Original Research

Factors Influencing Muscular Strength and Endurance in Disadvantaged Children from Low-Income Families

YI FANG†[1], RYAN D. BURNS‡[1], JAMES C. HANNON‡[2], and TIMOTHY A. BRUSSEAU‡[1]

[1]Department of Exercise and Sport Science, University of Utah, Salt Lake City, UT, USA; [2]College of Physical Activity and Sport Sciences, West Virginia University, Morgantown, WV, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 9(3): 306-317, 2016. Examining the correlates of muscular strength and endurance in children from low-income families will provide evidence for interventions to improve these parameters. The purpose of this study was to determine the predictors and trends of muscular strength and endurance in at-risk school-aged children. The sample included 1,232 children (Mean age = 8.8 ± 1.6 years; 625 girls, 607 boys; 60% Hispanic) recruited from three U.S. low-income schools. Children performed health-related fitness testing and wore pedometers for one school week. A stratified random subsample (n = 533) also wore accelerometers to record sedentary behaviors, MVPA, and vigorous physical activity. Generalized linear mixed models were employed to calculate odds ratios (OR) for achieving FITNESSGRAM's push-up and curl-up standards (met standard = HFZ) from various predictors and to determine odds of achievement across grade levels. A student who achieved the HFZ for $VO_{2\ Peak}$ had an OR = 1.66 ($p < 0.001$) for achieving the HFZ for pushups and an OR = 1.99 ($p < 0.01$) for achieving the HFZ for curl-ups. Additionally, students whose vigorous physical activity was 1% higher had an OR = 3.25 ($p < 0.05$) for achieving the HFZ for curl-ups. For cohorts of students separated by one grade level, the OR = 0.48 ($p < 0.01$) for achieving the HFZ for push-ups and OR = 0.71 ($p < 0.01$) for achieving the HFZ for curl-ups. The results suggest that $VO_{2\ Peak}$, vigorous physical activity, and grade level are significant predictors of muscular strength and endurance in at-risk children.

KEY WORDS: Accelerometers, Curl-ups, FITNESSGRAM, Push-ups, Standards

INTRODUCTION

Given the evidence supporting the benefits of resistance training, muscular strength and endurance is becoming an increasingly researched component of health-related fitness (HRF) in children (26). Optimal levels of muscular strength and endurance may help improve motor development (6), athletic performance (25), and may have a protective effect on the incidence of sport-related injuries such as low back pain (27, 33). It has recently been shown that 8-weeks of resistance training can significantly improve body composition parameters in overweight and obese children (23). Additionally, some studies have linked optimal muscular strength and endurance to decreases in the incidence and prevalence of cardio-metabolic disease risk factors (30). In school settings, these components of HRF are assessed in primary and secondary schools in the U.S. using the FITNESSGRAM fitness test battery. Specifically, upper body muscular strength and endurance is assessed using the dynamic push-up, and abdominal muscular strength and endurance is assessed using the dynamic curl-up (32).

The push-up is a common assessment in physical education classes in the U.S. and around the world. It is easy to administer, practical, and is recommended by the U.S. Centers for Disease Control as one of the modes of exercise to help children strengthen their musculature (37). The push-up is currently scored using FITNESSGRAM's age and sex specific criterion-referenced standards. Although the specificity of the movement is limited to the pectoral, triceps, and deltoid musculature (9), it is still considered a valid assessment of overall upper body strength and endurance (12). The push-up exercise may be especially useful in younger children because bodyweight can serve as a base resistance to progress to more advance movements involving heavier external weight loads (20). There has been limited research focusing on the predictors of push-up performance in young elementary school aged children, and no research examining the predictors and trends of the push-up in samples of at-risk children in the U.S.

The FITNESSGRAM curl-up is an assessment of abdominal strength and endurance. Research suggests that optimal abdominal muscular endurance aids in increasing athletic performance (2) and attenuates risk of lower back injuries by improving core stability (5, 16). Although recent research has devised effective school interventions to increase abdominal muscular endurance in children (3), no research has examined correlates of FITNESSGRAM curl-up achievement in children from low-income families.

