Cardiorespiratory Fitness Performance in Middle School Years: Changes and Correlates

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INTRODUCTION

Research has shown that high cardiorespiratory fitness is associated with lower cardio-metabolic and obesity risks in children (Boddy et al., 2014). Cardiorespiratory fitness performance has also been linked to improved academic performance among school-aged youth (Bass et al., 2013; Bezold et al., 2014; Welk et al., 2010).

While a number of studies have investigated cardiorespiratory fitness among school-aged youth, results are influenced by a variety of methodological limitations. Primarily, this research line relies heavily on small, convenient, or limited samples and does not take into consideration individual and/or school-level factors that can influence performance (Harris & Cale, 2006).

An existing cardiorespiratory endurance dataset collected by the school districts was analyzed for this study. A longitudinal multilevel design was used, where middle school students were tested annually over a period of three years as they progressed from sixth to eighth grade while the same curriculum (*Five for Life* Curriculum – Intermediate) was implemented.

METHODS

Participants

Participants included 44,801 middle school students from 33 middle schools in an Eastern state, shown below.

Student level	Frequency	School level	M ± SD	Min	Max
Boys/Girls	51.9%/48.1%	FARM (%)	40.11 ± 19.33	2.6	79.40
Grade 6	30.0%	S/F-PE	186.44 ± 40.39	93	281
Grade 7	33.6%	SAP (%)	77.65 ± 11.23	53.50	96.00
Grade 8	36.4%	PACER (lap)	34.91 ± 19.86	2	150

Variables and Instruments

This study included variables at both participant/person and school/institution levels. Participant level variables include grade, sex, and 15 meter Progressive Aerobic Cardiovascular Endurance Run (PACER) performance. PACER is a criterion-referenced field evaluated test for cardiorespiratory fitness (Welk et al., 2011), based on the number of laps completed successfully. PACER is a recommended assessment for its ease of use with motivating music, valid and reliable conversion to VO_2 Max, and convenient accommodation of 15m spaces.

The school level variables include percentage of students receiving free and reduced meal (FARM), student faculty ratio for physical education (S/F-PE), and school academic performance (SAP). FARM and S/F-PE were collected from school district website and report data from state department of education. S/F-PE is calculated by dividing enrollment by the number of fulltime PE teachers. We computed the aggregated average passing rate for each school to indicate SAP.

Data Analysis

Because participant as well as school level data were encompassed in the study, we used hierarchical linear modeling (HLM ver. 6.08; Scientific Software International, Inc; Skokie, IL) for data analysis (Raudenbush & Bryk, 2002). Since cardiorespiratory endurance (i.e., PACER scores) was measured at the student level multiple times, a three-level HLM was used to model the longitudinal performance change across years, individual factors, and school factors. Specifically, level 1 with an individual PACER performance growth model at time t of participant i in school j is specified:

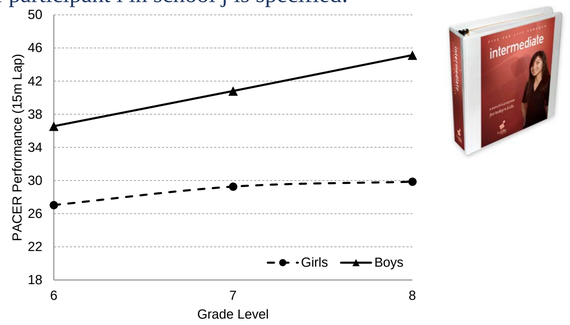
$$Y_{tij} = \pi_{0ij} + \pi_{1ij}(\text{Year})_{tij} + \pi_{2ij}(\text{Year})_{tij}^2 + e_{tij}$$

At level 2, we specified the model:

$$\pi_{0ij} = \beta_{00j} + \beta_{01j}(\text{Sex})_{ij} + r_{0ij}$$
$$\pi_{1ij} = \beta_{10j} + \beta_{11j}(\text{Sex})_{ij} + r_{1ij}$$
$$\pi_{2ij} = \beta_{20j} + \beta_{21j}(\text{Sex})_{ij} + r_{2ij}$$

