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Mediating effect of waist circumference on the relationship between physical activity and cardiorespiratory fitness in adolescents

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ABSTRACT

Background: Physical activity (PA) and waist circumference (WC) are bothrelated to cardiorespiratory fitness (CRF). However, the extent to which PA relates to CRF through WC is not known. The purpose of this study was to examine the mediating effects of WC on the PA and CRF relationship in U.S. adolescents.

Methods: Data from youths 12 to 15 years of age participating in the 2012 NHANES National Youth Fitness Survey (NNYFS) were used. Variables included self-reported moderate-to-vigorous PA (MVPA, min/day), WC (cm), and CRF (ml/kg/min). Linear regression was used to examine the sex-specific influencethatMVPA and WChave on CRFwhile controlling for confounding variables. The multivariate delta method was used to estimate standard errors for the indirect effects.

Results: Findings from the fully adjusted sex-specific models showed MVPA and WC independently and significantly (all $p < .05$) related to CRF.Mediation analysis for boys indicated a significant indirect effect (ab = 0.0009, 95% CI: 0.0004-0.0015, 29% mediation) of MVPA on CRF through WC. Conversely, MVPA had no significant ($p = .277$) indirect effect on CRF through WC in girls.

Conclusion: This study shows that WC partially mediates the relationship between PA and CRF in adolescent boys but not girls. These findings highlight that PA can be promoted to improve WC which can then improveCRF in adolescent boys.

Keywords: Body composition, Waist circumference, Cardiorespiratory fitness, Adolescent health

INTRODUCTION

Mediation is a theoretical relationship where an independent variable (X) affects another variable (M) that then affects a dependent variable (Y). In this scenario, the mediator variable (M) is said to account for the relationship between the independent variable (X) and dependent variable (Y) [1]. Furthermore, if the mediator variable (M) explains all the variation between the independent variable (X) and dependent variable (Y), the mediator variable (M) completely mediates the relationship [2]. However, if the mediator variable (M) explains a significant percentage of the variation (but not all) between the independent variable (X) and dependent variable (Y), the mediator variable (M) partially mediates the relationship [2].

Both waist circumference (WC) and physical activity (PA) are known indirect and direct correlates of cardiorespiratory fitness (CRF), respectively [3-5]. However, no known studies to date have examined WC as a mediator variable in the PA and CRF relationship. This mediated relationship would have vast implications, if established, because it highlights a lesser promoted mechanism for the causal link between PA and CRF. Moreover, the mediating role of WC in the PA and CRF relationship has not been investigated in adolescent populations. Therefore, the purpose of this study was to examine the mediating effects of WC on the PA and CRF relationship in U.S. adolescents.

MATERIALS & METHODS

Study procedures

Data for this research came from the 2012 National Health and Nutrition Examination Survey's (NHANES) National Youth Fitness Survey (NNYFS). The goal of NNYFS was to assess physical activity and physical fitness levels in U.S. youth aged 3 to 15 years[6]. The NNYFS design included a four-stage probability sample of noninstitutionalized civilian U.S. residents with 1,640 youthinterviewed and 1,576 youthexamined. NNYFS data are publicly available and organized by *Demographics*, *Dietary*, *Examination*, *Questionnaire*, and *Limited Access*. For this study, *Demographic* and *Examination* data only were used from adolescents aged 12 to 15 years.

Study variables

WC was measured in centimeters (cm) at a horizontal plane, using a mirror, just above the iliac crest [7].CRF was measured using one of five submaximal exercise treadmill protocols varying in speed and grade [8]. 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.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 [9]. Vigorous PA (VPA, min/wk) was assessed similarly but regarding activities of vigorous-intensity causing large increases in breathing or heart rate [9]. MVPA (min/wk) was assessed by adding MPA to 2 × VPA.

In order to describe the sample and 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) male and 2) female. 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.Binary variables were also created at the sex-specific median for WC, MVPA, and CRF, for descriptive purposes.

Statistical analyses

The first part of the statistical analysis consisted of describing the sample in terms of high and low CRF and sociodemographic characteristics. Cross-tabulation and the Rao-Scott chi-square statistic (χ^2) provided prevalence estimates, standard errors (*SE*s), 95% confidence intervals (*CI*s), and probabilities associated with variable independence. Multipleleast squares regression was used to estimate the sex-specific independent effects of WC and MVPA on CRF. Mediation analysis was conducted using the Sobel multivariate delta method [10]. All analyses were weighted to produce generalizations representative of noninstitutionalized U.S. adolescents aged 12–15 years. SAS version 9.4was used for all analyses [11-13].