At-risk children may especially benefit from optimal levels of muscular strength and endurance. At-risk children, in the current context defined as disadvantaged children from low-income families, may not have access to before or after school physical activity opportunities that include resistance training exercises, may have low self-efficacy for resistance exercise and may also have a greater disposition to early onset health risk factors that can be attenuated employing resistance exercise (19, 24). Given the importance of optimal strength and endurance levels in children, and the lack of research examining the correlates of this domain of HRF in the current literature in the at-risk pediatric population, it is imperative that research focuses on the predictors of muscular strength and endurance to identify measures to be targeted to increase the odds of improvement. Therefore, the purpose of this study was to examine the predictors and trends of muscular strength and endurance achievement in a sample of at-risk elementary school-aged children in the U.S. It was hypothesized that achieving standards for aerobic capacity ($VO_{2\ Peak}$), body mass index (BMI), and moderate-to-vigorous physical activity (MVPA) will associate with an increase in the odds of a child achieving optimal levels of muscular strength and endurance. It was also hypothesized that the prevalence of achievement of the age and sex specific standards for push-ups and curl-ups will be lower in older grade cohorts compared to younger grade cohorts.

METHODS

Participants

Participants were a convenience sample of 1,232 school-aged children recruited from three low-income or "Title I" elementary schools located in low socio-economic status neighborhoods from the Mountain West Region of the U.S. The majority of the sample was of Hispanic/Latino Ethnicity (60.60%), followed by Pacific Islander (13.70%), Caucasian (10%), African American (7.80%), Asian (3.50%), and approximately 4% was characterized as "Other". Children were recruited from the 1st–6th grades. The mean age of the sample was 8.8 ± 1.6 years and there were 625 girls and 607 boys who participated. The number of participants per grade was as follows: 214 first graders, 259 second graders, 227 third graders, 212 fourth graders, 218 fifth graders, and 102 sixth graders. Written assent was obtained from the students and consent was obtained from the parents prior to data collection. The University Institutional Review Board approved the protocols employed in this study.

Protocol

FITNESSGRAM's *Push-up* test was administered using an audio compact disk providing a cadence of 20 pushups per minute. Students were required to assume the standard push-up position (i.e. hands and toes on the mat, back flat, hands placed at shoulder width) and then required to bend their elbows to an angle of 90° followed by full extension in accordance to the given cadence. The test was terminated if a student either twice stopped to rest, did not achieve the required 90° bend in the elbow, or did not fully extend their elbows in accordance to the cadence. The 90° push-up has been shown to be a reliable measure with r > 0.80 (13). Push-up scores were recorded as total number of correctly performed repetitions with a maximum number of 80 repetitions (32).

FITNESSGRAM's *Dynamic Curl-up* consisted of having the students curl-up and down sliding their fingers across a distance of 3 inches (5 to 9 years old) or 4.5 inches (older students) at a specific cadence of 20 repetitions per minute provided by a recorded compact disk. The heels were to be on contact with the ground at all times with a 120° bend in the leg. On each curl-up, participants had to touch their back and head on a mat. Only 2 errors were allowed before the test was terminated. The test was terminated if a student twice stopped to rest, did not touch their back and head on the mat, or did not slide their fingers across the specified distance. The maximum number of curl-ups was 80 repetitions. Curl-up scores were recorded as total number of correctly performed repetitions. The reliability of this test has been established in the pediatric population with r > 0.85 for both girls and boys (29). These procedures are in accordance to those recommended by FITNESSGRAM (31).

