Encouraging physical fitness in Brazilian adolescents with excess weight: can they outperform their eutrophic peers in some activities?

We used generalized linear mixed models (GLMM) to analyze the relationship between nutritional status and performance in the fitness tests, controlled for maturity offset and fat mass percentage.

Results: 1,563 (51%) were boys, mean age 12.6 years (±1.8), 22.8% were overweight and 12.5% had obesity. In both sexes, adolescents with obesity did better in the upper body strength test than their eutrophic peers. Boys with obesity had worse cardiorespiratory fitness and lower body muscular strength than eutrophic boys. Girls with obesity had similar cardiorespiratory fitness and better lower body strength than eutrophic girls.

Conclusion: In muscular strength fitness tests, adolescents with obesity performed similarly to, or better than, their eutrophic peers. Motivation to maintain regular PA is reinforced by positive experiences. Interventions that emphasize muscular strength PF should be developed for adolescents with obesity.

Keywords: adolescent; Brazil; obesity; physical fitness.
motivation is an important aspect of sustainable lifestyle changes [6, 7]. Therefore, to achieve effective change in PA practice, it would be helpful to identify the activities at which the individual does best as their relative success is likely to encourage them to initiate and adhere to regular PA [8].

The assessment of several components of health-related physical fitness (PF) might indicate the capabilities and hurdles to practicing PA. For example, individuals who do well in cardiorespiratory fitness exercises are also likely to perform well in PA which requires displacement of body weight, such as running, swimming, and cycling [9].

Most educators and health professionals who care for adolescents follow general guidelines that recommend cardiorespiratory physical exercises to promote weight loss or weight control. However, some studies have observed that cardiorespiratory fitness is the most impaired health-related PF in adolescents with excess weight [10, 11]. Adolescents with excess weight who perform worse than their eutrophic peers in such activities may be demotivated by feelings of inability or failure or may fear being teased about their poor performance [12]. On the other hand, individuals who do well in muscular strength fitness exercises (at which adolescents with overweight or obesity may do well), are more likely to succeed in sports such as shot put, combat sports, and resistance training. We suggest that adolescents with excess weight should be encouraged to pursue regular PA by starting with activities in which they can perform as well as or better than their eutrophic peers.

Whether health-related PF is associated with nutritional status (eutrophic, overweight and obesity) is still controversial. Studies to evaluate PF in teenagers with excess weight in diverse populations are needed to identify the components of PF that this group of adolescents perform well. The objectives of this study, therefore, were to investigate the relationship between four health-related PF components, i.e., cardiorespiratory fitness, flexibility, upper and lower body muscular strength fitness and nutritional status, and to identify those that are more suited to adolescents with excess weight.

**Methods**

**Study design and ethical aspects**

In this cross-sectional study, we analyzed data from a large, school-based study performed in a middle-sized urban city, São Caetano do Sul, in the southeast region of Brazil. In 2011, data were collected from students of both sexes, aged 7–18 years, enrolled in 19 schools. The main purpose of this primary study was to identify students who had outstanding PF performance.

In the present study, we selected adolescents aged 10–18 years. A total of 4,739 students in this age group and their parents/guardians were invited to participate in the primary project. Those who agreed to join the study signed consent forms after receiving oral and written study information. Of the 3,213 consenting adolescents (68% participation rate), 151 were excluded from the analyses due to missing data (n=27), severe low body weight (n=64), and severe obesity (n=60). Those with extremes of nutritional status were excluded because medical evaluation and care might be required prior to physical exercise. The final sample of the current study thus comprised 3,062 participants.

The study protocol was conducted following the Declaration of Helsinki for human studies and it was approved by the Research Ethics Committees of the University of São Caetano do Sul (no. CAEE 79510017.1.0000.5510), and the Faculty of Medicine of the University of São Paulo, Brazil (Process no. 383/17).

