Associations Between Cardiorespiratory Fitness and Overweight With Academic Performance in 12-Year-Old Brazilian Children.

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Associations between cardiorespiratory fitness and overweight with academic performance in 12-year old Brazilian children.

Running title: Obesity, aerobic fitness and academic performance.

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Abstract

Obesity has been associated with poor academic achievement, while cardiorespiratory fitness (CRF) has been linked to academic success. ***Purpose:*** To investigate whether CRF is associated with academic performance in Brazilian students, independently of body mass index (BMI), fatness and socioeconomic status (SES). ***Methods:*** Three hundred and nine two 5^{th} and 6^{th} grade students (193 girls) (12.11±0.75 years old) were evaluated in 2012. Skinfold thickness measures were performed, and students were classified according to BMI-percentile. CRF was estimated by a 20-meter shuttle run test, and academic achievement by standardized math and Portuguese tests. Multiple linear regression analyses were conducted to explore the association between academic performance and CRF, adjusted for SES, skinfold thickness or BMI-percentile. ***Results:*** Among girls CRF was associated with higher academic achievement in math ($\beta=0.146; p=0.003$) and Portuguese ($\beta=0.129; p=0.004$) in crude and adjusted analyses. No significant association was found among boys. BMI was not associated with overall academic performance. There was a weak negative association between skinfold thickness and performance in mathematics in boys ($\beta=-0.030; p=0.04$), but not in girls. ***Conclusion:*** The results highlight the importance of maintaining high fitness levels in girls throughout adolescence a period commonly associated with reductions in physical activity levels and CRF.

Key words: Aerobic Fitness, Obesity, Academic Achievement, Physical Education, Students.

1. Introduction

The deleterious effects of obesity on physical health are well appreciated (39). It is also known that cardiorespiratory fitness (CRF) is an independent variable associated with a broad range of health outcomes including blood pressure and clustering of cardio-metabolic risk factors (32).

An inverse relationship between adiposity and academic performance in children has been reported (9, 45). Poor academic performance might be associated with excess body fatness, but could be mediated by other variables such as anxiety, depression, low self-esteem, teasing and social rejection, and low cardiorespiratory fitness (CRF) (5, 18, 46).

CRF is a general term often used to characterize an individual's performance during a standardized exercise test or protocol (41). School-based fitness test batteries traditionally include endurance performance (such as the 1-mile [1.6-km] or 20-meter shuttle run) as a field indicator of CRF described as maximum oxygen consumption (VO_{2max}) (40).

While some studies report an inverse association between obesity and CRF (11, 37), others suggest that due to growth and maturation the relationship between these two variables might be more complex in children and adolescents (41). It is reported that CRF and body fat contribute equally to endurance performance in field tests (40).

There is some evidence CRF may modulate cognition and academic performance (19), by contributing to structural changes in the brain, such as higher volume in specific regions of the basal ganglia and hippocampus (6), increased recruitment of neurons, and also by contributing to increases in the blood vasculature in the region of the cerebral cortex, stimulating the growth of new neurons and synapses (22).

Due to the bidirectional nature of the association between CRF and obesity, it is hard to determine the contribution of each individual factor to academic performance. Another important issue to consider is the association of socioeconomic status (SES) with academic performance due its relationship with both CRF and obesity (21, 23).

Thus, we hypothesized that CRF would be independently associated with child academic performance even when controlling for body mass index (BMI), body fat and SES. The aim of this study was to determine the relationship between CRF and academic performance in elementary school students.

2. Material and Methods

Participants

This cross-sectional study was conducted with 450 elementary school students between the ages of 10 and 13 years (5th and 6th grade), enrolled in public schools in Recife, an urban city in northeast Brazil. Subjects (n= 9120) came from 31 of 34 public elementary schools. Two schools with full day programs and one school without facilities for conducting CRF testing were not eligible to participate. Children were randomly (randomizer.org) selected using a 2-stage cluster sampling where the 31 schools and the corresponding 9120 students were separated as units at the first and second stages of sampling, respectively. Nine schools were selected and the principal of each selected school provided a list of the students, thereafter, fifty children from each school were selected, and invited to take part in the study (N=450).

This study was carried out with the principles of the declaration of Helsinki and was formally approved by the Ethics Committee of the University of Pernambuco (#192/11). Inform consent and assent were obtained from the parents or legal guardians and the children respectively.