Physical activity was measured using Yamax DigiWalker CW600 pedometers (Tokyo, Japan) and ActiGraph wGT3X-BT triaxial accelerometers (Pensacola, FL, USA). Each student in the sample (N = 1,232) wore a pedometer for one school week, and a stratified randomly selected sub-sample of 533 students (277 girls, 256 boys) also wore accelerometers. Only a randomly selected sub-sample of children wore accelerometers because of device availability. Both devices were worn for 5 school days between the hours of 8am and 3pm. Each pedometer and accelerometer was given an identification number and assigned to a student with the corresponding identifier. The devices were worn above the knee at the level of the iliac crest. Pedometers were worn on the left side of the body and accelerometers worn on the right side of the body. The pedometers used in this study included a seven-day memory that was used to record steps each day of the school week. Yamax DigiWalker models have been shown to provide an accurate recording of steps within ± 3% of actual steps (35) and have been shown to be a valid measure of free-living physical activity (11). Accelerometer data were recorded in 5-second epochs at 100 Hertz and processed using Evenson et al. (14) cut-points to classify behaviors as sedentary, light, moderate, or vigorous physical activity. The moderate and vigorous physical activity classifiers were aggregated for time in MVPA. Participants were included in the analysis if they had recorded data for the majority of the school week (4 days; 96% of the sub-sample; 512 children). The ActiLife 6.11.5 software program (Pensacola, FL, USA) was used to initialize, download, process, and store accelerometer data. Aerobic capacity was estimated using the 20-meter Progressive Aerobic Cardiovascular Endurance Run (PACER). The PACER was conducted on a marked gymnasium floor with background music provided by a compact disk. Each student was instructed to run from one floor marker to another floor marker across a 20-meter distance within an allotted time frame. The allotted time given to reach the specified distance incrementally shortened as the test progressed. If the student twice failed to reach the other floor marker within the allotted time frame, the test was terminated. The final score was recorded in laps (32).

The HRF and physical activity measures were collected during separate weeks at each of the three schools. During PE, students completed assessments in the following order: anthropometric assessments (i.e. height and weight), curl-ups, and push-ups, and PACER. At least 5 minutes was given in between consecutive fitness tests to allow for recovery. A trained member of the research team (PI, research associate, or graduate research assistant) collected all measures to maintain testing accuracy and consistency. Pedometers and accelerometers were administered no less than one week and no more than three weeks following HRF testing at each school using the procedures described previously.

Statistical Analysis

All HRF and MVPA continuous variable scores were stratified into a binary classification scheme based on FITNESSGRAM's age and sex specific criterion-referenced standards and current MVPA guidelines recommended by the Institutes of Medicine (8, 18). The two levels for push-ups, curl-ups, aerobic capacity, and BMI represented the Healthy Fitness Zone (HFZ or "met standard") and a Needs Improvement Zone (NIZ or "not met standard"). The pedometer step count cut-point was set at 6,000 steps per school day (one half of the 12,000 steps per day recommended by Colley et al. (10); 0 = not met standard, 1 = met standard). A dichotomous variable was calculated from accelerometer data using an average MVPA per school day cut-point of ≥ 30 minutes per day recommended by the Institutes of Medicine (18, 32).

The main analysis consisted of employing generalized linear mixed models (GLMMS's; logit link function) using classroom-level and school-level random intercepts to calculate odds ratios for meeting age and sex specific push-up and curl-up standards. GLMMs were used to account for the clustering of individual measurements within classrooms, as there were a total of 70 classrooms among the three schools. Separate model predictors included achievement of the age and sex specific $VO_{2\ Peak}$ and BMI standards (dichotomous variables), step count achievement (dichotomous variable), daily MVPA achievement (dichotomous variable), %sedentary behavior (continuous variable), and %vigorous physical activity (continuous variable). Results were reported as adjusted odds ratios for each of the aforementioned predictors.

To model the cross-sectional trends in HRF and MVPA, separate GLMM models (logit link function) with school-level random intercepts were employed. Each binary HRF and MVPA variable was used as the criterion in separate models. The predictor variable in each of the models was grade level. Sex was entered into each model to control for a possible modifying effect and the results were reported as grade level adjusted odds ratios. Chi-square tests were used to validate the use of GLMMs by examining the likelihood ratio null hypothesis that the fraction of variance due to differences among the panels (clusters) is equal to zero (i.e. Rho = 0). Less than 5% of the sample was missing for each variable, therefore missing data was assumed not to have biased any of the parameter estimates and no imputation was required. An a priori power analysis for logistic regression was conducted using G*Power 3.1 (15) and it was determined that a sample size of 204 was needed to achieve sufficient power (1 – β = 80%). Therefore, this study was determined to have sufficient sample size for the aforementioned analyses. Alpha level was set at $p \leq 0.05$ and all analyses were carried out using STATA 13.0 statistical software package (College Station, TX, USA).