RESULTS

A total of *N* = 437 adolescents wereincludedin the analysis with complete PA, WC, CRF, and demographic data. Table 1 displays prevalence of CRF status by sociodemographic characteristics and study variables. CRF status was not significantly (*p*s > .05) related to any demographic variable. However, both WC and MVPA were significantly (*p*s < .05) related to CRF status, with higher prevalence of high CRF seen among adolescents with low WC and high MVPA. Table 2 displays results from the sex-specific regression analyses of CRF regressed on MVPA, WC, and covariates. As a requirement for mediation analysis, both MVPA and WC were independently related to CRF in boy and girl models.

Albeit, a stronger relationship in boys compared to girls, with approximately 20% and 7% explained variance, respectively. Table 3 displays mediation analysis statistics for both boy and girl models. Figures 1 and 2 similarly display mediation statistics with effects. Figure 1 indicates a significant indirect effect of *ab* = 0.0009 (95% *CI*: 0.0004-0.0015). This indirect effect indicates that 29% of the MVPA and CRF relationship is mediated by WC. More specifically, for every 10 min/weekincrease in MVPA, CRF in boys will increase by approximately .01 ml/kg/min because of WC.Figure 2, **c**onversely, indicates that MVPA had no significant (*p* = .277) indirect effect on CRF through WC in girls.

DISCUSSION

Thepurpose of this study was to examine the mediating effects of WC on the PA and CRF relationship in U.S. adolescents. The findings clearly show that WC in fact partially mediates the PA and CRF relationship in boys only. Furthermore, the mediating relationship in boys was substantial, accounting for over a quarter of the PA and CRF relationship. Additionally, this mediating relationship is noteworthy, considering the fact that PA is known to improve CRF by improvements to the muscular and cardiorespiratory systems and is not known to be affected by WC [14,15]. Further research is recommended to better understand the mediating role of WC on the PA and CRF relationship. As well, additional research is needed to fully understand the null findings in female adolescents. It is possible that other measures of body composition, such as hip girth, may be a better mediator in the PA and CRF relationship.

One strength regarding this study is its use of a nationally representative sample of U.S.adolescents ages 12 to 15 years. Therefore, generalizations from this study have strong external validity. Another strength worth mentioning is the use of objectively measuredWC and objectively measured CRF, each assessed by trained medical professionals. This strength distinguishesthe study's findings from other studies utilizing self-reported measures and non-standardized protocols. Despite these strengths, there are some limitations worth declaring.The NNYFS is not a longitudinal study but rather cross-sectional and therefore these findings should only be considered correlational. Another limitation of this study was its inability to control for puberty. However, age was controlled for in the models and likely minimized the confounding effect of hormone levels. Given these limitations,these results should be considered with caution.

CONCLUSIONS

This study shows that WC partially mediates the relationship between PA and CRF in adolescent boys but not girls. These findings highlight that PA can be promoted to improve WC which can then improve CRF in adolescent boys.

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Peter D. Hart solely contributed to all aspects of this research, including its design, data management, analysis, and manuscript writing.

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Table 1. Prevalence of CRF status by sociodemographic characteristics and study variables in adolescents 12 to 15 years of age, 2012 NNYFS.

	Low CRF				High CRF				χ^2
Variable	*%*	*SE*	*LL*	*UL*	*%*	*SE*	*LL*	*UL*	*p*
Sex									.897
Male	50.6	1.81	46.76	54.51	50.3	2.45	45.07	55.58	
Female	49.4	1.81	45.49	53.24	49.7	2.45	44.42	54.93	
Age (yr)									.562
12	30.6	3.45	23.23	38.02	25.4	3.07	18.79	31.94	
13	22.5	3.23	15.59	29.43	25.1	3.79	16.96	33.22	
14	26.1	2.36	21.00	31.13	28.0	3.86	19.73	36.29	
15	20.8	1.85	16.83	24.76	21.5	3.03	15.05	28.03	
Race									.751
White	56.6	9.03	37.19	75.95	55.6	7.53	39.41	71.70	
Black	15.2	6.53	1.23	29.23	14.0	4.35	4.67	23.32	
Hispanic	20.1	5.24	8.82	31.31	24.0	5.26	12.69	35.26	
Other	8.1	1.48	4.95	11.31	6.5	2.13	1.90	11.04	
Income (US $)									.094
0-14,999	7.5	2.60	1.89	13.06	10.9	2.54	5.45	16.34	
15,000-24,999	15.4	2.44	10.18	20.63	18.2	3.71	10.29	26.19	
25,000-44,999	22.0	3.51	14.51	29.58	11.9	1.78	8.09	15.72	
45,000-64,999	13.2	2.14	8.59	17.78	17.0	3.75	8.94	25.04	
65,000+	41.9	5.53	30.02	53.74	42.0	5.45	30.28	53.65	
WC									<.001
Low	33.0	3.32	25.85	40.09	62.4	3.20	55.59	69.30	
High	67.0	3.32	59.91	74.15	37.6	3.20	30.70	44.41	
MVPA									<.001
Low	59.1	2.35	54.06	64.14	37.4	3.57	29.79	45.10	
High	40.9	2.35	35.86	45.95	62.6	3.57	54.90	70.21	