Study design

During the first visit to the school, the principle investigator explained the aims and the study protocol, and invited the children to participate. Those who agreed received an informed consent form to be signed by their parents. During the second visit, participants were asked to complete a SES questionnaire. At the third and fourth visits, CRF, anthropometry, body composition and academic performance were assessed. Due to the well-known negative effects of underweight on the outcomes variables (49) twenty-five underweight children (BMI < 5^{th} percentile) were not included in the analyses. The final sample consisted of 392 students (193 girls) enrolled in 5th (n=230) and 6th (n=162) grade (Figure 1).

*****INSERT FIGURE I*****

Measurements

Measurements were conducted in 2012 at the schools during school hours by a trained research staff member.

Socioeconomic Status

We used the questionnaire from the Associação Brasileira de Empresas de Pesquisa (Brazilian Association of Research Companies), as a valided instrument developed to measure SES in the Brazilian population (2). The instrument contains 9 questions (answers ranging from 0 to 5 points). The questions relate to the possession of electrical appliances, a bathroom in the home, automobile, housekeeper, washing machine, refrigerator and freezer, and information about parental education. Based on the sum of the scores, the individual was classified into socioeconomic class A, B, C or D, where class A had the highest purchasing power and highest educational level and class D had the lowest purchasing power and educational level.

Academic performance

To measure academic performance, tests were developed by an education specialist to assess students' knowledge of Portuguese and mathematics. The content of the test was based on the reference standards of the Prova Brasil, which is the preferential test from the Brazilian educational system to assess skills and abilities in Portuguese and Math (35). This multiple choice instrument had 10 questions to assess Portuguese reading comprehension and grammar and 10 mathematics questions focusing on logic, geometric design, mathematical operations, fractions, and decimals. Each question had four alternative responses, with only one being the correct one. The students had one hour to complete the tests (Portuguese and math).

For each correct answer, the student scored one point; thus the score for both Portuguese and math tests, ranged from 0 to 10. An overall score was calculated from the arithmetic average of both tests.

Anthropometry and body composition

Participants were weighed wearing light clothing and no shoes on a Filizola scale (model 160/300, Brazil) to the nearest 0.1 kg. Height was measured to nearest 0.5 cm using a wall-mounted stadiometer (Welmy®, Brazil). Body weight and height were measured in triplicate and the average values were used to calculate BMI by dividing body weight by height squared (kg/m^2). BMI-percentile was classified according to the age- and sex-growth charts from the Centers for Disease Control and Prevention (CDC) (29). BMI values between the 5^{th} and 84.9^{th} percentile were classified as normal weight and percentiles above 85^{th} were categorized as overweight. Triceps and calf skinfolds on the right side were determined in triplicate (the average value is reported) to the nearest 0.1 mm using standard techniques. Adiposity was estimated by sum of skinfolds (triceps and calf).

Cardiorespiratory fitness

The 20-meter shuttle run test was used to assess CRF as proposed by Léger et al. (31). Students were instructed to run 20 meters marked by a cone in time with an audible signal. The test was performed in groups of 10 students. The test started at 8.5 km/h and increased by 0.5 km/h for each level until the participant failed twice to keep up with the beep intervals or reached exhaustion. The VO_{2max} were estimated using the equation provided by Barnett et al. (3) below:

$$VO_{2max} = 24.2 – 5.0 * S – 0.8*A + 3.4*SP$$

Whereas S is sex (male =0, female =1); A is age; SP is final speed

This equation provides a high agreement (Mean difference: 1.3 $ml.kg^{-1}.min^{-1}$, 95% CI: -0.3 to 2.9) with directly measured VO_{2max} in children (42).

Statistical Analysis

Data normality was examined by the Kolmogorov-Smirnov test. Continuous variables are presented as means ± standard deviations; categorical variables are presented as absolute and relative frequency and 95% confidence intervals (95%CI). Differences between different variables according to sex were calculated by Student’s t test for independent samples or chi-squared, when appropriate. Univariate analysis associating 1) the number of shuttles completed, 2) BMI, and 3) the sum of skinfolds to academic performance were conducted. Crude and adjusted multiple linear regression analyses, stratified by sex, were conducted to examine the association between academic performance and CRF. Analysis between depended and independent variables was adjusted by sum of skinfolds and SES in a first model and by BMI-percentile and SES in a second model. A residual analysis was performed and the assumption of homoscedasticity and adherence to the normal distribution was followed for both models. Considering alpha = 0.05 and power = 0.80, the sample size in this study was sufficiently large to detect R-squared values greater than 0.05 in the regression analyses even when including independents variables (BMI-percentiles, body fat and SES) in the adjusted model. The level of significance was set as $p < 0.05$. Data were analyzed using SPSS v.10.0.