RESULTS

The descriptive data for HRF and physical activity are presented in Table 1 for the total sample and within each sex and grade group. Boys in this sample had higher pushup scores compared to girls ($t_{(1230)}$ = 4.07, Mean Δ = 1.84 reps , $p < 0.001$), higher curl-up scores compared to girls ($t_{(1230)}$ = 3.32, Mean Δ = 4.12 reps, $p < 0.001$), higher estimated $VO_{2\ Peak}$ compared to girls ($t_{(1230)}$ = 2.83, Mean Δ = 0.85 $ml \cdot kg^{-1} \cdot min^{-1}$, p = 0.001), more minutes in daily MVPA compared to girls ($t_{(510)}$ = 2.83, Mean Δ = 3.33 min, $p = 0.005$), and greater percentage of time spent in vigorous physical activity compared to girls ($t_{(510)}$ = 3.69, Mean Δ = 0.17%, $p < 0.001$). There were no differences between sexes in BMI ($p = 0.747$), step counts ($p = 0.06$) and no differences between sexes in % sedentary behavior (p = 0.215). Table 2 shows the adjusted odds ratios for meeting push-up and curl-up standards across the dichotomous and continuous predictors. If a child achieved the age and sex-specific standard for $VO_{2\,Peak}$, the OR =1.66 (95%CI: [1.09, 2.53], $p < 0.05$) for achieving the HFZ for push-ups and OR = 1.99 (95%CI: [1.24, 3.19], $p < 0.05$) for achieving the HFZ for curl-ups. Additionally, if a child achieved at least 6,000 steps during the school day the OR = 2.40 (95%CI: [1.06, 5.44], $p < 0.05$) for achieving the HFZ for curl-ups. Finally, for every 1% increase in vigorous physical activity, the OR = 3.25 (95%CI: [1.05, 9.92], $p < 0.05$) for achieving the HFZ for curl-ups. Being classified in the HFZ for BMI, achieving standards for MVPA, or achieving standards for % sedentary behaviors did not associate with any change in odds.

Table 1. Descriptive statistics for the total sample and within sex groups.

	Total Sample	Girls	Boys	1st Grade	2nd Grade	3rd Grade	4th Grade	5th Grade	6th Grade
Pushups (N = 1232)	12.8 ± 7.9	11.9 ± 7.2	**13.7* ± 8.5**	8.9 ± 6.2	**14.2** ± 8.5**	**12.5** ± 7.1**	**15.9** ± 9.4**	**12.2** ± 6.5**	**12.3** ± 7.1**
Curl-ups (N = 1232)	34.5 ± 21.7	32.4 ± 20.5	**36.6* ± 22.8**	22.8 ± 13.5	28.1 ± 16.5	31.2 ± 19.1	**45.0† ± 25.6**	**43.2† ± 24.3**	**42.1† ± 19.0**
$VO_{2\,Peak}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) (N = 1232)	44.3 ± 5.1	43.9 ± 4.8	**44.7* ± 5.4**	45.0 ± 3.0	45.3 ± 4.2	45.7 ± 5.4	44.7 ± 4.9	42.8 ± 4.9	44.0 ± 8.2
BMI[a] ($kg \cdot m^2$) (N =1232)	18.3 ± 5.0	18.3 ± 4.8	18.3 ± 5.1	16.7 ± 3.3	17.4 ± 3.6	18.9 ± 3.9	**19.0** ± 4.4**	**21.7** ± 7.7**	**20.6** ± 4.8**
Average Steps (N = 1232)	4285 ± 1535	4149 ± 1444	4442 ± 1620	4562 ± 1480	4291 ± 1571	4173 ± 1500	4529 ± 1599	4266 ± 1444	**3630** ± 1407**
% MVPA[b] (n = 512)	1.8 ± 1.0	1.7 ± 0.9	**2.0* ± 1.1**	2.4 ± 1.1	**1.8** ± 1.0**	**1.8** ± 0.8**	**1.6** ± 1.2**	**1.8** ± 0.8**	**1.4** ± 0.9**
% Sedentary (n = 512)	92.0 ± 3.5	92.2 ± 3.4	91.8 ± 3.6	89.7 ± 3.5	92.1 ± 3.4	92.1 ± 2.6	93.0 ± 4.0	92.4 ± 2.8	93.9 ± 3.3
% Vigorous (n = 512)	0.8 ± 0.5	0.7 ± 0.4	**0.9* ± 0.5**	1.1 ± 0.5	0.7 ± 0.5	0.7 ± 0.4	0.7 ± 0.6	0.8 ± 0.5	0.6 ± 0.5

Note: * statistical differences between sexes, $p < 0.01$; ** statistical differences compared to first grade, $p < 0.01$; † statistical differences compared to first and second grade, $p < 0.01$.