**Measurements**

Measurements were taken by six health professionals specifically trained to perform the anthropometric and PF test assessments. On their first visit to the school, they measured the anthropometric parameters and assessed cardiorespiratory fitness. Two days later, on the second visit, they assessed musculoskeletal fitness (upper and lower body strength) and flexibility.

The anthropometric evaluation included height, weight, skinfold thickness, trunk height and leg length measured under standardized conditions. Each feature was measured three times following the International Society for the Advancement of Kinanthropometry criteria [13] and the mean of measurements was used for the analyses. Body mass index (BMI) was calculated as weight (kg) divided by height squared meter (m²). BMI-for-age and -sex z-scores (BMI z-score) were calculated using AnthroPlus software downloaded from the World Health Organization (WHO) website [14]. All adolescents were then classified according to the WHO nutritional status categories [15]: underweight (BMI z-score <−2), eutrophic (−2≤ BMI z-score <1), overweight (1≤ BMI z-score <2), obesity (2≤ BMI z-score <3) and severe obesity (BMI z-score ≥3).

The trained professionals measured, on the subject’s right side, the skinfold thickness to the nearest 0.2 mm at two anatomical sites, subscapular and triceps, using a calibrated Lange caliper. Body fat mass percentage was calculated based on the skinfold thickness measures using the Boileau Protocol [16].

Pubertal status was assessed by the estimate of the time for maximum growth in height during puberty, an indicator of biological maturity offset proposed by Mirwald et al. [17]. The calculation was based on chronological age and measurement of trunk height and leg length to build a sex-specific equation of peak height velocity (PHV). The results of the equation were used to estimate the number of years to PHV. While negative values indicated age younger than the PHV, suggesting pre-pubertal status, positive values indicated that the PHV has been reached, i.e., that the pubertal phase might be considered advanced.

Health-related PF measurements, the outcomes of interest, were based on performance in four PF tests, chosen for their reliability and validity [18]. Cardiorespiratory fitness was evaluated by the 20-m shuttle run test proposed by Bangsbo [19]. Participants ran a distance of 20 m between two lines, with the initial speed of the test set at 8.5 km/h. With progressive increases of 0.5 km/h at 1-min intervals,
the test ended when the participant could no longer keep up with the pace. The speed of the last completed stage was recorded [20].

Flexibility was assessed by the sit and reach test. Participants adopted a sitting position on the floor with shoes off, both legs fully extended and the soles of their feet flat against the end of a box. With their palms down and one hand on top of the other, participants were asked to extend their arms forward along a measuring scale as far as possible without bending their knees. The best of three measurements was used for the analyses [21].

Upper body muscular strength was measured by the seated medicine ball throw test. Participants sat on the floor with their backs flat against a wall and legs straight. They were given a 4 kg rubber medicine ball to hold at chest level until instructed to throw. The stop at chest level was intended to minimize any motion or stretch-shortening cycle effects of using a dynamic start. Each participant performed three throws with at least 30 s rest between them. Using a tape measure, the distance from the wall to where the middle of the ball landed was measured to the nearest centimeter. The higher throw distance achieved was included in the analyses [22].

Lower body muscular strength was assessed by the standing broad jump test. Participants performed 5-min jogging and 5-min dynamic stretching warm-ups before the test. They then stood on the starting line with their feet shoulder-width apart and legs straight and parallel. From this position, participants had to bend their knees (knee flexion depth was self-selected) and put their arms behind their bodies. Following a sound signal, they extended their legs, moved their arms forward, and jumped as far as possible. The distance jumped was measured in meters. The test was performed three times and the best result was used in the analyses [23].

Statistical analysis

Descriptive data were presented as means and standard deviations or percentages. The means of measurements of the four test results (20-m shuttle run, sit and reach, medicine ball throw and standing broad jump) were calculated with a 95% confidence interval (CI).

