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Cardiorespiratory fitness in urban adolescent girls: associations with race and pubertal status

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Abstract

Cardiorespiratory fitness affords health benefits to youth. Among females, weight-relative fitness declines during puberty and is lower among African American (AA) than Caucasian girls. Data indicate racial differences in pubertal timing and tempo, yet the interactive influence of puberty and race on fitness, and the role of physical activity (PA) in these associations have not been examined. Thus, independent and interactive associations of race and pubertal development with fitness in adolescent girls, controlling for PA were examined. Girls in grades 5–8 (n = 1011; Caucasian = 25.2%, AA = 52.3%, Other Race group = 22.5%) completed the Pubertal Development Scale (pubertal stage assessment) and Fitnessgram® Progressive Aerobic Cardiovascular Endurance Run (PACER) test (cardiorespiratory fitness assessment). PA was assessed by accelerometry. Bivariate and multivariate analyses were used to examine associations among race, pubertal stage and fitness, controlling for vigorous PA, AA, and pubertally advanced girls demonstrated lower fitness than Caucasian and less mature counterparts. Puberty and race remained significantly associated with fitness after controlling for vigorous PA. The interaction effect of race and puberty on fitness was non-significant. The pubertal influence on fitness is observed among AA adolescents. Associations between fitness and race/puberty appear to be independent of each other and vigorous PA. Pubertally advanced AA girls represent a priority group for fitness interventions.

Keywords

VO_{2max}; physical activity; African American; Caucasian

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Introduction

Epidemiologic data indicating that the prevalence of obesity among African American (AA) girls, on average, is higher than among Caucasian girls, which is concurrent with a higher prevalence of Type II diabetes and elevated blood pressure in AA youth (Dabelea et al., 2014; Ogden, Carroll, Kit, & Flegal, 2012; Rosner, Cook, Daniels, & Falkner, 2013). The poor health profile of AA children warrants the investigation of factors which protect against the development of chronic diseases and associated risk factors. Cardiorespiratory fitness (also referred to as VO_{2max}) is associated with a range of positive health outcomes for children and adolescents and may thus be an important health attribute for AA youth to accrue (Ortega et al., 2008; Silva et al., 2013).

Multiple studies report lower weight-relative fitness levels among AA youth when compared to Caucasian youth (Andreacci et al., 2004; Pivarnik, Bray, Hergenroeder, Hill, & Wong, 1995; Shaibi, Ball, & Goran, 2006; Trowbridge et al., 1997; Wong et al., 1999). Suggested explanations for this difference include lower hemoglobin levels (Andreacci et al., 2004; Hunter, Weinsier, McCarthy, Enette Larson-Meyer, & Newcomer, 2001; Pivarnik et al., 1995) and a lower percentage of Type I muscle fibers among AAs than Caucasians (Ama et al., 1986). One factor not considered in many of these studies, which may contribute to racial differences in fitness among youth, is pubertal development.

During adolescence and across the pubertal years, VO_{2max} declines in females by 3–12 ml · kg.min^{-1} between the ages of 8–18 years (Malina, Bouchard, & Bar-Or, 2004). The decline in weight-relative fitness may reflect a puberty-related increase in body fat percentage, which results in a lower proportion of metabolically active tissue in females (Malina et al., 2004). The timing and tempo of pubertal events varies by racial group. Compared with Caucasian girls, AA girls are reported to start puberty earlier, take longer to progress from pubertal onset (the first appearance of secondary sexual characteristics) to menses, and take longer to progress from stage 2 to stage 3 of sexual maturation, according to Tanner's criteria (Herman-Giddens et al., 1997). These racial differences may contribute to differences in body composition (Kimm et al., 2001) and size (Sirard, Pfeiffer, Dowda, & Pate, 2008), which can affect performance during a cardiorespiratory fitness test. This information suggests that puberty and racial group may have an interactive influence on weight-relative fitness, yet this contention has not been examined. To our knowledge, the only study reporting fitness levels by pubertal status among AA and Caucasian youth reported higher relative VO_{2max} values for pubertally advanced compared with prepubertal youth in both AA and Caucasian groups (Andreacci et al., 2004). The inclusion of males and females in the calculation of average VO_{2max} values may explain these findings, as weight-relative fitness is known to decline in girls but increase in boys, post-puberty (Malina et al., 2004). Given the racial variation in the pubertal process and potential importance of fitness to the long-term health of AA females, direct examination of the interactive association of puberty and race with fitness is necessary.

