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Physical activity and a dual measure of body composition are independently related to cardiorespiratory fitness in U.S. adolescents

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Abstract
Background: Abdominal fat is a less known correlate of health-related fitness in adolescents.
Aim: The purpose of this study was to investigate the influence that physical activity (PA) and a dual measure of body composition (BC) have on cardiorespiratory fitness (CRF) in U.S. adolescents.
Methods: Data were used from the 2012 NHANES National Youth Fitness Survey (NNYFS) and included youth aged 12 to 15 years. Four different measures of PA were used: moderate PA (MPA), vigorous PA (VPA), moderate-to-vigorous-PA (MVPA), and number of days per week physically active for 60+ minutes (D60Min). Body mass index (BMI) and waist circumference (WC) were used as BC measures and maximal oxygen consumption (VO2max) used as the measure of CRF. Binary variables of "high" and "low" were created for the PA, BC, and CRF variables. A final binary BC variable (BMI.WC) was created to indicate "high" on both BMI and WC.
Results: Fully adjusted models showed a significant increased odds of low CRF for adolescents with low VPA (OR = 2.47, 95% CI: 1.86-3.29), low MVPA (OR = 2.48, 95% CI: 1.59-3.86), and low D60Min (OR = 1.50, 95% CI: 1.00-2.25). MPA was not significantly related to CRF. In all four PA models, odds of low CRF were almost three times greater in adolescents with high BMI.WC.
Conclusion: This study showed that PA and a dual measure of BC independently predict CRF in U.S. adolescents. With the exception of MPA, which was not related to CRF in these youth.

Keywords: body composition, physical activity, cardiorespiratory fitness, adolescent health

Introduction

The 2018 Physical Activity Guidelines for Americans (2nd edition) recommends adolescents engaging in 60+ minutes of moderate-to-vigorous physical activity (MVPA) daily [1] The World Health Organization (WHO) promotes comparable guidelines for adolescents and similarly stipulates that most of the accumulated PA should be aerobic [2] The promotion of these abovementioned guidelines, in part, is for improvement in health-related physical fitness. Specifically, increased amounts of PA equate to enhanced cardiorespiratory fitness (CRF) in adolescents [3-5] with the importance of adequate CRF lying with its relationship to improved cardiovascular disease risk factors [6, 7].

Body composition (BC) refers to the relative amounts of muscle and adipose tissue and is commonly measured in adolescents using body mass index (BMI), waist circumference (WC), or estimated percent body fat (PBF)[8] Overweight and obesity are growing health problems in adolescents with current obesity estimates reaching approximately 20% in the United States (U.S.) [9] This growing obesity pandemic in adolescent is of great concern due to the strong amount of evidence linking excess body fat to certain chronic diseases such as hypertension, diabetes, metabolic syndrome, and heart disease.[10] BC also has strong links to CRF in adolescents, with overweight and obese youth showing lower levels of CRF than their normal weight counterparts [11].

Although research supports the relationship between PA, BC, and CRF in adolescents, specific data regarding the extent to which PA and BC independently associate with CRF is sparse. Moreover, no studies to date examine such a relationship using two different measures of BC in tandem. Therefore, the purpose of this study was to examine the extent to which PA and a dual measure of BC relate to CRF in US adolescents.

Materials and Methods

Study procedures

Data for this research came from the 2012 National Health and Nutrition Examination Survey's (NHANES) National Youth Fitness Survey (NNYFS). NNYFS was developed to assess physical activity and health-related physical fitness levels in U.S. youth aged 3 to 15 years [12]. The NNYFS design included a four-stage probability sample of noninstitutionalized civilian U.S. residents with 1,640 youth interviewed and 1,576 youth examined. NNYFS data are publicly available and organized by *Demographics*, *Dietary*, *Examination*, *Questionnaire*, and *Limited Access*. For this study, *Demographic*, *Examination* and *Questionnaire* data only were used from adolescents aged 12 to 15 years.

Study variables

BMI and WC were measures of BC used in this study, each assessed by trained health personnel using standardized methods [13] BMI was assessed using both body mass and standing height (by wall stadiometer) and computed as kg/m^2.