3. Results

From the total of 392 students analyzed, ninety-seven were stratified into socioeconomic class B (24.7%; CI 95%: 20.5-29.3), two hundred and forty-seven into class C (63.0%; CI 95%: 58.0-67.8) and forty-eight into class D (12.2%; CI 95%: 9.1-15.9). None of the students were classified as socioeconomic class A.

Table 1 shows anthropometry, sum of skinfolds, number of shuttles completed, CRF and academic performance of the students according to sex. The results revealed that boys had a lower sum of skinfolds ($p<0.001$), a higher number of shuttles completed and higher CRF ($p<0.001$) compared to girls.

*****INSERT TABLE 1*****

One hundred forty-two girls were classified as normal weight (73.5%; CI 95%: 66.7-79.6) and 51 as overweight (26.5%; CI 95%: 20.3-33.2). Among boys, 142 had normal weight (71.4%; CI 95%: 64.5-77.5) and 57 were overweight (28.6%; CI 95%: 22.4-35.4). There were no sex differences (χ^2= 0.24, p=0.62).

CRF and number of shuttles completed was significantly higher in normal weight girls compared to overweight girls (normal weight = 42.79±

2.26 ml.kg^{-1}.min^{-1}; 23.66±10.74 and overweight= 41.24±1.50 ml.kg^{-1}.min^{-1}; 16.41±5.42; t= 5.48, p =<0.001). Lower CRF and a lesser number of shuttles completed was also seen in overweight boys compared to normal weight boys (normal weight = 50.07±2.75 ml.kg^{-1}.min^{-1}; 35.40±13.71 and overweight= 47.77±2.37 ml.kg^{-1}.min^{-1}; 24.98±13.83; t= 5.74, p =<0.001). However, no statistical differences were noted between weight status and academic performance in Portuguese (normal weight= 4.54±2.12 and overweight = 4.44±1.82; t= 0.45, p=0.65), Math (normal weight= 3.92±2.28 and overweight= 3.68±1.98; t= 1.02, p=0.30) and overall average (normal weight= 4.22±1.94 and overweight= 4.06±1.55; t= 0.89, p= 0.37) in both sexes combined or separated.

The number of laps completed in the shuttle run test was not significantly associated with performance in Portuguese (β= 0.018; p= 0.21 – in girls; β= -0.015; p= 0.13 - in boys), mathematics (β= 0.019; p= 0.18 - in girls; β= -0.011; p= 0.34 - in boys) or with the overall average (β= 0.018, p= 0.13, girls; β= -0.013, p= 0.17). Similarly, BMI was not significantly associated with performance in Portuguese (β= -0.019; p= 0.65 - girls; β= -0.051; p= 0.14 - boys), mathematics (β= -0.042; p= 0.33 and β= -0.073; p= 0.06 – for girls and boys) or overall average (β= -0.030; p= 0.40 for girls; β= -0.062; p= 0.06 for boys). There was not a significant association between the sum of skinfolds and performance in Portuguese (β= 0.006, p= 0.70 girls; β= -0.013, p= 0.33 boys) or overall average (β= -0.005, p= 0.71 girls; β= -0.022, p= 0.08 boys). There was a weak inverse association between sum of skinfolds and performance in mathematics in boys (β= -0.030, p= 0.04), but not in girls (β= -0.016, p= 0.31).

Multiple linear regression in model 1 revealed that CRF was associated with academic performance among girls even after adjustments by the sum of skinfolds and SES. Similarly, multiple linear regression in model 2 showed that CRF was associated with academic performance among girls after adjustments for BMI-percentiles and SES. No associations were observed among boys on crude or adjusted analyses (Table 2).

*****INSERT TABLE 2*****

4. Discussion

To the best of our knowledge, this is the one of few studies examining the relationship between overweight, CRF and academic performance in elementary school students. The main finding was that CRF was positively associated with academic performance in girls regardless of BMI, body fat and SES, but not in boys.