In addition, few studies have examined the role of physical activity (PA) in the association between puberty and fitness, and race and fitness in youth. AA youth are reported to engage in less moderate-to-vigorous intensity physical activity (MVPA), and more sedentary

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behaviour than Caucasian youth (Bradley, McMurray, Harrell, & Deng, 2000; Sirard et al., 2008). The positive association between PA and fitness (albeit weak to moderate in youth; Baquet, Twisk, Kemper, Van, & Berthoin, 2006; Katzmarzyk, Malina, Song, & Bouchard, 1998; Pfeiffer, Dowda, Dishman, Sirard, & Pate, 2007), suggests that lower PA levels may contribute to lower cardiorespiratory fitness levels among AA youth, yet few studies exploring racial differences in fitness have examined the concomitant influence of PA. Thus, the purpose of this study was to examine the independent and interactive associations of race and pubertal development with cardiorespiratory fitness in adolescent girls, while controlling for PA.

Methods

Study design and participants

Baseline data collected during the fall of the first (2012) and second years (2013) of a group randomised controlled trial (RCT) that included a school-based PA intervention were used. A detailed description of the intervention and its theoretical basis has been reported elsewhere (Robbins et al., 2013). Inclusion criteria for the RCT were: (1) girls in grades 5–8, and (2) able to read, understand, and speak English. Exclusion criteria were: (1) involvement in organised sport or activity requiring MVPA on 3 or more days a week after school, and (2) having a health condition that prevented participation in PA or exercise. Data included herein were collected prior to randomization to intervention versus control condition.

Procedure

The University Biomedical Institutional Review Board and school district administrators approved the study protocol (IRB# 11–247, initial application #: i038097). At the beginning of the 2012–2013 and 2013–2014 academic years, the research team introduced the study to prospective participants at each school. Students were provided with information packets (including consent and assent forms, and an inclusion/exclusion-criteria screening questionnaire) to share with their parents. Students were informed that returning completed forms the following day would earn them $5.00, regardless of whether they decided to participate or not.

Demographics

Age, race, ethnicity, and school grade were reported by the participants' parent/legal guardian. Socio-economic status (SES) was assessed by asking about the participants' eligibility for a free or reduced-price school lunch.

Anthropometrics

Height (cm) and weight (kg) were measured according to standardised procedures (Lohman, Roche, & Martorell, 1988). Two measures of height (within 0.5 cm of each other), and two measures of weight (kg) were averaged, and the mean value was used to calculate body mass index (BMI; weight [kg]/height [m^2]) and BMI-z score (http://www.cdc.gov).

Fitness

Cardiovascular fitness was assessed using the Progressive Aerobic Cardiovascular Endurance Run (PACER) test, the procedure for which is described in detail elsewhere (The Cooper Institute, 2010). Participants were required to run 15 m or 20 m laps (depending on school space) between two cones, reaching each cone in time with an audio cue. As the test progressed, the time between the audio cues decreased. Participants were considered to have ended the test when they failed to reach the next cone in time with the matching audio cue for two consecutive laps. The number of laps completed by the participant were converted to the mile equivalent and used to estimate VO_{2max} (ml.kg $\cdot$ min^{-1}) according to the following equation: $VO_2 = (-8.41 \times(\text{mile equivalent})) + (0.34 \times(\text{mile equivalent} \times \text{mile equivalent})) + (0.21 \times(\text{age} \times \text{gender})) - (0.84 \times \text{BMI}) + 108.94$ (Cureton, Sloniger, O'Bannon, Black, & McCormack, 1995).