The level 3 model was presented below:

$$\beta_{00j} = \gamma_{000} + \gamma_{001}(\text{FARM})_j + \gamma_{002}(\text{SF-PE})_j + \gamma_{003}(\text{SAP})_j + u_{00j}$$
$$\beta_{01j} = \gamma_{010}$$
$$\beta_{10j} = \gamma_{100}$$
$$\beta_{11j} = \gamma_{110}$$
$$\beta_{20j} = \gamma_{200}$$
$$\beta_{21j} = \gamma_{210}$$



where Y_{tij} was the PACER performance at time t for participant i in school j; $(\text{Year})_{tij}$ was centered on sixth grade (Year = Grade -6). π_{0ij} is the initial PACER performance for child ij at grade 6. π_{1ij} is the growth rate for participant ij during the academic year; and e_{tij} is the level 1 random effect. The level 2 random effects included r_{0ij}, r_{1ij}, and r_{2ij}. The level 3 random effect included u_{00j}.

RESULTS

The school level grand mean for 15m PACER performance was 34.91 ± 19.86 laps (Table 1) across three grade levels. The full unconditional HLM model showed that intra-class correlation coefficient was $\rho = 0.16$, suggesting that a significant portion of the variances in student PACER performance can be explained at individual and/or school level. Through the HLM testing process, as level 1, level 2, and level 3 predictors were added to the model, the model progressively fit better as indicated by significant deviance differentials. The final three level model showed that the predicted average girls' 15m PACER performance at sixth grade was 27.04 ± 0.78 laps. Holding other factors constant, boys on average had significantly higher performance than girls ($\Delta = 9.52 \pm 0.47$, $p < 0.001$). As shown in Table 2 and Figure 1, boys and girls had significantly different quadratic growth curves for PACER performance during middle school years. Girls' performance growth tended to form a concaving down quadratic curve, meaning that the annual performance increase was smaller as participants advanced to higher grade levels. Boys' PACER performance growth was almost linear with a small quadratic curve concaving slightly up, suggesting that their annual performance increase tended to be stable with a slight increase.

The school level factors FARM and S/F-PE were negatively associated with PACER performance, meaning that higher school level FARM and S/F-PE tended to have lower average PACER performance. However, these associations were not statistically significant ($p > 0.05$). School level SAP was positively associated with average PACER performance with a borderline statistical significance ($p = 0.063$). One standard deviation increase in SAP is associated with an average of 1.79 laps increase PACER performance in schools.

Table 2. Children PACER performance changes in sixth through eighth grades

Fixed Effect	Coefficient	se	t ratio	df	*p*
Model for test score, π_{0ij}					
Predicting β_{00j}					
Intercept, γ_{000}	**27.04**	**0.78**	**34.72**	**29**	**.000**
FARM, γ_{001}	**-2.84**	**2.38**	**-1.19**	**29**	**.245**
S/F-PE, γ_{002}	**-1.44**	**2.50**	**-0.58**	**29**	**.568**
SAP, γ_{003}	**1.79**	**0.93**	**1.93**	**29**	**.063**
Predicting β_{01j}					
Intercept sex, γ_{010}	**9.52**	**0.47**	**20.35**	**44799**	**.000**
1st order growth rate, π_{1ij}					
Intercept, γ_{100}	**3.05**	**0.55**	**5.59**	**44799**	**.000**
Intercept sex, γ_{110}	**1.16**	**0.32**	**3.58**	**44799**	**.001**
2nd order growth rate, π_{2ij}					
Intercept, γ_{200}	**-0.82**	**0.17**	**-4.83**	**44799**	**.000**
Intercept sex, γ_{210}	**0.86**	**0.14**	**5.93**	**44799**	**.000**

DISCUSSION & CONCLUSIONS

While increases in cardiorespiratory fitness were evident across all participants over the three-year span, the data revealed that boys and girls experienced varied quadratic growth curves during their middle school years.

The borderline significance for the positive association between SAP and PACER performance adds to the growing evidence of the positive effects of health-related fitness on academic performance in schools (Bass et al., 2013; Bezold et al., 2014; Welk et al., 2010).

Particularly in this study, an average of 1.79 laps increase in PACER was associated with one standard deviation increase in SAP, a substantial improvement for school administrators looking for behaviors that relate to school level academic performance.

Limitations

This study reports growth in cardiorespiratory fitness under a natural context in the U.S., without the inclusion of a comparison group. As such, findings should be interpreted without overgeneralization pertaining to a causal-effect relationship.

Conclusion

Results indicate that students' cardiorespiratory fitness improved across three years when *Five for Life* curriculum was implemented, with a divergent growth curve between boys and girls.

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