Some previous studies found that CRF is positively associated with academic performance, independent of BMI (7, 38, 43). However, another study, which adjusted the analysis by sex and SES but not for BMI and body fat, did not find a significant association between academic performance and CRF (5).

Some studies also examined the association between physical activity and academic performance (30, 33). Similar to the present study Martínez-Gómez et al. (33) reported that active commuting to school was associated with better cognitive performance only in adolescent’s girls, independent of participation in extracurricular physical activities. The different results for boys and girls was also found in some other studies. Kwak et al. (30) found that CRF was associated with academic performance in boys but not in girls. Others reported in effects in both sexes (12, 20). These differences might be attributed to the age of the subjects (12, 20, 30), different measurement instruments (e.g. standardized vs cognitive tests) (12, 20, 30), and assessment of CRF.

A negative association between adiposity and academic performance has been shown in few studies in the USA, Europe and Asia (1, 36, 44). Some studies found adiposity to be significantly related to lower cognitive performance and academic results (25, 26), but other studies did not find such an association (4, 14). It is not clear if academic performance is directly mediated by fatness or if it is influenced by factors associated with excessive fatness, such as poor self-esteem, anxiety⁄depression (16), teasing and social rejection (18), impairment in motor skills (20) and poor physical fitness (44). Future studies should focus on identifying possible factors associated with adiposity (such as low self-esteem, body dissatisfaction, depression, psychological problems, eating disorders, physical inactivity, cardiovascular risks, motor impairment) that might be more strongly related to academic performance than just fatness by itself.

The mechanism of the association between academic performance and CRF remains unclear. It is hypothesized that improvements in CRF, as induced by changes in physical activity levels, may have a positive influence on cognition mediated by increased levels of brain-derived neurotrophic factor (BDNF) (22). In a systematic review, Knaepen et al. (28) suggested that exercise training would increase BDNF synthesis, facilitating learning and maintenance of cognitive functions by improving synaptic plasticity, acting as a neuroprotective agent, increasing blood flow in the brain and enhancing neuroelectric functionality. It is known that genetics may account for approximately 50% of CRF (37) and cognition (10). Thus, genetic background may have an influence on the association between CRF and academic performance.

The mechanisms underlying the association between CRF and academic performance in girls may be, at least partially, attributed to the lower levels of physical activity experienced by girls compared to boys (47). Similarly, hormonal changes associated with menarche (27) could lead to psychological alterations such as problems with interpersonal skills and internalizing behaviors (15). Academic performance is typically lower in boys as was observed here (albeit non-significant), and, moreover, even normal weight girls appear to be less fit than overweight boys. These differences may have masked the relationship in boys.

The relationship between CRF and academic performance has been investigated mainly using CRF field-based exercise tests (7, 38, 43, 50). However, evidence suggests that the association between CRF and academic performance might be protocol/test dependent, as reported by Dwyer et al. (13), Haapala et al. (20) and Van Der Niet et al. (48). This dependency may be partly attributed to motor skills and running efficiency (24), rather than pure CRF. A shuttle run test which measures cardiovascular and motor performance (i.e. considers both CRF and motor skills) seems to be adequate to assess the effects of CRF on children's academic performance (20).

There are some limitations to consider in this study. First, maturation was not measured. Other potential confounding factors such as physical activity, race, familiar characteristics and family support were also not measured. Our sample consisted mainly of children from SES classes C and D (75% of participants). Therefore, we should be careful on generalization of data. Other limitations from this study include the indirect assessment of CRF. There are concerns on the use of the 20-meters shuttle run to predict VO_{2max} as it might underestimate participants' maximal capacity due to the effect of body composition (34) and motivation (17). The cross-sectional design of the study limits our ability to make assumptions about the causal nature of the CRF and academic performance.

Nevertheless, the study has some strengths including use of linear models to assess the association between the variables. We also included a number of potential confounders that are consistent with previous literature on the topic, including SES, BMI, body fat and sex. Additionally, most studies on this topic generally examined populations in the United States and used SES proxies such as student eligibility for free or reduced-price lunch in schools and only measured mother's education (5, 9, 38, 43). We believe that the use of our SES measurement tool, which assesses the purchasing power of families and educational level of both parents, is more accurate to assess SES and verify the influence on academic performance. BMI is commonly used to define overweight, but is not a measure that is specific to adiposity (8). Skinfold measurements are a more direct indicator of adiposity and can be used to provide information on the association between adiposity and academic performance. However, on the other hand the BMI analysis enhances the comparability of the results from the present study with other.

