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Associations between physical activity and health-related fitness: Differences across childhood

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Abstract

The purpose of this study is to evaluate associations between physical activity (PA) intensities to aspects of health-related physical fitness (HRPF) across childhood (4-11 years). A sample of 160 children, including 4-5 years (n=55), 7-8 years (n=60), and 10-11 years (n=45) old, participated in this study. Five day PA levels (light, moderate, and vigorous) were measured using accelerometry. HRPF was assessed using curl-ups (abdominal strength/endurance), pushups (upper body strength/endurance), PACER (cardiorespiratory fitness) and grip strength. Hierarchical and linear multiple regression analysis quantified associations between HRPF components and PA levels across childhood. After controlling for BMI and age, cardiorespiratory fitness accounted for 3% of variation in vigorous in PA in 4-11 year-old children and significantly predicted 23% of variance in vigorous PA in late childhood. No other statistically significant associations between any aspect of fitness and any PA intensities were noted across age groups. These results support other research suggesting cardiorespiratory fitness may be the only aspects of HRPF that is related to various intensities of PA (as assessed via accelerometry), across childhood. An important implication of this study is that physical education should provide an equal emphasis on developing PA habits and HRPF as both are independently associated with health in childhood.

Keywords: Physical activity intensities, health, accelerometry, cardiorespiratory endurance, strength.

INTRODUCTION

Physical activity (PA) is a global descriptor of voluntary movement at various intensities that an individual performs (28), while physical fitness can be defined as the capacity to perform PA (25). Specifically, health-related physical fitness (HRPF) is defined by five components: cardiorespiratory fitness, muscular strength, muscle endurance, flexibility and body composition (8). While there is strong evidence linking both PA (17) and fitness (15) to health in youth, the relationship between the two constructs has been noted to generally be weak with correlations ranging from -0.16 to +0.24 (1,2,9,18,14,21,30). The generalized weak association between PA and HRPF in youth may be a function of the variability in measurement of PA/energy expenditure in children and adolescents across studies as well as potential differences in the strength of associations across age.

Limited evidence has addressed potential developmental differences across age when examining the relationship between PA and multiple components of HRPF. Katzmarzky et al. (18) in a cross-sectional study with a sample of 9-18 years old boys and girls, demonstrated that PA (measured by activity diaries) explained only 11% to 21% of the variance in health-related items (sit-ups, static leg strength, PWC150, skinfolds) (13). Though all canonical correlations were significant in most age groups, there were fluctuations in the strength of associations between each component of HRPF and moderate-to-vigorous PA and there was no clear trend in associations among HRPF components and PA across age groups. Aires et al., also followed changes in fitness (summed z-score of push-ups, curl-ups, 20m shuttle run) and total PA (measured by questionnaire) for three years in a sample of 11-19 year-old adolescents (1). Changes in PA were directly and independently associated with changes in fitness in three consecutive years after adjustments for sex, age, and fitness at baseline. However, to our knowledge, no research has examined changes in the strength of associations among objectively measured PA and components of HRFP across childhood age groups (i.e., early, middle and late childhood). This study is significant as it addresses associations between PA and multiple aspects of fitness across three specific age groups across childhood. Additionally, while the majority of data suggest the relationship between aspects of fitness and PA (i.e., total or moderate-to-vigorous PA) is relatively weak in youth, differences in associations among different PA intensities levels (i.e., light, moderate, and vigorous) and aspects of fitness have not been addressed. Although the promotion of 60 minutes or more of daily PA focuses on moderate-to-vigorous PA for youth, the 2008 PA guidelines emphasize the health benefits of physical activities that typically are classified as vigorous (e.g., jumping rope) (35). Vigorous activities are important as continually high effort levels of PA in vigorous activities are demanded to produce consistent physiological changes associated with fitness improvement (35). Thus, it seems logical that higher fit children may be participating in more high intensity, or vigorous PA.

