day's testing. The test was composed of up to 4 2-minute stages, with the initial workload set to 0.25 kg or 0.5 kg, depending on body mass (< 50 kg or ≥ 50 kg). Pedaling frequency was 60 revolutions per minute, and girls were instructed to follow a metronome set to 120 beats per minute. Through all test stages, girls were encouraged to maintain the pedaling frequency. Trained research assistants observed the test performance by the girls to ensure

that they maintained the cadence and recorded cases in which they did not. The research assistants recorded the data measured by the heart rate monitor (Polar Electro, Inc. Lake Success, NY, USA) during each minute of the test. Change in resistance for the next stage followed a protocol based on the participant's heart rate at the end of the stage.

The test was complete at the end of the stage when a girl reached a heart rate of at least 165 beats per minute. The majority of girls completed 3 stages to obtain a final stage of 165 beats per minute. In some cases, an additional stage was necessary to meet the criteria. A small percentage of the sample ($n = 97$) completed only 2 stages of the fitness test as measured by PWC_{170} ; multiple imputation was used to predict a stage 3 heart rate and workload for this subsample. Details of the imputation procedure have been reported elsewhere.²⁷ Workload results were expressed as absolute values ($\text{kg}\cdot\text{m}\cdot\text{min}^{-1}$) and relative to body weight ($\text{kg}\cdot\text{m}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$).

The validity of predicted workload was assessed for all girls by regressing workload on heart rate; girls for whom $R^2 < .80$ were excluded from analyses ($n = 4$). Seventy-four other girls were excluded because they did not complete the test ($n = 40$) or were unable to keep cadence during the test ($n = 34$).

Physical Activity—Physical activity was measured using accelerometers (Actigraph, MTI model 7164; Manufacturing Technology, Inc., Fort Walton Beach, FL). Trained personnel from the study fit the Actigraphs worn at the waist level (over the anterior superior iliac spine) and instructed girls to wear it during waking hours for 7 days, except when it could get wet or when competitive sports required it to be removed. The accelerometers were initialized to begin collecting data in 30-second epochs at 5:00 a.m. on the day after they were distributed, providing 6 full days of data. Missing accelerometry data within the 6 days were replaced using an imputation model described elsewhere.²⁸ Moderate to vigorous physical activity (MVPA) was measured using a threshold of > 1500 counts per 30 seconds (4.6 METs), which a pilot study found was the optimal threshold to discriminate between slow and brisk walking.²⁹ Vigorous physical activity was measured using a threshold of > 2600 counts $\cdot 30\text{ sec}^{-1}$ (or 6.5 METs), which was found to effectively distinguish between brisk walking and running.²⁹ Girls who were missing accelerometer data ($n = 129$) were excluded from analyses.

Student Questionnaire—Race/ethnicity and sports participation were reported using a written questionnaire completed by girls when they returned the accelerometers. A list of sports activities was provided, and students were asked to check those in which they had participated during the past year. Barbara Ainsworth's compendium of physical activity³⁰ was used to categorize sports by intensity, using the same MET thresholds that were used to categorize activity intensity. Basketball, field hockey, dance/cheerleading, ice hockey, soccer, lacrosse, and tennis were classified as vigorous, and baseball/softball, Frisbee, track and field, golf, volleyball, and gymnastics were classified as moderate.

The distribution of sports participation was highly skewed, with approximately 2% of girls reporting that they participated in > 5 moderate sports or > 5 vigorous sports. To adjust for

overreporting of activity, which is common in adolescents³¹ and can bias analyses, girls who reported such levels of participation were recoded as 5 and 5, respectively.

Anthropometry—Height was measured without shoes using a calibrated stadiometer (Shorr Productions, Olney, Maryland). Weight was assessed with the girls wearing light clothing using a calibrated digital scale (Seca 800; Seca Corporation, Hanover, MD). Body mass index (BMI) was calculated by dividing weight (kg) by height squared (m²). Percentage of body fat was estimated using the equation developed by Loftin et al for use in the TAAG study:³²

$$\begin{aligned} \text{Percent body fat} = & -23.39 + 2.27(\text{BMI}) + 1.94[\text{triceps skin folds}(\text{mm})] \\ & - 2.95[\text{race}(1=\text{black}, 0=\text{other})] - 0.52[\text{age}(\text{years})] \\ & - 0.06[\text{BMI} \times \text{triceps skinfold}(\text{mm})]. \end{aligned}$$

This equation estimates 88% percent body fat, as measured by dual-energy x-ray absorptiometry, and the root mean squared error was 3.61.