Note. *N* = 437. MVPA is moderate-to-vigorous physical activity. WC is waist circumference. CRF is cardiorespiratory fitness. % is weighted prevalence estimate. SE is standard error. LL is lower limit of the 95% CI. UL is upper limit of the 95% CI. χ^2 is the Rao-Scott chi-square test of independence statistic. Low WC < 77.6 cm (girls) &< 76.5 cm (boys). Low CRF < 36.5 ml/kg/min (girls) &< 41.9 ml/kg/min (boys). Low MVPA < 324 min/week (girls) &< 472 min/week (boys).

Table 2. Regression analyses of CRF regressed on MVPA, WC, and covariates in adolescents 12 to 15 years of age, 2012 NNYFS.

	Boys (n = 219)			Girls (n = 218)		
Variables	*b*	*SE*	*p*	*b*	*SE*	*p*
MVPA (min/week)	0.002	0.001	**.024**	0.002	0.001	**.040**
WC (cm)	-0.239	0.057	**.001**	-0.151	0.063	**.032**
Age (yr)	1.482	0.544	**.017**	0.315	0.614	.617
Race						
White	ref			ref		
Black	2.040	2.506	.429	-1.499	1.662	.382
Hispanic	0.716	1.674	.675	-0.852	1.434	.562
Other	-0.939	1.852	.620	-3.277	1.434	**.038**
Income (1-12)	0.039	0.238	.872	-0.359	0.296	.244
R^2	.20			.07		
SEE	8.30			8.99		

Note. *b* is unstandardized slope coefficient. *SE* is standard error.

Table 3. Mediation analysis statistics using the Sobel multivariate delta method.

Statistic	Boys	Girls
a	-0.003932	-0.002389
b	-0.239187	-0.150935
ab	0.000941	0.000361
c'	0.002277	0.001844
c	0.003218	0.002205
SE.a	0.000592	0.001951
SE.b	0.057212	0.064007
SE.ab	0.000266	0.000332
Z	3.54	1.09
p	.000	.277
LL	0.0004	-0.0003
UL	0.0015	0.0010
%M	29.2	16.4

Note. a = direct effect of MVPA on WC. b = direct effect of WC on CRF. ab = indirect effect of MVPA on CRF. c' = direct effect of MVPA on CRF. c = total effect of MVPA on CRF (i.e., ab + c'). SE = standard error for respective coefficient. Z = test statistic for ab. p = p-value for Z. LL = lower limit of 95% confidence interval (CI) for ab. UL = upper limit of the 95% CI for ab. %M = percentage of total effect mediated by WC.