Alternatively, light physical activities also increase metabolic rate from baseline and contribute to total daily energy expenditure (26), especially in overweight/obese youth. It also is conceivable that daily light PA may have a protective effect against excess fat mass (9). While most studies that have examined associations between PA and HRPF have assessed total PA (14,21,30) we noted only one study that has examined the relationship between aspects of fitness and different intensities of PA (2). Aires et al. examined associations between cardiorespiratory fitness (only one components of HRPF) and objectively measured PA intensities (light, moderate, moderate-to-vigorous, vigorous, very vigorous) in adolescents aged 11-18 years old and found cardiorespiratory fitness was correlated only with vigorous PA (2). To our knowledge, no research has examined associations among all components of HRPF and various objectively measured PA intensities across younger children. The diversity in measurement approaches and analytical approaches across the literature makes it difficult to draw appropriate conclusions regarding strength of associations between various measures of HRPF and various intensities of PA across ages. Therefore, the purpose of this study was to examine associations between multiple components of HRPF and objectively measured light, moderate and vigorous PA levels in samples of children in early middle and late childhood.

MATERIALS & METHODS

Participants

A convenient sample of youth ages 4–11 years (93 boys, 67 girls; Mean = 7.68 years, *SD* = 2.31) in three categories including early childhood (4-5 years; n=55, 28 boys and 27 girls), middle childhood (7-8 years; n=60, 36 boys and 24 girls), and late childhood (10-11 years; n=45, 29 boys and 16 girls), were tested. We grouped children into three age groups for data analysis to assess the potentially different associations across age group. Children were recruited from two rural schools in the southwest US. The sample was 58% Hispanic with the remaining participants being predominately non-Hispanic white. The majority of the children in the sample were classified as low socioeconomic status based on reduced lunch status. Prior to participation, approval from the schools districts and institutional human participants review board was obtained. Parental consent and child assent also were obtained. Youth with any physical disability or health condition that prevented completion of any of the fitness tests were not allowed to participate in testing. We conducted fitness testing using *FITNESSGRAM* (22) protocols for curl-ups (abdominal strength/endurance), pushups (upper body strength/endurance), and PACER (cardiorespiratory endurance) tests. We also included grip strength as a measure of total body strength. Previous research has demonstrated acceptable validity and reliability of these tests (22).

For younger children (4–5 years), we adapted the original PACER test protocols by having an adult run individually with children until the test ended. A recent study using 4–5 year old children (7) demonstrated high reliability for this adapted protocol (r = .84, p< .001). It is important to note that formal testing using the FITNESSGRAM is not recommended until the fourth grade (22) as many younger children, specifically ages 4–5, have difficulty in performing any pushups or curl-ups. A lack of experience, strength, and/or coordination and control in younger children may have influenced technical completion of pushup and curl-up tests. We examined grip strength using a children's hand grip dynamometer (Lafayette Instrument, Lafayette IN). The best score of three trials for each hand was averaged and used for data analysis (6).

Five-day daily PA levels were assessed using Actigraph accelerometers (Pensacola, FL). The Actigraph accelerometer has been validated for use in children and even children as young as preschool (29). Children were instructed to wear the accelerometers, which were attached by an elastic belt on the right hip during waking hours, with the exception of time spent bathing and engaging in other activities involving water. Children wore accelerometers for a minimum of five days (3 week and 2 weekend days) and were set at 15-second epochs. Counts were classified into light, moderate, and vigorous categories using empirically based cut points (10). Evenson et al.'s (10) ActiGraph cut points are recommended to estimate time spent in sedentary, light, moderate, and vigorous physical intensity activity in children and adolescents (33). Acceptable inclusion criterion for wear time was at least nine hours per day (27).

Procedures

Children completed a general warm-up routine before any HRPF testing. Height and mass of participants were measured using a physician's scale. Values to the nearest 0.5 cm and 100 g were recorded and these data used to calculate body mass index [BMI = weight (kg)/height (m^2)]. Trained research staff tested younger children (ages 4–5) individually on pushups, curl-ups, grip strength and the PACER test. Children ages 7–11 were tested in groups of two or three. Instruction and modeling for all children were provided on curl-ups, pushups, grip strength and the PACER test. Children also were prompted to demonstrate correct technique, if possible, on curl-ups and pushups (one or two trials) before the actual testing. Fitness tests were performed in a school gymnasium during their normal physical education time. In general, participants completed the HRPF tests during two testing sessions. Children completed the PACER test on a separate day from all other fitness tests. Compliance with wearing accelerometers was facilitated by guidelines previously published (34) and included: 1) a letter to the parents explaining placement of the accelerometer and by providing a simple diagram, 2) the use of parent-teacher conference nights to physically show the parent how to place the accelerometer, 3) a smiley face on accelerometer and belt to indicate right side up, 4) training in physical education classes to fit the belt and practice wearing it prior to formal data collection, 5) phone calls at home on the weekend to prompt wearing the belt, 6) checking placement of accelerometers in the children's home room every morning before classes started, and, 7) a sticker reinforcement chart to promote daily wearing of the belt to school.