Physical activity

PA was assessed by accelerometry (ActiGraph GT3X-plus). Participants wore the monitor on the right hip for 7 days. They were instructed on how to wear monitor, and told that they should wear the monitor at all times during the monitoring period, with the exception of swimming, bathing, and sleeping. To remind them to wear the monitor, participants received an automated phone call each morning during the data collection period.

The accelerometers were programmed to start collecting data at 5.00 am on the day following the distribution of monitors to participants. Data were collected in raw mode and integrated into 15-s epochs, and cut-points established by Evenson, Catellier, Gill, Ondrak, and McMurray (2008) were used to distinguish activity of sedentary (<26 counts per 15 s), light (26–573), moderate (574–1002), and vigorous intensity (≥1003). Non-wear periods were identified as intervals of at least 60 consecutive minutes of zero activity counts, and these data were excluded from the final analysis. Only participants providing a minimum of 8 hours of valid accelerometer data on 4 days (three weekdays and one weekend day) were included in the analysis (Jago et al., 2013; Matthews, Hagströmer, Pober, & Bowles, 2012; Patnode et al., 2011). To control for differences in wear time, PA variables were expressed as minutes of PA per hour.

Pubertal development

Pubertal development was assessed using the Pubertal Development Scale (Petersen, Crockett, Richards, & Boxer, 1988). The Pubertal Development Scale is a self-report measure of pubertal development, which has been validated against physician assessments of pubertal status with correlations of 0.6–0.7 (Brooks-Gunn, Warren, Rosso, & Gargiulo, 1987). Girls self-reported their pubertal development in the following areas: body hair, breast growth, skin changes, and growth spurt, by indicating one of the following four response choices: (a) no, (b) yes, barely, (c) yes, definitely, (d) development complete. The response choices were scored from 1–4 points, respectively. Participants were also asked whether they had experienced menarche ("yes" or "no" response choices, no = 1 point, yes = 4 points). A summary score for pubertal development was created, by calculating the average of the five questions (higher scores indicated more advanced pubertal development). To create pubertal categories, the scores for body hair and breast growth were summed.

Participants with a total score of three or less and reporting “no” for menstruation were categorised as being in early puberty. Participants with a total score of four or more and reporting “no” for menstruation were categorised as being in middle puberty. Participants were categorised as being in late puberty if they responded “yes” to menstruation (Carskadon & Acebo, 1993). The Pubertal Development Scale was completed behind a privacy screen. A female member of the research team was present to assist participants with the completion of the survey, if needed.

Statistical analyses

Data were analyzed using Statistical Package for the Social Sciences (SPSS) 22.0 for Windows. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were calculated to describe demographic and PA variables. Previous literature indicates that of the typical PA intensity classifications (sedentary, light, moderate, moderate–vigorous, vigorous), vigorous PA consistently demonstrates the strongest association with fitness (Denton et al., 2013). To verify that vigorous PA was the most appropriate activity variable to use as a covariate in the final analysis, correlations between fitness and time spent sedentary and in light, moderate, moderate-vigorous, and vigorous PA were inspected. Vigorous PA demonstrated the strongest correlation with fitness ($r = 0.20$, $P < .001$) and was included as the PA covariate in subsequent analyses. Age and BMI were components of the VO_{2max} prediction equation and therefore were not included as covariates. To control for age differences across pubertal categories, school grade was included as a covariate. One-way analysis of variance (ANOVA) with Scheffé post hoc tests was used to examine fitness by race and pubertal status, controlling for vigorous PA and school grade. Two-way ANOVA was used to examine the interactive effect of race and pubertal status on fitness, controlling for vigorous PA, and school grade.