WC was measured in centimeters (cm) at a horizontal plane, using a mirror, just above the iliac crest. Four different PA variables were used in this study and assessed via questionnaire responses [14] Moderate PA (MPA, min/wk) was assessed from questions asking respondents about the number of days per week and number of minutes on average they engaged in moderate-intensity sports, fitness, or recreational activities causing small increases in breathing or heart rate.

Vigorous PA (VPA, min/wk) was assessed similarly but regarding activities of vigorous-intensity causing large increases in breathing or heart rate. MVPA (min/wk) was assessed by adding MPA to 2 × VPA. Finally, the number of days per week participants were physically active at least 60 minutes (D60Min, # of days) was assessed via a very similar question.

CRF was the outcome variable in this study and assessed using one of five submaximal exercise treadmill protocols varying in speed and grade [15].

Participants were assigned to a specific four-stage protocol based on their age, sex, BMI, and self-reported physical activity readiness (PAR) score. Submaximal heart rate and predicted submaximal oxygen consumption (VO2) during each of the middle two stages were used to estimate participant maximal oxygen consumption (VO2max) in ml/kg/min. BMI, WC, MPA, VPA, MVPA and CRF measures were converted to binary variables using sex-specific median values. Those in the lower 50% were considered "low" and those in the upper 50% were consider "high".

D60Min was also converted to a binary variable where "high' was defined as 7 days, else "low". Additionally, a final binary BC variable (BMI.WC) was created to indicate "high" on both BMI and WC, otherwise "low".

In order to control for possible demographic confounding, sex, age, race, and income were used in this study. Sex was a categorical variable represented by two groups: 1) boys and 2) girls.

Age was a numeric variable ranging from 12 to 15 years. Race was a categorical variable and comprised the following four groups: 1) Non-Hispanic White, 2) Non-Hispanic Black, 3) Mexican/Hispanic, and 4) Other Races / Multi-racial.

Finally, income was a numeric variable, collected as family income, and comprised twelve different income brackets ranging from 1 = $0 to $4,999 to 12 = $100,000 and over.

Statistical analyses

The first part of the statistical analysis consisted of describing the study variables in continuous form by sex. Regression ANOVA table F statistics were computed to test for mean sex differences in all continuous study variables. Non-normal variables were log and square root transformed but saw results no different from non-transformed analyses. Multivariate logistic regression was used to estimate the independent effects of each PA variable and dual BMI.WC on CRF while controlling for confounding variables. All analyses were weighted to produce generalizations representative of noninstitutionalized U.S. adolescents aged 12–15 years. SAS version 9.4 was used for all analyses [16-19]

Results

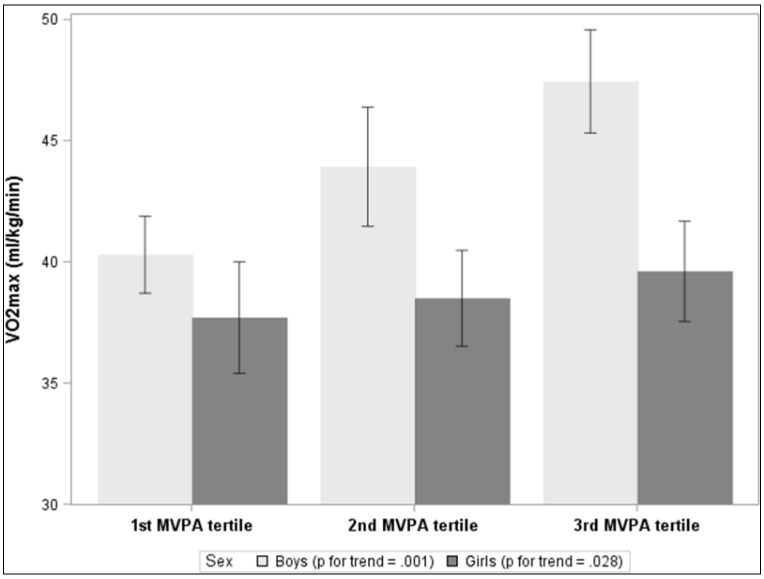
A total of *N* = 451 (boys = 228, girls = 223) adolescents with complete CRF data were included in the analysis with a loss of 4 and 10 youth with missing PA and income information, respectively.