Statistical Analyses

All analyses used linear mixed models with school and site modeled as random effects to account for intraclass correlation. Models adjusted for age (continuous), race/ ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, non-Hispanic other), treatment group, fat mass (continuous), fat-free mass (continuous), and an interaction between race and fat-free mass. Lohman et al reported that these variables were associated with cardiorespiratory fitness in an independent study of adolescent girls in TAAG.²⁷

First, to assess whether girls who participated in sports were more physically active, the study regressed each measure of physical activity—minutes of moderate-vigorous physical activity (MVPA), MVPA weighted by intensity (MET-weighted MVPA), and vigorous physical activity (VPA)—on the total number of sports in which girls participated. The model was then repeated with sports categorized by intensity to estimate the independent associations between both vigorous and moderate sports and physical activity. Vigorous and moderate sports were analyzed in the same model.

Subsequently, a similar approach was used to model the association between cardiorespiratory fitness and total sports, moderate sports, and vigorous sports. Fitness was modeled in both absolute terms (kg·m·min⁻¹) and relative to body weight (kg·m·min⁻¹·kg⁻¹). This analysis tested if the association between sports and fitness varied by race/ethnicity by adding interaction terms between sports and each racial/ethnic group (minus the referent, non-Hispanic white) and using a likelihood ratio test to determine if the associations were significantly different ($\alpha = 0.05$).

Physical activity was not included in the initial models of fitness because the study hypothesized that it was part of the causal mechanism between sports and fitness. To evaluate this hypothesis, the model was repeated with MET-weighted MVPA and this study

examined if the associations between sports and fitness were reduced. All analyses were conducted with Stata, Version 12.

Results

Sample characteristics are displayed in Table 1. The sample was 46.8% non-Hispanic white, 21.5% non-Hispanic black, 21.3% Hispanic, and 10.4% non-Hispanic other. Girls reported participating in an average of 2.22 sports in the past 12 months, though 22% of girls reported zero sports. Participation was similarly skewed for moderate sports (mean = 0.97, 49% reported zero) and vigorous sports (mean = 1.24, 34% reported zero). Absolute and relative fitness were approximately normally distributed, with means of 660.33 kg·m·min⁻¹ and 11.69 kg·m·min⁻¹·kg⁻¹, respectively.

In bivariate analyses (Table 2), the total number of sports in which girls participated was positively correlated with their absolute fitness ($r = .06$, $P = .05$). The number of vigorous sports had a slightly stronger correlation with both absolute and relative fitness ($r = .07$ and 0.08 , $P = .04$ and 0.01 , respectively), while the number of moderate sports had a slightly weaker correlation with absolute fitness ($r = .05$, $P = .16$) and was not associated with relative fitness. MET-weighted MVPA was positively correlated with both fitness measures ($r = .14$ and 0.19 , respectively, $P < .001$), total sports ($r = .08$, $P = .004$), and vigorous sports ($r = .09$, $P = .002$), but had a relatively weak correlation with moderate sports ($r = .05$, $P = .05$).

No evidence was found that the associations between sports and fitness or activity varied by race/ethnicity; the results of the likelihood ratio tests (not shown) were nonsignificant in each analysis. Tables 3 and 4, therefore, display the associations between sports participation and physical activity and fitness measures, respectively, for the overall sample. Total sports participation was positively associated with MVPA, VPA, and MET-weighted MVPA, but results suggest that these associations were largely attributable to vigorous sports, not moderate sports. Each additional vigorous sport was associated with an increase of 4.38 minutes of MET-weighted MVPA (95% CI: 0.44, 8.32) and 0.30 minutes of VPA (95% CI: 0.08, 0.52). These coefficients represent 3.3% and 5.8% of the mean activity levels in the study sample. In contrast, each additional moderate sport was associated with an increase of only 0.62 minutes of MET-weighted MVPA (95% CI: -3.33, 4.58) and a decrease of 0.05 minutes of VPA (95% CI: -0.28, 0.17).

The adjusted association between total sports and cardiorespiratory fitness was positive but not statistically significant for both absolute fitness ($\beta = 3.73$, 95% CI: -0.83, 8.29) and relative fitness ($\beta = 0.04$, 95% CI: -0.04, 0.12). As in Table 3, however, the associations varied by sports intensity. The number of vigorous sports was significantly associated with both absolute ($\beta = 10.20$, 95% CI: 0.57, 19.83) and relative fitness ($\beta = 0.17$, 95% CI: 0.01, 0.34), whereas the number of moderate sports had a negative, nonsignificant association with both fitness measures. Adjusting for MET-weighted MVPA reduced the association between vigorous sports and cardiorespiratory fitness, but by a relatively small magnitude. The adjusted association between vigorous sports and absolute fitness, for example, declined from 10.20 to 9.10 after adjusting for MET-weighted MVPA.