Results

A total of 1011 5th–8th grade girls from 16 urban schools, with a mean age of 12.20 years ($SD = .96$) participated. The majority of the sample ($n = 803$, 85.5%) qualified for a free or reduced price school lunch. The sample included 255 Caucasian girls, 528 AA girls, and 228 girls from other races (combined to represent an “Other Races” group; see Table 1). The Other Race group comprised Asian, Indian, and Hawaiian girls, girls identifying with more than one racial group, and girls indicating “other racial group” on the demographic questionnaire. The majority of the sample (51.4%, $n = 519$) were classified as being in the late stage of pubertal development, with smaller proportions in the middle (38.3%, $n = 387$) and early (10.2%, $n = 103$) stages of pubertal development (see Table 2).

Mean age and BMI z-score were significantly higher among AA girls when compared with Caucasian girls, and among girls in late puberty when compared with girls in early and middle puberty (see Tables 1 and 2). Time spent sedentary, and in light, moderate and vigorous PA did not differ by racial group. Activity levels were significantly different across pubertal categories, with girls in the early stages of pubertal development engaging in the highest levels of light, moderate, and vigorous PA and girls in late pubertal stages engaging in the lowest. Time spent sedentary was significantly higher among girls in late pubertal stages. Caucasian girls had significantly higher cardiorespiratory fitness than AA girls (38.5 ml.kg · min^{-1} vs. 37.0 ml.kg · min^{-1}, respectively, $P < 0.05$), and girls in late puberty had significantly lower cardiorespiratory fitness (36.0 ml.kg · min^{-1}) than girls in early (39.7 ml.kg ·min^{-1}) and middle (38.8 ml.kg · min^{-1}) stages of puberty. After controlling for vigorous PA and grade, the independent associations between fitness and race, [F(2923) = 4.956, $P = .007$] and fitness and puberty [F(2921) = 21.690, $P < 0.001$] remained significant. There was a non-significant interaction effect of race and puberty on fitness, before and after controlling for vigorous PA and grade.

Discussion

This study examined independent and interactive associations between pubertal development and race with cardiorespiratory fitness in adolescent girls, adjusting for vigorous PA. AA race and late pubertal stage were associated with significantly lower cardiorespiratory fitness, and the associations were not explained by variation in vigorous PA. The non-significant interaction effect of race and puberty on fitness suggests that race and pubertal development influence fitness independently.

The greater cardiorespiratory fitness among Caucasian girls when compared with AA girls is consistent with previous findings (e.g., Pivarnik et al., 1995; Shaibi et al., 2006). Research has indicated that lower hemoglobin levels, a lower proportion of Type I muscle fibers, and racial differences in muscle physiology are likely to play a role in explaining the lower fitness of AAs (Ama et al., 1986; Pivarnik et al., 1995; Roy et al., 2006). Previous research has also suggested that lower PA among AA youth may contribute to lower cardiorespiratory fitness among this racial group (Lohman et al., 2008), although few studies have examined this contention. The current results do not indicate that differences in vigorous PA, explain the lower cardiorespiratory fitness among AA youth. Consistent with this finding, Sirard et al. (2008) compared AA and Caucasian youth, and reported lower PA among the AA children, but no racial differences in weight-relative cardiorespiratory fitness, indicating that differences in PA were not reflected in racial differences in fitness. In addition, Ceaser, Fitzhugh, Thompson, and Basset Jr (2013) examined National Health and Nutrition Examination Survey (NHANES) data on fitness, race, and PA among adults, and reported that race remained a significant predictor of VO_{2max} after controlling for PA. Collectively, the findings suggest that racial differences in cardiorespiratory fitness are not reflective of variation in vigorous PA, and the extant literature supports the role of physiological differences in explaining the lower cardiorespiratory fitness of AAs.

The finding of a negative association between pubertal development and weight-relative fitness among females has been well-documented (Malina et al., 2004; Mota et al., 2002; Ortega et al., 2008), and the current investigation extends this finding to a large cohort of AA adolescents. Only one other study was found that provided cardiorespiratory fitness values by pubertal status for different racial groups. Conflicting with findings of the current study, results indicated pubertally advanced Black youth had higher weight-relative VO_{2max} values compared with prepubertal Black youth, and pubertally advanced White youth had higher weight-relative VO_{2max} values than prepubertal White youth (Andreacci et al., 2004). The inclusion of males and females in the calculation of average VO_{2max} values in the study by Andreacci et al. (2004) may account for the unexpected findings, as weight-relative fitness is known to decline in girls but increase in boys, postpuberty (Malina et al., 2004; Mota et al., 2002). The current study thus adds to a limited evidence reporting the association between fitness and puberty among AA youth.