Statistical Analysis

Three hierarchical multiple regressions were conducted to examine associations between fitness components and intensities of PA (light, moderate, and vigorous). Prior to conducing a hierarchical multiple regression, the relevant assumptions of this statistical analysis were tested. Firstly, a sample size of 160 was deemed adequate given 6 independent variables (age, BMI, curl-up, push-up, PACER, and hand grip) to be included in the analysis (32). The assumption of singularity was also met as the independent variables were not a combination of other independent variables. Residual and scatter plots indicated the assumptions of normality, linearity and homoscedasticity were all satisfied in entire sample (12). Age and BMI were entered at stage one of each regression as independent control variables. Cardiorespiratory endurance (PACER) was entered in stage two. Since muscular components (curl-up, push-up, and hand grip) measure health-related component differs from cardiorespiratory fitness, they all entered as independent variables at stage three to examine how they induce variance in PA above and beyond the cardiorespiratory fitness. Follow-up linear regressions by age group were run to examine predictors of the different PA intensities in each age group, separately if age was a significant predictor of hierarchical multiple regressions at stage three. Totally, a three-staged hierarchical multiple regression for each PA intensities (light, moderate, and vigorous) and three linear multiple regressions for each PA intensity in three age groups (4-5, 7-8, and 10-11 years) were conducted. Data analysis was carried out via SPSS version 20.0 for

Windows (Chicago, IL, US). Statistical significance was set at alpha levels less than 0.05.

RESULTS

Table 1 shows subjects' descriptive characteristics of age, fitness and PA levels across the three age groups. All measures of HRPF demonstrated higher average performances across age groups. PA levels did not follow that same trend. The 10-11 year-old group had the highest average LPA and that was followed by the 4-5 year-old group. The 4-5 year-old group and 7-8 years-old group had highest MPA and VPA, respectively. Correlations between variables are reported in Table 2 and the regression statistics are reported in Table 3.

The hierarchical multiple regression revealed that at stage one, age and BMI contributed significantly to the regression model, F (2,157) = 11.82, *p*< .001) and accounted for 13% of the variation in VPA. Introducing the cardiorespiratory fitness variables explained an additional 3% of variation in VPA and this change in R^2 was significant, F (1,156) = 6.72, *p*< .05. BMI was no longer a significant predictor of VPA when cardiorespiratory fitness was added in stage two. Adding muscular components in stage three did not explain any additional variance in VPA. When all six independent variables were included in stage three of the regression model, age and cardiorespiratory fitness were significant predictors of VPA and accounted for 17% of the variance in VPA, F (6,153) = 5.23, *p*<.001. Given the significant contribution of age and cardiorespiratory endurance as predictors of VPA, results of the follow-up linear regressions run by age group (4-5, 7-8, and 10-11 years old) showed that cardiorespiratory fitness was the only factor of HRPF significantly associated with VPA and accounted for 23% variance in VPA (β =.39, *p*<.05) in late childhood only. No other significant results were found between any component of HRPF and any intensity of PA across age groups.

Table 1. Descriptive data and row scores (n = 160; Mean ± SD).

Variables	4-5 years old (n=55)	7-8 years old (n=60)	10-11 years old (n=45)	Total (n=160)
Age (year)	4.96 ± 0.55	7.96 ± 0.59	10.63 ± 0.43	7.68 ± 2.31
BMI (kg/m^2)	16.11 ± 2.48	18.26 ± 4.09	21.97 ± 6.16	18.57 ± 4.92
Hang Grip	9.51 ± 3.11	16.98 ± 2.50	22.22 ± 3.93	15.89 ± 5.97
Pacer (S)	7.80 ± 3.26	17.28 ± 8.32	26.48 ± 12.32	16.61 ± 11.22
Push-ups (count)	1.98 ± 3.36	7.21 ± 7.09	8.11 ± 8.38	5.66 ± 7.02
Curl-ups (count)	2.22 ± 3.38	18.13 ± 19.72	32.17 ± 21.96	16.61 ± 20.56
Ave LPA (min/day)	156.20 ± 57.56	146.42 ± 32.82	163.35 ± 63.01	154.55 ± 51.68
Ave MPA (min/day)	42.21 ± 17.80	25.14 ± 6.95	24.18 ± 12.07	30.83 ± 15.49
Ave VPA (min/day)	16.16 ±7.29	27.77 ± 4.87	10.78 ± 8.04	13.41 ± 7.27

BMI, body mass index; LPA, light physical activity; MPA, moderate physical activity; VPA, vigorous physical activity; SD, standard deviation; S, second; Ave, average.