Based on the results of this study, we believe that interventions to improve CRF in children should be promoted, not only to promote health benefits but also cognition and academic achievement. Additionally, we suggest that educational information should be provided to physical education teachers and sports coaches on the importance of developing CRF in children for improvement on academic performance.

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Competing interests

Authors declare no competing interests

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Table 1. Anthropometry, fatness cardiorespiratory fitness and academic performance of students according to sex.

Variables	Girls N=193	Boys N=199	T	P
Age (years)	12.04±0.72	12.19±0.76	-1.81	0.07
Body Mass (kg)	43.86±9.25	42.51±12.39	0.32	0.74
Stature (cm)	148.91±7.14	147.51±8.14	1.36	0.17
BMI (kg/m^2)	19.69±3.37	19.27 ±4.36	0.11	0.90
BMI-percentiles	58.81±27.70	53.77±32.23	1.66	0.98
Triceps skinfolds (mm)	16.87±5.10	15.64±6.54	2.06	0.03
Calf skinfolds (mm)	17.48±4.26	16.04±4.99	3.07	<0.001
Sum of skinfolds (mm)	34.36±8.95	31.69±11.03	2.62	<0.001
Number of shuttles completed	21.73±10.12	32.45±14.49	-8.43	<0.001
VO_{2max} ($ml \cdot kg^{-1} min^{-1}$)	42.38±2.19	49.41±2.84	-27.42	<0.001
Portuguese (score)	4.70±2.00	4.30±2.10	1.81	0.07
Mathematics (score)	3.75±2.02	3.95±2.36	-0.91	0.36
Overall average (score)	4.22±1.71	4.14±2.00	0.45	0.65

Table 2. Children's academic performance predicted by estimated VO_{2max} (ml/kg/min) crude and adjusted analysis (model 1 and model 2).

Dependent variable	β(SE)	B standardized	p
Girls			
[a]Performance in Portuguese			
Crude	0.129 (0.064)	0.143	0.047
Model 1	0.163 (0.069)	0.181	0.019
Model 2	0.149 (0.067)	0.166	0.027
[b]Performance in Mathematics			
Crude	0.146 (0.066)	0.159	0.027
Model 1	0.147 (0.070)	0.159	0.039
Model 2	0.155 (0.068)	0.168	0.025
[c]Performance Overall			
Crude	0.138 (0.055)	0.177	0.014
Model 1	0.155 (0.059)	0.199	0.010
Model 2	0.152 (0.058)	0.195	0.009
Boys			
[a]Performance in Portuguese			
Crude	-0.014 (0.053)	-0.019	0.789
Model 1	-0.056 (0.062)	-0.075	0.371
Model 2	-0.052 (0.057)	-0.071	0.358
[b]Performance in Mathematics			
Crude	-0.010 (0.059)	-0.011	0.873
Model 1	-0.102 (0.069)	-0.123	0.142
Model 2	-0.067 (0.063)	-0.081	0.291
[c]Performance Overall			
Crude	-0.012 (0.049)	-0.017	0.811
Model 1	-0.079 (0.058)	-0.114	0.175
Model 2	-0.060 (0.053)	-0.086	0.261