Variation in vigorous PA did not explain the lower cardiorespiratory fitness of girls in late puberty, and this finding is consistent with a small body of previous literature (Nes, Østhus, Welde, Aspenes, & Wisløff, 2013; Ortega et al., 2008). According to Mota et al. (2002), a puberty-driven increase in body fat in females may explain the decline in weight-relative fitness during the adolescent years. Previous literature has reported that body fat is a stronger predictor of fitness in youth when compared with variables such as height and PA (Janz & Mahoney, 1997; Mota et al., 2002). Neither body fat nor BMI were treated as covariates in this study due to the inclusion of BMI in the prediction equation for VO_{2max} (Cureton et al., 1995). Controlling for BMI-z score or body fat in the statistical analyses would not have been appropriate because body mass was accounted for.

The influence of puberty on cardiorespiratory fitness may be partially mediated by PA, as the current findings and previous literature indicate a negative association between pubertal development and PA (Cumming, Sherar, Esliger, Riddoch, & Malina, 2014; Smart et al., 2012) and positive association between PA and fitness (Baquet et al., 2006; Katzmarzyk et al., 1998). However, the relationship between PA and fitness is typically weak among youth (Pfeiffer et al., 2007), particularly when compared to the association between body fat and fitness (Janz & Mahoney, 1997). Thus, the inclusion of an indicator of body mass in the calculation of VO_{2max} may be overshadowing any vigorous PA-related variation in cardiorespiratory fitness in the current study. The relationships among fitness, fatness, PA, and puberty are complex and future research using longitudinal study designs would help to clarify the causal pathways between these variables, and independent versus interactive influences of these variables on fitness.

The interaction effect of puberty and race on VO_{2max} was non-significant, suggesting that puberty and race are independently associated with cardiorespiratory fitness among this cohort of low SES, urban, adolescent girls. Supporting the non-significant interaction effect, the previous discussion highlights that these variables influence fitness via different mechanisms. Additionally, lower fitness and lower hemoglobin levels among AAs have been reported among prepubertal samples (Andreacci et al., 2004; Trowbridge et al., 1997), suggesting that racial differences in fitness and physiological determinants of VO_{2max} are present prior to puberty. The mean age of the current sample was 12.2 years and the majority of participants were in the late stages of pubertal development, particularly among the AA subgroup. Thus, to substantiate the current finding of no interactive effect of puberty and race on cardiorespiratory fitness, replication of this study with a younger cohort, among which variation in pubertal development would be greater, is necessary.

Strengths of this study include the large sample size and representation of AA adolescent girls. The findings make a valuable contribution to a limited body of literature examining the influence of puberty on fitness in AA females and the role of vigorous PA in explaining racial and pubertal differences in fitness. The recruitment of a low SES sample provides valuable information about a population demographic at increased risk for chronic disease. Limitations of this study include controlling for school grade, rather than decimal age, in the statistical analyses, the estimation of VO_{2max} using a field test rather than a laboratory-based test with expired gases collected, and a self-reported method of assessing pubertal status. The large sample size and school-based data collection sessions made the use of indirect calorimetry and objective assessment of pubertal status not feasible. Time spent sedentary and screen time are related to fitness in youth (Fröberg & Raustorp, 2014; Hardy, Dobbins, Denney-Wilson, Okely, & Booth, 2009; Mitchell, Pate, & Blair, 2012); the role of screen time in the relationships among race, puberty, and fitness has not been explored and represents an area for future research.