DISCUSSION

The purpose of this study was to evaluate associations between PA intensities, assessed by accelerometer, and aspects of HRPF across early (4-5), middle (7-8) and late (10-11) childhood. The main finding of this study was that after controlling for BMI and age, cardiorespiratory fitness accounted 3% of variation in vigorous in PA in 4-11 years old children and, more notably, 23% of variance in vigorous PA late childhood. No other significant associations between any intensity of PA with any aspect of HRPF were found. While this result is consistent with the general findings of previous literature, these data provide more direct evidence on the relationship between multiple measures of HRPF and objectively assessed PA across childhood age groups. These results agree with a number of studies, specifically in late childhood

(e. g., 18) that reported a weak to moderate association between PA and cardiorespiratory fitness. Indeed, youth that engage in more intense exercise are more likely to improve their cardiorespiratory fitness (11) and sustain intense activity for a longer time. In addition, the alignment of the measurement device with the mode of fitness assessment (i.e., cardiorespiratory endurance via running) may also provide an understanding of why cardiorespiratory fitness is the most consistent correlate with accelerometry. This result also may be due in part to differences in age groups via and growth-related changes that occur in late childhood as the age range of 10-12 years is the time frame where maximal aerobic power (VO_2 max) experiences an increase in most children (19). It was somewhat surprising that no other statistically significant associations were found between any HRPF test and vigorous PA levels. This speaks to the relative independence between aspects of HRPF and PA, specifically as they change across childhood (4,21). For example, Malina (21) did not find an association between PA and muscle strength or body composition, even though one of the outcomes suggested to be developed with PA across childhood is muscle strength (21). This result may indicate that other types of stimulus (e.g. specific types of resistance training) are needed in order to improve muscular strength (36). Overall, the relationship of PA with muscular strength is poorly understood especially in young people and more research is warranted.

Table 2. Correlations among variables across age-groups.

Variables	BMI	Handgrip	PACER	Push-ups	Curl-ups	AveLPA	AveMPA	AveVPA
Age								
4-11 yrs.	.470**	.865**	.670**	.374**	.615**	.035	-.482**	-.289**
BMI								
4-5 yrs.		-.003	-.149	-.050	-.185	.031	.200	-.085
7-8 yrs.		.340	-.400	-.429	-.187	.168	.009	-.227
10-11 yrs.		.532**	-.552**	-.452**	-.182	-.180	-.141	-.322*
4-11 yrs.		.552**	-.003	-.171*	.139	-.006	-.203*	-.328**
Handgrip								
4-5 yrs.	-.003		.578**	.361**	.437**	-.115	-.144	.049
7-8 yrs.	.340		.085	-.060	.161	.134	.123	.061
10-11 yrs.	.532		-.086	.053	.006	-.125	-.046	-.194
4-11 yrs.	.552**		.580**	.346**	.528**	-.009	-.459**	-.276**
PACER								
4-5 yrs.	-.149	.578**		.471**	.578**	-.125	-.169	.124
7-8 yrs.	-.400	.085		.430	.403	-.130	.106	.221
10-11 yrs.	-.552	-.086		.768**	-.027	.051	.279	.422**
4-11 yrs.	-.003	.580**		.655**	.487**	.013	-.260**	.008
Push-ups								
4-5 yrs.	-.050	.361**	.471**		.515**	.100	.043	.160
7-8 yrs.	-.429	-.060	.430		.260	-.106	.118	.275
10-11 yrs.	-.452	.053	.768		.148	.116	.173	.231
4-11 yrs.	-.171*	.346**	.655**		.367**	.038	-.137	.081
Curl-ups								
4-5 yrs.	-.185	.437**	.578**	.515**		-.033	-.070	-.014
7-8 yrs.	-.187	.161	.403	.260		-.195	.057	.160
10-11 yrs.	-.182	.006	-.027	.148		-.042	-.034	.073
4-11 yrs.	.139	.528**	.487**	.367**		-.037	-.288**	-.103

*P<.05; **P<.01

Table 3. Summary of hierarchical regression analysis for variables predicting VPA (n = 160).