Multiple variable analysis was used to study the relationship between PF and nutritional status, considering sex, age, maturity offset (measured by PHV) and body fat mass percentage. Since we found that chronological age was highly correlated with biological maturation offset, only maturation was included in the analyses. A significant interaction effect between sex and nutritional status was observed in the exploratory analysis; thus, analyses were performed separately for boys and girls.

Four generalized linear mixed models (GLMM) were used to analyse the variables related to each of the outcomes of interest, i.e., the performance in the PF tests. The point estimates, and 95% CI, of the average values of the four PF tests, were obtained for each of the nutritional status categories. All models included body fat mass percentage and biological maturity offset as covariates because they were considered, \( a \ priori \), to be important factors for comprehending the relationship between PF and nutritional status. We used the Sidak correction post-hoc test to account for multiple testing.

Statistical analyses were performed using the Statistical Package for Social Sciences (IBM SPSS Statistics Windows v. 24.0; SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at a p-value <0.05.

Results

Characteristics of the study population by sex are shown in Table 1. Girls (1,499; 49%) showed a higher mean body fat mass percentage than boys (p<0.001). No statistically significant differences were observed in the means of age and biological offset between sexes. Participants were classified as eutrophic (64.7%), overweight (22.8%), or as having obesity (12.5%). The prevalence of obesity among girls was higher than in boys, at 14.2% and 11.5%, respectively (p=0.007).

Performance comparison between girls and boys in the four PF tests showed that boys had statistically significantly better results than girls, except for flexibility in which girls performed better than boys (Table 2).

Figures 1–4 show the results, separately for male and female participants, of the GLMM analyses comparing the average values of each of the four PF tests between nutritional status categories controlled by body fat mass percentage and biological maturity. Male adolescents with obesity performed worse in the 20-m shuttle run test than their eutrophic peers (mean number of arrivals 15.9 vs. 22.5 respectively, p<0.001); whereas no statistically significant difference was observed between girls with obesity and the eutrophic girls (Figure 1, Figures 1S and 2S). Nutritional status was not associated with flexibility (sit and reach test) in either sex (Figure 2, Figure 3S). In the medicine ball throw test, girls with overweight performed better than the eutrophic girls (mean distance of throw in meters 2.9 vs. 2.5 respectively, p<0.001), as did the girls with obesity compared to the eutrophic girls (mean distance of throw in meters 3.3 vs. 2.5 respectively, p<0.001). Boys with overweight and obesity performed better in the upper body strength test, ball throw, than the eutrophic boys (Figure 3, Figure 4S). Boys with obesity performed worse than the eutrophic boys in the standing broad jump test (mean distance of jump in meters 1.5 vs. 1.6 respectively, p<0.001); girls with overweight and obesity performed better in that lower muscular strength test than eutrophic girls (Figure 4, Figures 5S and 6S).

Discussion

The research question of this study was whether there was a relationship between nutritional status and health-related PF. We observed that nutritional status was associated with cardiorespiratory fitness (20-m shuttle run test) and muscular strength fitness (medicine ball throw and standing long jump tests). It is noteworthy that, for both
sexes, adolescents with excess weight performed better in the upper body strength tests than their eutrophic peers.

While several studies have reported that excess weight in adolescents is associated with poor PF [10, 11, 24], others have observed that in some components of PF, their performance is equal to, or better than, their eutrophic peers [25–29]. Comparisons among study findings, though, are very difficult to make due to differences in terms of the age range, assessment of pubertal status, and nutritional condition of the study participants. Also, the type of PF tests used varies greatly between studies.

We observed that eutrophic boys performed better in the cardiorespiratory fitness test than their counterparts with overweight and obesity. Similarly, Moliner et al. reported that adolescents with high total and central fat percentage performed worse in the 20-m shuttle run test than their eutrophic peers, controlled for age and maturity offset assessed by Tanner’s criteria [25]. In a Swedish study, boys with excess weight also had worse results in the cardiorespiratory test [11]. This may be because those individuals with excess weight, especially with obesity, require higher energy expenditure, leading to earlier fatigue due to the displacement of a larger body mass compared to their eutrophic peers [9].