Table 2. Adjusted odds ratios (ORs) from generalized linear mixed models.

	Odds Ratio	95% C.I.[a]	p-value	Rho[b]
Criterion is HFZ Push-ups				
HFZ[d] $VO_{2\ Peak}$	**1.66****	1.09, 2.53	0.018	**0.18****
HFZ[d] BMI[e]	1.10	0.76, 1.60	0.600	**0.19****
Steps ≥ 6,000/school day	1.22	0.74, 2.10	0.423	**0.20****
MVPA ≥ 30 min/day	1.06	0.59, 1.89	0.834	**0.25****
%sedentary	1.04	0.94, 1.15	0.384	**0.23****
%vigorous	1.15	0.69, 1.91	0.299	**0.40****
Criterion is HFZ Curl-ups				
HFZ[d] $VO_{2\ Peak}$	**1.99****	1.24, 3.19	0.004	**0.16****
HFZ[d] BMI[e]	1.58	0.77, 3.23	0.208	**0.25****
Steps ≥ 6,000/school day	**2.40****	1.06, 5.44	0.035	**0.23****
MVPA ≥ 30 min/day	3.88	0.97, 15.46	0.054	**0.14****
%sedentary	0.98	0.83, 1.16	0.825	**0.20****
%vigorous	**3.25****	1.05, 9.92	0.039	**0.17****

Note: [a] 95% C.I. stands for the 95% Confidence Interval; [b] Rho is the proportion of variance explained by classroom affiliation; [c] MVPA stands for moderate-to-vigorous physical activity; [d] HFZ stands for the Healthy Fitness Zone; [e] BMI stands for Body Mass Index; Boldface indicates statistical significance ($^{**}p < 0.001$).

Table 3 shows the grade level parameter estimates (cross-sectional tracking) from the GLMMs using various criterion (dependent) variables. Older cohorts separated by one grade level displayed an OR = 0.48 (95%CI: [0.42, 0.54], $p < 0.05$) and OR = 0.71 (95%CI: [0.55, 0.92], $p < 0.05$) for achieving the HFZ for push-ups and curl-ups, respectively. Additionally, OR = 0.48 (95%CI: [0.45, 0.51], $p < 0.05$), OR = 0.82 (95%CI: [0.78, 0.88], $p < 0.05$), and OR = 0.73 (95%CI: [0.55, 0.94], $p < 0.05$) of achieving the HFZ for $VO_{2\ Peak}$, the HFZ for BMI, and meeting the daily standard for MVPA for cohorts who were in one successively older grade level, respectively. Only pedometer step count achievement did not associate with grade level ($p = 0.665$).

Table 3. Adjusted grade level odds ratios from generalized linear mixed models.

Criterion	Grade Level Odds Ratio	95% C.I.[a]	*p* - value	Rho[b]
HFZ Push-ups	**0.48****	0.43, 0.54	**< 0.001**	**0.04****
HFZ Curl-ups	**0.71***	0.55, 0.92	**0.010**	0.00
% HFZ $VO_{2\,Peak}$	**0.48****	0.45, 0.51	**< 0.001**	**0.09****
% HFZ[c] BMI[d]	**0.82****	0.78, 0.87	**< 0.001**	**0.08****
% Steps ≥ 6,000/school day	1.02	0.92, 1.14	0.665	**0.08****
% MVPA[e] ≥ 30 min/school day	**0.73***	0.55, 0.96	**0.020**	**0.19****

Note: [a] 95% C.I. stands for the 95% Confidence Interval; [b] Rho is the proportion of variance explained by school affiliation; [c] HFZ stands for the Healthy Fitness Zone; [d] BMI stands for Body Mass Index; [e] MVPA stands for moderate-to-vigorous physical activity; Boldface indicates statistical significance (*$p < 0.05$, **$p < 0.001$).