Discussion

This study adds to a growing body of evidence suggesting that only programs that promote vigorous activity are associated with higher physical fitness levels in adolescents. Utilizing data from a diverse sample of eighth-grade girls located in multiple centers across the United States, this study found the association between cardiorespiratory fitness was positive and statistically significant for sports of vigorous intensity, yet negative and nonsignificant for sports of moderate intensity. Associations were consistent across all racial/ethnic groups.

Previous observational^{21,23,33} and experimental^{2,20,24} studies had similarly found that only vigorous physical activity was associated with physical fitness. Physical activity undoubtedly accounted for a portion of the association found between vigorous sports and fitness, but the association remained even after adjusting for MET-weighted activity. Vigorous sports participation may confer additional benefits that improve fitness levels (eg, psychosocial health) beyond simply increasing activity levels. A review of the benefits of physical education and sports participation concluded that participation was associated with many physical, lifestyle, affective, social, and cognitive benefits that did not result entirely from physical activity.³⁴ Methodologists have criticized the method of adjusting for causal intermediates and interpreting the remaining association as an “indirect effect,”^{35,36} however, so this portion of the results should be interpreted cautiously.

Promoting and maintaining sports participation at an early age can have a lasting impact beyond improved cardiorespiratory fitness during youth. Several studies have reported that sports participation and having a favorable attitude toward sports at an early age predicts physical activity during later adolescence³⁷ and adulthood,³⁸ when low physical activity and fitness levels are associated with a wide range of health consequences, including all-cause mortality.^{10–13} Yet sports participation, like most physical activity measures, declines as girls age. The proportion of high school girls who participated in at least 1 sport in 2009 declined across grades, from 56.6% in ninth grade to 44.1% in 12th grade,¹⁶ and the decline in vigorous sports participation is even more precipitous.²⁵

To promote and maintain sports participation and improve fitness, girl-friendly programs should be available for all girls in multiple contexts. Sports programs must be available throughout the year and be offered at different times and places to allow for time demands of the girls as they move into high school and beyond. A recent study of middle school students reported that time was the biggest barrier to sports participation among girls, and Latinos generally reported more barriers than whites.³⁹ More research needs to be done to determine what types of vigorous sports attract racial/ethnic minority adolescents; in 2009, fewer black and Hispanic girls in the U.S. participated in sports (46.7% and 44.5%, respectively) compared with white girls (57.7%).¹⁶ Physical activity interventions that are culturally tailored to racial/ethnic minority youth have reported mixed findings,^{40–42} as no intervention model has consistently been able to increase physical activity or fitness levels among minorities. Promoting sports participation among minorities is critical for not only improving fitness levels, but reducing racial/ethnic disparities in youth obesity.^{43,44}

The lack of association between moderate sports participation and cardiorespiratory fitness is not an indication that moderate sports should be discouraged. Even experts who reported little association between moderate physical activity and fitness or body composition have argued that moderate activities should be promoted among unfit adolescents.^{21,23} Moderate activities are relatively strenuous for unfit youth, whereas vigorous activities can lead obese youth to decrease their energy expenditure on subsequent days.⁴⁵ Furthermore, there is likely some degree of reverse causality in this study's results, as adolescents of low fitness levels may feel discouraged from participating in vigorous sports. Adolescents of low fitness levels and higher weight status should be encouraged to engage in moderate activities by seeing the social and psychological benefits (eg, spend time with friends), and then progress to sports and other activities of higher intensity.

Limitations and Conclusions

Sports participation was measured using a comprehensive list of sports in different contexts, but the instrument used for this study did not measure physical activity levels within specific sports, nor was data collected on the frequency of participation, duration of class or practice, or the proportion of the year in which girls were involved in sports activities. Study results indicate that girls who participated in more vigorous sports were more physically active, but this cannot be directly attributed to the sports themselves. Moreover, there is likely a wide range of participation levels across sports, which could not be measured, and this may have influenced the findings. The study results may also be affected by recall bias. Girls were asked to remember activities they had done in the past year, and those who participated in several activities throughout the year may not recall as accurately. Finally, the cross-sectional design precludes the authors from drawing a causal relationship between vigorous sports participation and cardiorespiratory fitness. The possibility that girls who chose to engage in vigorous sports were those who were already at a higher fitness level cannot be ruled out.

Despite these limitations, this study adds to the body of literature that supports the promotion of vigorous sports to increase cardiorespiratory fitness among adolescent girls. A concerted effort among state and local school administrators, and community organizations, is needed to support vigorous sports that are appealing to adolescents and can be maintained as girls mature and are faced with more time demands throughout adolescence. Longitudinal research is needed to determine if increasing participation in vigorous sports at a young age can reverse the age-related decline in fitness in this population.