Model 1: Adjusted for absolute skinfold thickness and SES (socioeconomic status)- Girls: aF=3.982; p=0.047; r=0.143; r2=0.020; SEE (Std. Error of the Estimate) =1.961. aF*= 2.350; P=0.026; r=0.190; r2=0.036; SEE=1.956. bF=4.968; p=0.027; r=0.159; r2=0.025; SEE=2.001. bF*=2.577; p=0.055; r=0.198; r2=0.039; SEE=1.997. cF=6.150; p=0.014; r=0.177; r2=0.031; SEE=1.688. cF*=3.147; p=0.026; r=0.218; r2=0.048; SEE=1.682. Boys: aF=0.072; p=0.789; r=0.019; r2=0.000; SEE=2.104. aF*= 0.671; p=0.571; r=0.101; r2= 0.010; SEE=2.104. bF=0.026; p=0.873; r=0.011; r2=0.000; SEE=2.371. bF*=2.180; p=0.092; r=0.180; r2=0.032; SEE=2.344. cF= 0.057; p=0.811; r=0.017; r2=0.000; SEE=1.977. cF*=1.603; p=0.190; r=0.155; r2=0.024; SEE=1.963. Model 2: Adjusted for BMI-percentiles and SES- Girls: aF=7.057; p=0.009; r=0.189; r2=0.036; SEE=1.946. aF*= 2.124; P=0.025; r=0.181; r2=0.033; SEE=1.960. bF=8.515; p=0.004; r=0.207; r2=0.043; SEE=1.983. bF*=2.597; p=0.054; r=0.199; r2=0.040; SEE=1.997. cF=10.776; p=0.001; r=0.231; r2=0.053; SEE=1.668. cF*=3.175; p=0.025; r=0.219; r2=0.048; SEE=1.682. Boys: aF=0.020; p=0.065; r=0.032; r2=0.001; SEE=2.103. aF*= 1.187; p=0.316; r=0.134; r2= 0.018; SEE=2.096. bF=0.084; p=0.772; r=0.021; r2=0.000; SEE=2.371. bF*=1.965; p=0.121; r=0.171; r2=0.029; SEE=2.348. cF= 0.172; p=0.679; r=0.030; r2=0.001; SEE=1.976. cF*=1.904; p=0.130; r=0.169; r2=0.028; SEE=1.959

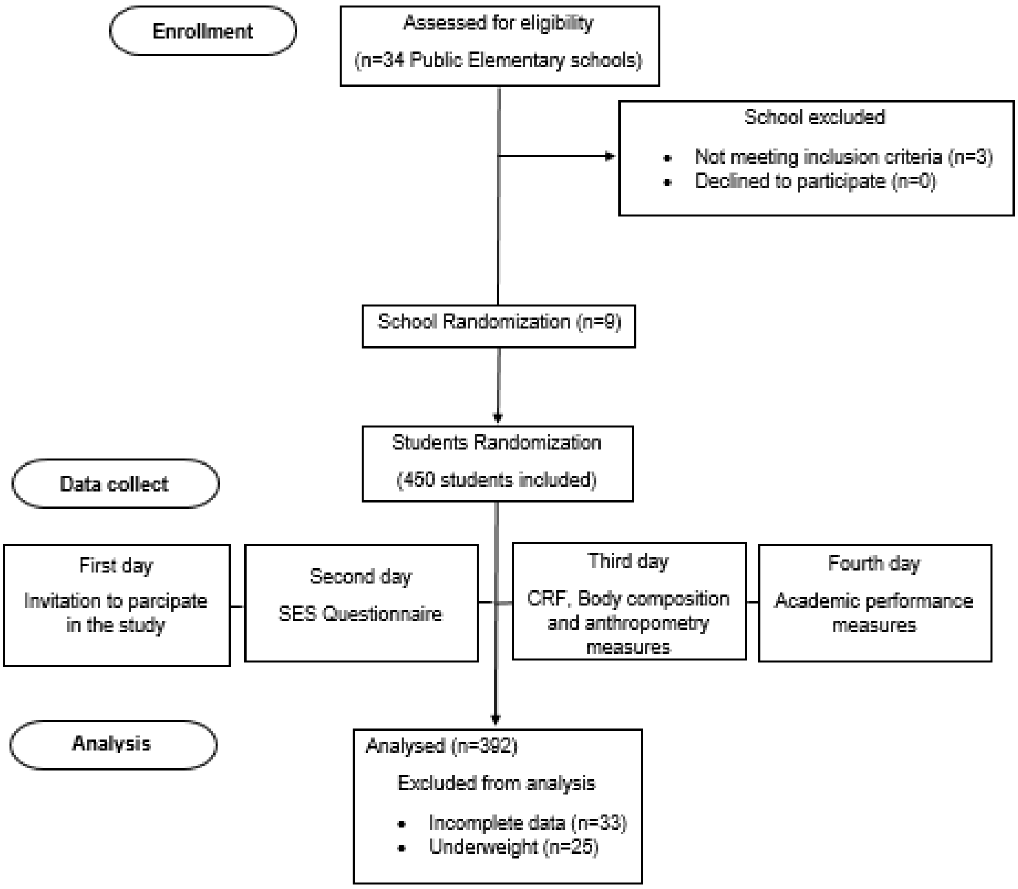

Figure 1. Study design