DISCUSSION

The purpose of this study was to examine the predictors and trends of muscular strength and endurance achievement in a sample of at-risk elementary school-aged children. The results indicate that aerobic capacity achievement, step count achievement, vigorous physical activity, and grade level all associate with odds of achieving optimal levels of muscular strength and endurance in at-risk children. At-risk children have additional burdens for achieving optimal muscular strength and endurance and its associated benefits. Aerobic capacity, steps per school day, vigorous physical activity, and grade level associated with the odds of achieving FITNESSGRAM's age and sex specific standards for push-ups and curl-ups and thus should be a priority in future intervention strategies targeting at-risk children.

Performance on the push-up and curl-up assessment were strongly related to estimated VO2 Peak. Cardiorespiratory endurance (i.e. aerobic capacity or VO2 Peak) and muscular strength and endurance are separate domains of HRF (38), however the results from this study indicate that a complementary relationship exists. Research has shown strong relationships between these two domains in the pediatric population (21) and this study provides evidence that the domains are also related in the at-risk pediatric population. Many Title I school programs do not integrate resistance-training exercises with aerobic exercises due to time limitations and a lack of educator expertise in how to properly resistance train children (8). In the at-risk population there is often a lack of support and equipment to perform resistance-training movements needed to elicit improvements in muscular development.

However, Allen et al. (3) shown that a 6-week equipment-free intervention improved abdominal and core parameters in grade-school children. These types of equipment-free interventions, when complemented with an aerobic training component, may increase the odds of a student achieving optimal muscular strength and endurance. The shared "endurance" component of these assessments may play a significant role of why these two domains of HRF are strongly related, possibly due to the activation of Type I fiber musculature (29).

Nevertheless, future research needs to be conducted examining the combination of cardiorespiratory and resistance exercise (concurrent training) to optimize the strength and endurance potential of the at-risk child.

Interestingly, step count achievement and vigorous physical activity were strongly related to curl-up achievement but not to push-up achievement. Research has shown numerous benefits of MVPA in the pediatric population (7), however research has also shown that the cross-sectional relationships between MVPA and HRF are, at best, weak-to-moderate (4). Although optimal MVPA levels itself may decrease blood pressure, improve cholesterol, and improve functional daily living performance, vigorous physical activity behaviors more strongly relate to HRF parameters. Vigorous physical activity may elicit a greater physiological response compared to MVPA needed to improve cardiorespiratory and musculoskeletal performance. In this study, only curl-ups strongly related to vigorous physical activity and step count achievement in at-risk children. Performance on the push-up was independent of step count achievement or vigorous physical activity levels. Anecdotally, the curl-up may have a greater 'endurance" component compared to the push-up because core musculature is primarily comprised of aerobic Type I muscle fibers; in contrast, the push-up may have a greater "strength" component as musculature in the chest and triceps are primarily comprised of anaerobic Type 2 fibers. The average push-up score was approximately 13 repetitions; therefore the assessment lasted on average for approximately 40 seconds. In contrast, the average curl-up score was approximately 34 repetitions; therefore the assessment lasted on average for approximately 102 seconds. These estimates are based on the 20 repetitions per minute cadence provided by the audio compact disk for each assessment. Given these assessment durations, the push-up test would require a greater anaerobic energy system compared to the curl-up, which is more aerobic and more likely to be developed via ambulatory physical activity (29).

There were significant decreases in muscular strength and endurance achievement between first and sixth grade students in this sample. There have been several studies showing decreases in physical activity behaviors in children, especially as they approach the developmental years (28). However, this study provides evidence that both cardiorespiratory and muscular strength and endurance levels negatively tracks in separate cohorts of at-risk children from the first through sixth grades. This is a concerning finding given that these children are already burdened when it comes to having ample opportunities for cardiorespiratory and resistance exercise after-school hours. The drastically lower prevalence of HRF achievement in at-risk children gives them additional risk for poor motor development, poor athletic performance, and increases odds for the incidence of musculoskeletal injury when they do engage in physical activity. Researchers and practitioners engaged in intervention work need to be aware of these trends and devise strategies to attenuate the decline in achievement in at-risk children. Health agencies have recommended Comprehensive School Physical Activity

Programming (CSPAP) to foster a school environment conducive to optimal physical activity and HRF achievement (8). However, the long-term efficacy of these types of interventions has not been documented and their specific effect on muscular strength and endurance levels in at-risk children is non-existent.