Variable	R^2	ΔR^2	b	t
Step one	.13*	.13*		
Age			-.54*	-2.05*
BMI			-.36*	-2.92*
Step two	.16*	.03*		
Age			-1.33*	-3.33*
BMI			-.18	-1.34
PACER			.18*	2.59*
Step three	.17	.004		
Age			-1.3*	-2.44*
BMI			-.14	-.89
PACER			.17*	2.04*
Handgrip			-.06	-.32
Push-up			.05	.48
Curl-up			.01	.55

* $p < .05$.

Findings of this study also did not show any other significant associations among aspects of HRPF and other intensities of PA. This may be due to a lack of agreement in cut-off points used to define PA with accelerometer. However, we used established cut point classifications acceptable for all levels of PA in children and adolescents (33). Indeed, there is a lack of consensus with regard to the cut-off points applied to define intensity levels in youth, which can lead to differences in the amounts of time spent in each PA level depending on the criterion selected to distinguish different intensities of PA (3).

A strength of this study was the use of accelerometers to assess different intensities of PA. The use of an objective PA measure with a high compliance rate (at least 9 hours/day) enhances the confidence in our findings because it was suggested that objective measures such as accelerometers provide more valid assessments for youth of all ages (37). Moreover, this study methodology specifically addressed potential differences across three childhood age ranges (i.e., early, middle, and late childhood). However, in light of findings from this study, some methodological issues should be considered. One potential consideration is associated with differences in estimating vigorous PA according to epoch time (sampling interval) procedures. Some studies point out that a shorter epoch (5 or 1 seconds) would be more sensitive to assess PA than the epoch used in this study (15 seconds), specifically for vigorous PA in young children as they demonstrate more short bursts of PA (24). In addition, the construct validity of HRPF assessments in early and middle childhood may not be as strong as in late childhood due to various issues including a lack of experience (i.e., coordination and control) in specific multi-joint movements (e.g., push-ups and curl-ups) as well as potential cognitive capability and motivation issues related to completing the tests with maximum effort (15). However, a child's capability to complete the HRPF tests at various levels demonstrates their functional capability to control and coordinate their body mass in various types of real-life movements. Thus, these types of field-based tests (along with other developmentally appropriate movements) are important for children to be able to demonstrate across childhood (23). Although the relationship between PA and HRPF in youth may be confounded by physical development and maturational changes (20), we could not assess potential effects of maturation as these data were not available. Although this study compared associations across different age groups; longitudinal tracking of HPRF and PA would provide more specific information regarding changes in the strength of associations across childhood.

This study demonstrates the relative independence of PA behaviors and HRPF levels across specific ages in childhood. Based on results of this study and others, as well as the fact that PA and HRPF are independently associated with health markers and outcomes, it seems logical that childhood interventions should emphasize both PA and aspects of HRPF to meet the goal of at least 60 min moderate to vigorous/vigorous PA per day and healthy fitness levels in childhood. However, since recent meta-analyses suggest childhood focused PA and fitness interventions have largely been either unsuccessful or only minimally impactful in producing sustained increases in PA or fitness (31) developing and implementing intervention strategies with a developmental focus may be warranted. There is strong evidence showing a positive relationship between the development of motor competence and different intensities of PA and multiple aspects of

HRPF across childhood and into adolescence (e.g., 16). Thus, it may be important to promote context specific, developmentally appropriate physical activities that enhance a child's capability to successfully navigate various PA environments and enhance aspects of fitness data indicates these integrated aspects of child development, along with aspects of self-concept, synergistically and recursively interact across childhood (e.g., 5). Thus, a comprehensive approach for developing and sustaining health-enhancing PA and HRPF across childhood may prove to be more successful than addressing them individually.

Applicable Remarks

- This is the first study to examine associations between objectively assessed physical activity and multiple components of health-related physical fitness across childhood.
- Data generally agrees with previous data which cardiorespiratory fitness is only related to vigorous physical activity.
- No other associations noted between physical activity and health-related physical fitness.
- This study highlights potential need to address physical activity and health-related physical fitness separately to promote health.

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