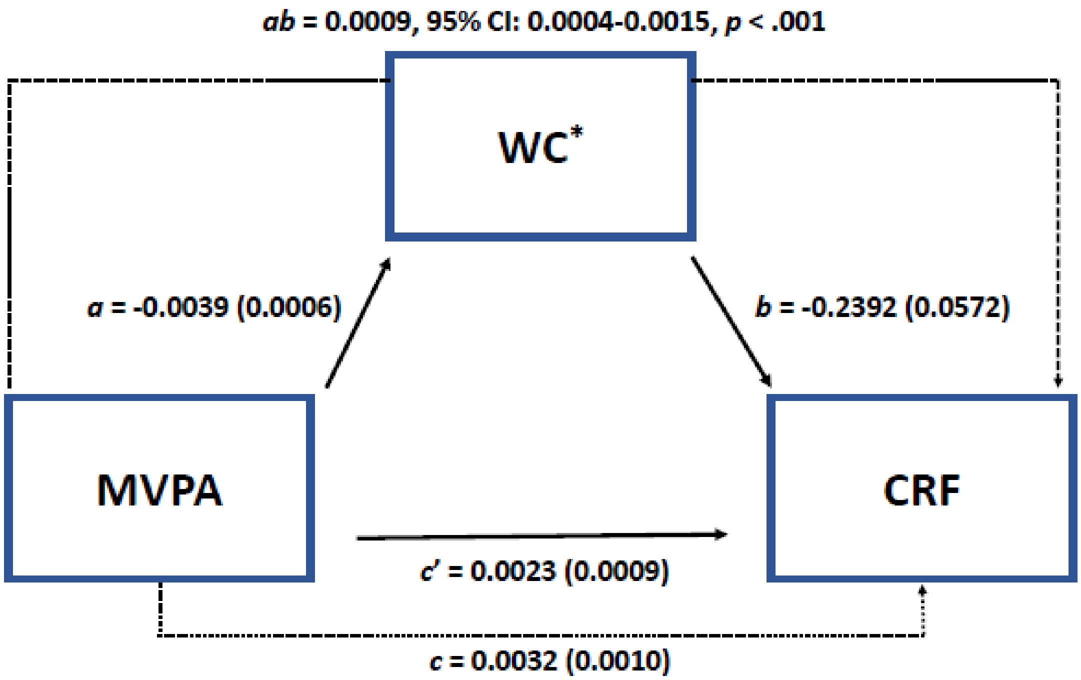

Figure 1. Association between MVPA and CRF mediated by WC and adjusted for age, race and income in boys. *a, b,* and *c′* = direct effects (SE) (solid arrows). *ab* = indirect effect (dashed arrow). *c* = total effect (SE) (dotted arrow). *WC mediates 29% of the MVPA and CRF relationship.

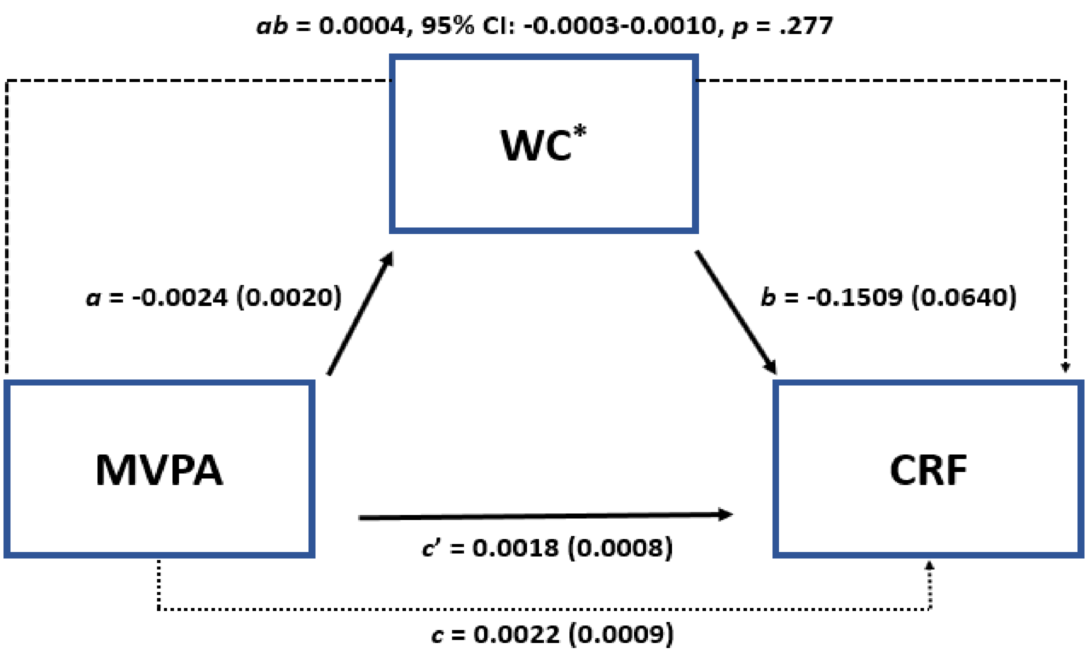

Figure 2. Association between MVPA and CRF mediated by WC and adjusted for age, race and income in girls. *a, b,* and *c′* = direct effects (SE) (solid arrows). *ab* = indirect effect (dashed arrow). *c* = total effect (SE) (dotted arrow). *WC does not mediate the MVPA and CRF relationship.