There are limitations to this study that must be considered before generalizations can be made. First, the sample consisted of first through sixth grade students recruited from three low-income Title I schools from the Mountain West Region of the U.S., therefore the external validity of the results is questionable if generalized to other grade cohorts, regions of the U.S., or to samples with different ethnic and socio-economic representation. Future research should compare the predictive trends between low-income children and national representative samples using NYHFS or NHANES data. Second, this study used a cross-sectional correlational/predictive research design; therefore the longitudinal effects at the student level could not be addressed resulting in greater between-subject error. Future research examining trends of muscular strength and endurance achievement in at-risk children should employ prospective/longitudinal research designs to more adequately address the research question. Third, although the assessments employed to evaluate upper body and abdominal strength and endurance are widely used due to FITNESSGRAM being the U.S.'s national fitness test battery (38), they are only specific to the anterior deltoid/pectoral/triceps and the rectus abdominus (9), respectively, and do not effectively evaluate musculature of the back (latissimus dorsi, trapezius) or the internal and external obliques. Finally, this study only evaluated muscular strength and endurance and not muscular power, therefore the results do not generalize to the latter domain.

In conclusion, aerobic capacity achievement, step count achievement, vigorous physical activity, and grade level all associate with the odds of achieving age and sex specific muscular strength and endurance standards in at-risk elementary school-aged children. These parameters should be a priority for intervention work in order to improve the odds that a child can perform optimally on the push-up and curl-up assessments. This study provides unique insights on the predictors and trends of muscular strength and endurance achievement in a disadvantaged population of children in the US.

REFERENCES

1. Ainsworth BE, Haskell WL, Herrmann SD, et al. Compendium of physical activities: A second update of codes and MET values. Med Sci Sports Exerc 43:1575−1581, 2011.

2. Akuthota V, Nadler SF. Core strengthening. Arch Phys Med Rehabil 85:86−92, 2004.

3. Allen BA, Hannon JC, Burns RD, Williams SM. Effect of a core conditioning intervention on tests of trunk muscular endurance in school-aged children. J Strength Cond Res 28:2063−2070, 2014.

4. Armstrong N, Tomkinson G, Ekelund U. Aerobic fitness and its relationship to sport, exercise training and habitual physical activity during youth. Br J Sports Med 45:849–858, 2011.

5. Behm DG, Brinkwater EJ, Willardson JM, Cowley PM. The use of instability to train the core in athletic and nonathletic conditioning. App Physiol Nutr Metab 35:109−112, 2010.

6. Behringer M, Vom Heede A, Matthews, M, et al. Effects of strength training on motor performance skills in children and adolescents: a meta-analysis. Pediatr Exerc Sci 23:186–206, 2011.

7. Boreham C, Riddoch C. The physical activity, fitness, and health of children. J Sports Sci 19:915−919, 2001.

8. Centers for Disease Control and Prevention. Comprehensive School Physical Activity Programs: A Guide for Schools. Atlanta, GA: U.S. Department of Health and Human Services; 2013.

9. Cogley RM, Archambault TA, Fibeger JF, et al. Comparison of muscle activation using various hand positions during the push-up exercise. J Strength Cond Res 19:628−633, 2005.

10. Colley RC, Janssen I, Tremblay MS. Daily step target adherence to physical activity guidelines in children. Med Sci Sports Exerc 44:977−982, 2012.

11. Crouter SE, Schneider PL, Karabulut M, Bassett DR. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. Med Sci Sports Exerc 35:1455–1460, 2003.

12. Ebben WP, Wurm B, VanderZanden TL, et al. Kinetic analysis of several variations of push-ups. J Strength Cond Res 25:2891−2894, 2011.

13. Engelman ME, Morrow Jr JR. Reliability and skinfold correlates for traditional and modified pull-ups in children grades 3-5. Res Q Exerc Sport 62:88−91, 1991.

14. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. J Sports Sci 26:1557−1565, 2008.

15. Faul F, Erdfelder E, Georglang A, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Meth 39:175−191, 2007.

16. Harreby M, Neergaard K, Hesselsoe G, Kjer J. Are low back pain and radiological changes during puberty risk factors for low back pain in adult age? A 25-year prospective cohort study of 640 school children. Ugeskr Laeger 159:171−174, 2007.