In our analysis, flexibility was the only test in which sex and nutritional condition were not associated. Both girls and boys with overweight performed better than their eutrophic peers, or those with obesity. Our results are in accordance with Andreasi et al. who observed that adolescents with overweight and obesity performed 80% better in the flexibility test results than their eutrophic peers [10]. One possible explanation for this finding is that flexibility training is not usually included in PA practice, thus, this physical ability is weak in all adolescents, independently of their nutritional status.

Tests that assess muscular strength may or may not involve body movement. We used two tests to assess strength: medicine ball throw, which does not involve body movement, and horizontal jump, which does. Among girls, those with obesity did better than those who were overweight, who, in turn, did better than the eutrophic girls in the performance of the upper body muscular strength test. Looking at differences among boys, those with overweight and obesity performed similarly to each other and better than their eutrophic peers. In this test, displacement of body mass does not occur which may explain the better performance by adolescents with excess weight [25, 30]. Their absolute force may be greater than that of eutrophic adolescents. In general, people with excess weight have more muscle mass, since it is proportional to total body mass, and they have better neuromuscular activation [31]. For this reason, it could be expected that adolescents with excess weight perform better than their eutrophic peers in sports such as weightlifting and rotational shot-put.

In the standing broad jump test, we found that girls with excess weight performed better than the eutrophic

| Characteristics | All (n=3,062) | Male (n=1,563) | Female (n=1,499) | p-Value |
|-----------------|--------------|----------------|------------------|---------|
| Age, years      | 12.6±1.8     | 12.6±1.8       | 12.6±1.8         | 0.372   |
| Peak height velocity$^a$ | $-1.92±1.4$ | $-1.89±1.5$ | $-1.95±1.2$ | 0.197   |
| Body fat mass percentage | 23.9±7.4 | 21.5±7.5       | 26.4±6.3         | <0.001  |
| Nutritional status$^c$ classified according to BMI z-score | | | |
| Eutrophic       | 1,980 (64.7%) | 988 (63.2%)     | 992 (66.2%)      | 0.093   |
| With overweight | 688 (22.8%)  | 354 (22.6%)     | 334 (22.3%)      | 0.841   |
| With obesity    | 384 (12.5%)  | 221 (14.2%)     | 163 (11.5%)      | 0.007   |

Values are mean ± SD, or n (%). $^a$Peak height velocity (PHV) is a tool to assess maturity offset and it is calculated by an equation proposed by Mirwald et al. [17]. The unit is number of years to PHV. $^c$Nutritional status classified according to the WHO [15] categories based on body mass index z-score (BMI z-score) adjusted by age and sex: eutrophic ($-2 <$ BMI z-score $<1$), overweight ($1 <$ BMI z-score $<2$), obesity ($2 <$ BMI z-score).

Table 2: Comparison of performance physical fitness tests between male and female adolescents.

| Physical fitness tests                     | All        | Male        | Female       | p-Value   |
|-------------------------------------------|------------|-------------|--------------|-----------|
|                                           | N | Mean ± SD | n | Mean ± SD | n | Mean ± SD | |
| 20-m shuttle run test (number of arrivals) | 2,945 | 18.1±9.6   | 1,503 | 22.4±10.4 | 1,442 | 13.7±5.0 | <0.001 |
| Sit and reach test (distance of reach in centimeters) | 3,031 | 21.7±8.0   | 1,541 | 19.3±7.4 | 1,490 | 24.2±8.0 | <0.001 |
| Medicine ball throw (distance of throw in meters) | 3,049 | 2.9±0.9    | 1,562 | 3.2±1.1  | 1,487 | 2.6±0.6  | <0.001 |
| Standing broad jump (distance of jump in meters) | 3,045 | 1.4±0.3    | 1,558 | 1.6±0.3  | 1,487 | 1.3±0.2  | <0.001 |
girls, as in two other studies, by Kim et al. [32] and Ervin et al. [26]. Our results may be explained by the poor PF level of girls in general [17]. Eutrophic girls are consistently presenting worse strength fitness results now than those observed 20 years ago, as has been reported in several countries [33]. Among boys, those with obesity performed worse in the standing broad jump test than eutrophic boys or those with overweight, corroborating findings reported by Moliner Urdiales et al. [25] and Polawska et al. [28]. These studies, like ours, showed that boys and girls with overweight had greater success in strength activities that did not involve body displacement. They are likely to perform less well in exercises that require moving one’s own body weight, such as the standing broad jump test.
Moving a larger body mass increases the mechanical overload, which in turn, overburdens the muscles leading to poor performance [9].