Acknowledgments

This research was funded by grants from the National Heart, Lung, and Blood Institute. Grant numbers: U01HL066858, U01HL066857, U01HL066845, U01HL066856, U01HL066855, U01HL066853, and U01HL066852. The authors thank the schools, parents, and students; and all the study staff, including project coordinators and measurement staff.

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Table 1
Descriptive Statistics of Girls Who Provided Complete Data on Fitness and Sports
Participation: Trial of Activity for Adolescent Girls (N = 1019)

Variable	Mean	Std
Age	13.99	0.53
BMI (kg/m ²)	22.71	5.25
Fat mass (kg)	19.37	9.63
Fat-free mass (kg)	39.08	6.27
Percent body fat (%)	31.44	8.30
MET-weighted MVPA (min/day)	134.13	72.31
Absolute fitness (kg·m·min ⁻¹)	660.33	186.36
Relative fitness (kg·m·min ⁻¹ ·kg ⁻¹)	11.74	3.54
Sports (total)	2.22	2.27
Sports (moderate)	0.97	1.27
Sports (vigorous)	1.24	1.28
Race/ethnicity	%	
White, non-Hispanic	46.81	
Black, non-Hispanic	21.49	
Hispanic	21.30	
Others, non-Hispanic	10.40	

Table 2
Pearson Correlations Among Cardiorespiratory Fitness, Sports Participation, Physical Activity, BMI, and Body Composition*

	AF	RF	Sports (total)	Sports (vig)	Sports (mod)	MET-MVPA	BMI	% fat	Fat mass
RF [†]	0.71								
Sports (total)	0.06	0.05							
Sports (vig)	0.07	0.08	0.88						
Sports (mod)	0.05	0.00	0.88	0.54					
MET-MVPA [‡]	0.14	0.19	0.08	0.09	0.05				
BMI	0.11	-0.54	-0.03	-0.07	0.01	-0.13			
% fat	0.10	-0.53	-0.02	-0.06	0.03	-0.12	0.84		
Fat mass	0.16	-0.54	-0.02	-0.06	0.02	-0.11	0.95	0.92	
Fat-free mass	0.27	-0.34	0.01	-0.02	0.04	-0.04	0.79	0.50	0.76

* Correlations with absolute value > 0.06 are statistically significant ($\alpha = .05$).
Abbreviations: AF, Absolute fitness; RF, Relative fitness; MET-MVPA, MET-weighted moderate to vigorous physical activity.

Table 3
Association Between Number of Sports, Categorized by Intensity, and Measures of Physical Activity

Outcome	Sports	Unadjusted [*]			Adjusted [†]		
		β	SE	P	β	SE	P
MVPA	Total	0.43	0.14	0.003	0.37	0.14	0.009
	Vigorous [‡]	0.66	0.30	0.03	0.57	0.30	0.06
	Moderate [‡]	0.21	0.31	0.48	0.19	0.30	0.52
MET-weighted MVPA	Total	2.77	0.96	0.004	2.44	0.95	0.01
	Vigorous [‡]	4.95	2.04	0.02	4.38	2.01	0.03
	Moderate [‡]	0.69	2.05	0.74	0.62	2.02	0.76
V PA	Total	0.13	0.05	0.01	0.12	0.05	0.03
	Vigorous [‡]	0.34	0.12	0.004	0.30	0.11	0.008
	Moderate [‡]	-0.06	0.12	0.59	-0.05	0.11	0.63

^{*} School and site included as random effects.

[†] Adjusted for age, treatment group, race, fat mass, fat-free mass, and interaction between race and fat-free mass; school and site included as random effects.

[‡] Vigorous and moderate sports were tested in same model.

Table 4
Association Between Number of Sports, Categorized by Intensity and Measures of Cardiorespiratory Fitness

Outcome	Sports	Unadjusted			Adjusted		
		β	SE	P	β	SE	P
Absolute fitness	Total	4.82	2.52	0.06	3.73	2.33	0.11
	Vigorous [§]	7.89	5.34	0.14	10.20	4.91	0.04
	Moderate [§]	2.05	5.38	0.70	-2.45	4.96	0.62
Relative fitness	Total	0.07	0.05	0.17	0.04	0.04	0.29
	Vigorous [§]	0.29	0.10	0.003	0.17	0.08	0.04
	Moderate [§]	-0.16	0.10	0.12	-0.09	0.08	0.31

* School and site included as random effects.

[†] Adjusted for age, treatment group, race, fat mass, fat-free mass, and interaction between race and fat-free mass; school and site included as random effects.

[‡] Adjusted for age, treatment group, race, fat mass, fat-free mass, interaction between race and fat-free mass, and MET-weighted MVPA; school and site included as random effects.

[§] Vigorous and moderate sports were tested in same model.