The current study indicates that among this sample of low SES, urban adolescent girls, race and pubertal development were independent predictors of fitness. While vigorous PA was significantly associated with pubertal development and VO_{2max}, differences in vigorous PA did not explain pubertal or racial differences in cardiorespiratory fitness. AA girls in later stages of puberty should be considered a priority group for fitness interventions. While physiological predictors of racial differences in fitness have been identified, few modifiable factors are known; in the endeavour to improve the long-term health prospects of AA youth, future research should endeavour to identify predictors of fitness among this racial group, which are amenable to change and can be targeted in public health interventions.

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Table 1

Participant characteristics by racial group; mean (SD).

	Total sample (*n* = 1011)	**Caucasian (*n* = 255)**	**African American (*n* = 528)**	**Other Race (*n* = 228)**	**Group comparisons (*P* < 0.05)**
Age (years)	12.2 (0.96)	12.0 (0.93)	12.3 (0.92)	12.2 (1.07)	AA > C
Height (cm)	155.1 (8.0)	152.9 (7.8)	156.7 (7.5)	153.6 (8.5)	AA > C, OR
Weight (kg)	58.0 (18.1)	53.6 (16.6)	60.4 (18.0)	57.3 (19.0)	AA > C
BMI z-score	1.06 (1.03)	0.89 (1.02)	1.13 (1.02)	1.07 (1.03)	AA > C
Vigorous PA (minh^{-1})	0.7 (0.6)	0.7 (0.5)	0.8 (0.6)	0.7 (0.5)	NS
VO_2max (ml.kg · min^{-1})	37.5 (5.2)	38.5 (4.9)	37.0 (5.2)	37.3 (5.4)	AA < C
Accelerometer counts per minute	397.6 (238.2)	387.7 (127.6)	408.0 (282.4)	379.2 (121.6)	NS
Accelerometer wear time (minday^{-1})	832.3 (88.3)	807.8 (68.2)	843.4 (95.4)	835.1 (87.1)	C < AA, OR
Time spent sedentary (minh^{-1})	39.3 (4.3)	39.3 (4.3)	39.2 (4.3)	39.6 (4.2)	NS
Light PA (minh^{-1})	17.8 (3.5)	17.9 (3.5)	17.8 (3.5)	17.7 (3.4)	NS
Moderate PA (minh^{-1})	2.1 (0.8)	2.1 (0.9)	2.2 (0.8)	2.0 (0.8)	NS

AA = African American, C = Caucasian, OR = Other Race, NS = Non-significant

Table 2

Participant characteristics by pubertal group; mean (SD).

	Early puberty (*n* = 103)	**Middle puberty (*n* = 387)**	**Late puberty (*n* = 519)**	**Group comparisons (*P* < 0.05)**
Age (years)	11.6 (0.77)	11.8 (0.77)	12.7 (0.92)	L > E, M
Height (cm)	148.6 (7.4)	152.2 (7.4)	158.5 (6.9)	L > E, M M > E
Weight (kg)	47.1 (12.3)	52.1 (15.7)	64.5 (18.2)	L > E, M M > E
BMI z-score	0.66 (1.14)	0.82 (1.09)	1.31 (0.88)	L > E, M
Vigorous PA ($minh^{-1}$)	0.96 (0.59)	0.80 (0.58)	0.62 (0.49)	L < E, M M < E
VO_2max ($ml.kg \cdot min^{-1}$)	39.7 (4.0)	38.8 (4.9)	36.0 (5.3)	L < E, M
Accelerometer counts per minute	449.6 (142.3)	420.4 (123.9)	366.7 (279.5)	L < E, M
Accelerometer wear time ($minday^{-1}$)	824.4 (92.7)	827.1 (83.3)	837.9 (91.1)	NS
Time spent sedentary ($minh^{-1}$)	37.8 (4.1)	38.2 (4.0)	40.6 (4.23)	L > E, M
Light PA ($minh^{-1}$)	18.9 (3.1)	18.7 (3.3)	16.9 (3.5)	L < E, M
Moderate PA ($minh^{-1}$)	2.4 (0.9)	2.3 (0.8)	1.9 (0.8)	L < E, M

E = Early Puberty, M = Middle Puberty, L = Late Puberty, NS = Non-Significant