This study has strengths that should be mentioned. Several studies have investigated health-related PF and nutritional status in adolescents [10, 11, 25–28] but there is great methodological heterogeneity among them. Comparison is difficult due to the variety of parameters used to define nutritional categories, types of tests used to assess PF, and statistical controlling for important confounders such as maturity status, sex, and body fat mass percentage. We have taken a comprehensive approach in our study by including potential confounders in the analyses. Other strengths of the present study are the large sample of in-school adolescents, the high participation rate and having anthropometric measurements and PF tests conducted by experienced health professionals using standardized equipment and procedures. A systematic review [18] which analyzed studies on the validity of field-based fitness tests for children and adolescents, reported that the 20-m shuttle run and standing broad jump tests were the most appropriate parameters to evaluate cardiorespiratory fitness and lower body physical strength, respectively. Also, the authors suggested that body fat percentage, measured by skinfold thickness, is a suitable estimate of body composition in adolescents. Our study used these recommended parameters.

There were several limitations to this study. Firstly, its cross-sectional design does not allow a causal interpretation of the findings. Secondly, although BMI is widely used to assess nutritional status in large population assessments, it alone does not adequately assess nutritional status since it does not measure body composition. We tried to minimize this limitation by including body fat mass percentage in the analyses. Thirdly, there was a lack of information about the participants’ PA patterns, intensity, and daily amount of PA. Such information should be included in future studies. Further, we did not assess the degree of engagement of participants in the tests, which may have introduced measurement bias. Finally, we did not use Tanner’s clinical criteria which is the gold standard to assess biological maturity stages. Instead, we used PHV, which has been widely applied for the assessment of maturity offset for research purposes due to its facility to be used in a field or scholarly environment [34, 35].

Programs for obesity control for adolescents often recommend combined interventions including a healthy diet, regular PA, and counseling [4]. However, there is no clear evidence on how to implement these recommendations or how effective they are [36]. We hypothesize that designing a tailored PA plan for adolescents with excess weight may motivate them to engage in regular PA [37]. Regular PA has known benefits for this group in that it improves metabolic profile, decreases cardiovascular risk in adulthood, and increases life satisfaction [38], even if it does not directly lead to weight loss [39].

In conclusion, we observed that cardiorespiratory fitness, and upper and lower body muscular strength fitness were associated with nutritional status. Our results suggested that adolescents with excess weight perform worse than their eutrophic peers in the cardiorespiratory fitness test, but they perform better than their eutrophic peers in the muscular strength fitness tests. Therefore, we recommend that PA plans for adolescents with excess weight should avoid aerobic exercises at the initial phase since these types of exercises may discourage and demotivate them. The inclusion of strength exercises, such as weightlifting, handgrip strength, and rotational shot-put may be appropriate options to introduce adolescents to PA practice. We hypothesize that by promoting PA modalities in which they do well they could feel motivated to engage in and adhere to a regular PA schedule. Future
studies will be needed to evaluate the effectiveness of diverse intervention strategies based on PF exercises tailored to adolescents with excess weight.

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