17. Hides JA, Jull GA, Richardson CS. Long-term effects of specific stabilizing exercises for first episode low back pain. Spine 25:E243−E248, 2001.

18. Institute of Medicine. Educating the Student Body: Taking Physical Education to School. Washington, DC: The National Academies Press; 2013.

19. Lampard AM, Jurkowski JM, Lawson HA, Davison KK. Family ecological predictors of physical activity parenting in low-income families. Behav Med 39:97−103, 2013.

20. Lloyd RS, Faigenbaum AD, Stone MH, et al. Position statement on youth resistance training: The 2014 international consensus. Br J Sports Med 0:1−12, 2013.

21. Malina RM, Bouchard C, Bar-Or O. Growth, Maturation, and Physical Activity (2nd Ed.). Champaign, IL: Human Kinetics; 2004.

22. Marta C, Marinho, DA, Barbosa TM, Izquierdo M, Marques MC. Effects of concurrent training on explosive strength and $VO_{2\ MAX}$ in prepubescent children. Int J Sports Med 34:888−896, 2011.

23. McGuigan MR, Tatasciore M, Newton RU, Pettigrew S. Eight weeks of resistance training can significantly alter body composition in children who are overweight or obese. J Strength Cond Res 23:80−85, 2009.

24. Messiah SE, Arheart KL, Lopez-Mitnik G, Lipshultz SE, Miller TL. Ethnic group differences in cardio-metabolic disease risk factors independent of body mass index. Obesity 21:424−428, 2013.

25. Milliken LA, Faigenbaum AD, LaRousa Loud R. Correlates of upper and lower body muscular strength in children. J Strength Cond Res 22:1339–1346, 2008.

26. Moliner-Urdiales D, Ruiz JR, Ortega FB, et al. Secular trends in health-related physical fitness in Spanish adolescents: the AVENA and HELENA studies. J Sci Med Sport 13:584588, 2010.

27. Myer GD, Faigenbaum AD, Chu D, et al. Integrative training for children and adolescents: techniques and practices for reducing sports-related injuries and enhancing athletic performance. Phys Sports Med 39:74–84, 2011.

28. Nader PR, Bradley RH, Houts RM, McRitchie SL, O'Brien M. Moderate-to-vigorous physical activity from ages 9 to 15 years. JAMA 300:295–305, 2008.

29. National Strength and Conditioning Association. Essentials of Strength training and Conditioning (3rd Ed). Champaign, IL: Human Kinetics; 2008.

30. Patterson P, Bennington J, de LaRosa T. Psychometric properties of child and teacher-reported curl-up scores in children ages 10-12 years. Res Q Exerc Sport 72:117−124, 2001.

31. Peterson MD, Saltarelli WA, Visich PS, Gordon PM. Strength capacity and cardio-metabolic risk clustering in adolescents. Pediatrics 133:e896−e903, 2014.

32. Plowman SA, Meredith MD. Fitnessgram/Activitygram Reference Guide (4th Edition). Dallas, TX: The Cooper Institute; 2013.

33. Richardson RA, Snijders CJ, Hides JA, Damen J, Pas MS, Storm J. The relationship between the transverse abdominis muscles, sacroiliac joint mechanics, and low back pain. Spine 27:399−405, 2002.

34. Schneider PL, Crouter SE, Lukajic O, Bassett DR. Accuracy and reliability of 10 pedometers for measuring steps over a 400-m walk. Med Sci Sports Exerc 35:1770–1784, 2003.

35. Trost SG, Loprinzi PD, Morre R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. Med Sci Sports Exerc 43:1360−1368, 2011.

36. Trudeau F, Shephard RJ. Physical education, school physical activity, school sports and academic performance. Int J Behav Nutr Phys, 2008. doi:10.1186/1479-5868-5-10.

37. U.S. Department of Health and Human Services. Youth Physical Activity: The Role of Schools. Washington, DC: U.S. Department of Health and Human Services; 2009.

38. Welk GJ, Going SB, Morrow Jr JR, Meredith MD. Development of new criterion-referenced fitness standards in the FITNESSGRAM program: Rationale and conceptual overview. Am J Prev Med 41:S63−S67, 2011.