Table 1 contains descriptive statistics for continuous study variables.

Significant (p <.05) mean (*Mean* ± *SE*) sex differences were seen for CRF, with boys having greater estimated values (43.2 ml/kg/min ± 0.87) than girls (38.4 ml/kg/min ± 0.52). Boys compared to girls also had significantly (*p*s <.05) greater amounts of self-reported MPA (196.9 min/wk ± 23.26 vs. 131.2 min/wk ± 19.52), VPA (313.4 min/wk ± 24.05 vs. 216.2 min/wk ± 24.96), and MVPA (707.2 min/wk ± 63.52 vs. 478.7 min/wk ± 52.93). Finally, boys had significantly (p <.05) greater D60Min (4.7 days ± 0.11) than girls (4.2 days ± 0.11). BMI and WC were statistically equivalent for both adolescent sex groups.

Table 2 contains results from the multivariate logistic regression models, displaying odds of low CRF in relation to each PA measure and dual BMI.WC status. Differences between the unadjusted and adjusted regression models were negligible. For the model including MPA, adolescents with low MPA had no significant change in odds (OR = 1.09, 95% CI: 0.67-1.78) whereas adolescents with high BMI.WC had significant increased odds (OR = 2.92, 95% CI: 2.15-3.95) of low CRF. For the model including VPA, adolescents had significant increased odds of low CRF if they had low VPA (OR = 2.36, 95% CI: 1.65-3.36) and high BMI.WC (OR = 2.89, 95% CI: 2.25-3.71). For the model including MVPA, adolescents had significant increased odds of low CRF if they had low MVPA (OR = 2.40, 95% CI: 1.56-3.69) and high BMI.WC (OR = 2.89, 95% CI: 2.25-3.73).

Finally, for the model including D60Min, adolescents had significant increased odds of low CRF if they had low D60Min (OR = 1.46, 95% CI: 1.00-2.14) and high BMI.WC (OR = 2.94, 95% CI: 2.22-3.90). Figure 1 displays mean (95% CI) VO2max values for each MVPA tertile by sex, where amounts of MVPA increase as tertile increases from the 1^{st} to the 3^{rd}. The graph indicates VO2max sex differences for the 2^{nd} and 3^{rd} tertiles (adjusted *p*s <.05). Moreover, a significant direct linear trend between VO2max and MVPA tertile was observed for both boy (p =.001) and girl (p =.028) participants.



Note: Amounts of MVPA increase as tertile increases from the 1st to the 3rd

Fig 1: Mean (95% CI) VO2max values by MVPA tertile and sex.

Table 1: Descriptive statistics of study variables, 2012 NNYFS adolescents 12 to 15 years of age.

Sex	Variable	N	Min	Max	Median	Mean	SE	CV
Boys	Age (yr)	228	12.0	15.0	12.9	13.4	0.10	0.77
	VO2max (ml/kg/min) [a]	228	27.8	92.6	41.9	43.2	0.87	2.02
	MPA (min/wk) [a]	224	0.0	2100.0	106.3	196.9	23.26	11.81
	VPA (min/wk) [a]	224	0.0	1680.0	217.2	313.4	24.05	7.67
	MVPA (min/wk) [a]	224	0.0	4620.0	474.0	707.2	63.52	8.98
	D60Min (days) [a]	227	0.0	7.0	4.5	4.7	0.11	2.30
	WC (cm)	228	57.0	125.8	76.4	79.2	0.71	0.90
	BMI (kg/m^2)	228	14.2	37.5	21.4	22.4	0.23	1.04
Girls	Age (yr)	223	12.0	15.0	12.9	13.4	0.08	0.62
	VO2max (ml/kg/min)	223	23.2	87.5	36.5	38.4	0.52	1.35
	MPA (min/wk)	223	0.0	900.0	38.1	131.2	19.52	14.88
	VPA (min/wk)	223	0.0	1680.0	59.5	216.2	24.96	11.55
	MVPA (min/wk)	223	0.0	2400.0	321.9	478.7	52.93	11.06
	D60Min (days)	223	0.0	7.0	4.1	4.2	0.11	2.50
	WC (cm)	223	59.8	132.3	77.6	80.5	1.24	1.54
	BMI (kg/m^2)	223	14.7	48.3	21.8	23.1	0.41	1.80

Note: [a] indicates a significant ($p<.05$) mean sex difference. VO2max is estimated maximal oxygen consumption. MPA is moderate physical activity (PA). VPA is vigorous PA. MVPA is moderate-to-vigorous PA. D60Min is number of days physically active at least 60 minutes. WC is waist circumference. BMI is body mass index. SE is standard error of Mean. CV is coefficient of variation.

Table 2: Odds of low CRF in relation to PA and dual BMI.WC status, 2012 NNYFS adolescents 12 to 15 years of age.

	MPA			VPA			MVPA			D60Min		
Variables	OR	LL	UL	OR	LL	UL	OR	LL	UL	OR	LL	UL
Unadjusted												
PA												
High	1.00			1.00			1.00			1.00		
Low	1.02	0.66	1.57	2.24	1.54	3.26	2.20	1.47	3.30	1.38	1.00	1.90
BMI.WC												
Low	1.00			1.00			1.00			1.00		
High	2.81	2.08	3.80	2.73	2.12	3.52	2.77	2.15	3.55	2.82	2.12	3.74
Adjusted												
PA												
High	1.00			1.00			1.00			1.00		
Low	1.09	0.67	1.78	2.36	1.65	3.36	2.40	1.56	3.69	1.46	1.00	2.14
BMI.WC												
Low	1.00			1.00			1.00			1.00		
High	2.92	2.15	3.95	2.89	2.25	3.71	2.89	2.25	3.73	2.94	2.22	3.90

Note: PA is physical activity. BMI.WC is a dual measure where ‘high’ represents high on both WC and BMI otherwise ‘low’. Low and high MPA, VPA, MVPA and CRF groups were created at sex-specific median values. High D60Min was defined as meeting 60+ minutes of PA 7 days per week. Unadjusted models include PA and BMI.WC only. Adjusted models additionally control for age, sex, race, and income. OR is odds ratio estimate. LL is lower limit of the 95% CI. UL is upper limit of the 95% CI.

Discussion

The purpose of this study was to examine the extent to which PA and a dual measure of BC relate to CRF in US adolescents. Results clearly showed that PA and the dual BC measure each independently relate to CRF in this population. With one caveat, that MPA was not independently or otherwise related to CRF in adolescents. This finding indicates that the vigorous-intensity component in measures of VPA, MVPA, and D60Min, likely explains the CRF association. Moreover, this finding has been corroborated in the literature, with research showing improvements in CRF from VPA intervention in adolescents [20] other studies also have shown improvements in CRF from VPA intervention with less or no improvements from MPA intervention [21-24] the current study also saw a dose-response relationship between MVPA and CRF in adolescents. These results are consistent with published research, with one study specifically showing a linear trend in adolescent CRF across VPA tertiles [25] finally, the current study found that the dual BC measure, BMI.WC, was independently related to CRF in adolescents. This finding is a unique contribution to the literature. However, research has shown PA and single measures of BC independently related to CRF [26] Conversely, some research has found single BC measures not independently related to CRF [27] Therefore, future research is needed to support dual measures of BC as independent predictors of CRF in adolescents.

The current study has strengths worth mentioning. One strength is its use of a nationally representative sample of U.S. adolescents ages 12 to 15 years. Another strength is the use of objectively measured BC and objectively measured CRF, assessed by trained medical professionals. There are also some limitations worth stating. The NNYFS is a cross-sectional study and therefore any findings should be considered correlational. Another limitation of this study was its inability to control for puberty. However, participant age was used as a control variable and likely minimized the confounding effect that puberty may have had. Given these limitations, these results should be considered with caution.

Conclusions

This study showed that PA and a dual measure of BC are independently related to CRF in U.S. adolescents. Specifically, adolescents with low amounts of VPA were much more likely to have low CRF, independent of BC. Additionally, adolescents dually high in BMI and WC were much more likely to have low CRF, independent of PA. Health promotion specialists should be aware that poor BC may lead to poor CRF, regardless of PA amounts, in this population.

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