REPEATED SPRINT TEST PERFORMANCE INDICES AND AEROBIC FITNESS IN NORMAL AND OVERWEIGHT PRE-PUBERTAL CHILDREN

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ABSTRACT

We determined relationships between aerobic fitness and performance indices (fastest sprint time – FS, total sprint time – TS, and performance decrement – PD) of repeated sprint tests (RST) in normal and overweight children (BMI%: 59.8±12.9 versus 96.4±1.9%, respectively). Aerobic fitness, FS, and TS were significantly higher in normal weight children. Significant negative correlations were found between aerobic fitness and TS (r=–0.802), FS (r=–0.762) and PD (r=–0.670) in normal weight children. Significant negative correlations between aerobic fitness and TS (r=–0.767) and FS (r=–0.738), but not with PD were found in overweight children. While aerobic and anaerobic capabilities were significantly higher in normal weight children, strong relationships were found between aerobic fitness and RST indices in both normal and overweight children.

Key words: aerobic, anaerobic fitness, childhood obesity, repeated sprint test Speed, fatigue, anaerobic, endurance.

INTRODUCTION

Children usually engage in short bursts of physical activity separated by brief periods of rest [2]. Accordingly, a typical voluntary physical activity among children includes multi-sprint sports such as soccer and basketball, or games such as tag. The ability of children to sustain intensity during repeated sprints was examined in previous studies [26, 27]. In these studies a wide range of age groups (9–17 yrs.) performed different protocols of repeated sprint tests (RST). It was found that pre-pubertal boys (9.6±0.7 yrs.) needed less recovery time to sustain their peak power output compared to pubertal boys (15.0 ±0.7 yr) and to young adults (20.4±0.8 yrs.) during repeated cycling sprints [32]. These findings were consistent with Hebestreit et al. [16] and Soares et al. [30], who showed that pre-pubertal children recovered their initial performance faster following high-intensity exercise (peak power or maximum isometric force) than did young adults.

In adults, a high level of aerobic fitness is suggested to be a prerequisite for increased anaerobic performance during repeated sprints [33]. However, correlation between VO_2 max and performance indices of RST have been inconsistent, and only several studies reported significant correlations between the two tests [e.g., 10, 21]. In children, these relationships seem to be especially relevant, due to their characteristic intermittent activity patterns. Moreover, examination of the relationship between aerobic fitness and performance indices of RST is also challenging in unique pediatric populations such as overweight children. This group is particularly important in light of the epidemic of childhood and adolescent obesity in Westernized societies [4]. Both aerobic and anaerobic capacities are reduced in obese compared to normal weight children [12, 20, 34], and as seen in all children, patterns of physical activity among overweight and obese children are also characterized by brief segments of exercise, performed at different intensities and separated by rest intervals of different durations [9, 24]. Better understanding of RST characteristics and their relationship to aerobic fitness in obese children, in comparison to normal weight children, is important and may assist in the design of exercise interventions for obese children. Surprisingly, however, to the best of our knowledge, these relationships were never studied in obese or overweight children. The aim of the present study was to determined the relationship between short running interval (i.e., 12 × 20 m) RST and aerobic fitness (measured by the distance of a 20 m shuttle run test) in pre- and early-pubertal overweight children and to compare them to pre- and early-pubertal normal weight children. Since in children, there is a faster adaptation of the oxygen transport system during exercise [35], we hypothesized that a significant relationship between indices of RST and aerobic fitness will be found in both normal and overweight children. In addition, we hypothesized those aerobic and anaerobic capabilities of normal weight children will be significantly higher compared to overweight children.

METHODS

Eighteen normal weight (males=9, females=9; 10.1±1.4 yrs), and fourteen overweight children (males=6, females=8; 10.5±1.5 yrs) volunteered to participated in the study. All the overweight children participated in a weight reduction program in the Child Health and Sport Center at the Pediatric Department of Meir Medical Center. The normal weight children studied at a public elementary school of the same geographical region. Body Mass Index (BMI) percentile was assessed in all children as an indication of adiposity. Normal weight was defined as BMI <85%, and overweight as BMI>85%. A physician assessment was performed for pubertal stage by pubic hair [18]. The study was approved by the Institution's ethics committee. The testing procedure was explained to the children and to their parents, and a written informed consent was obtained from both.

Procedure

All the participants, (normal and overweight children) performed two tests: 1. aerobic power test, and 2. 12 X 20 m RST. The tests were separated by a week from each other, and were performed at random order. Before each test, the children participated in a special habituation session which included exercise pattern at the intensity level that was required in the upcoming tests. In order to prevent undesirable effects and/or feelings, each test was performed individually without the presence of other children in the near area. A warm-up procedure, including 5 min of jogging, 5 min of stretching and 3–5 20 m running repetition at increasing speed, was performed by the participants before each test.

Performance tests

Aerobic Power Test – Twenty-Meter Shuttle Run Test

The 20-meter shuttle run test is a field test that has been shown to be a reliable and valid indicator [31] of aerobic power in various populations including children older than 8 years old [19]. The main reason for the use of this test in the present study to evaluate aerobic fitness was its back and forward run which best characterizes children's voluntary activity patterns. The test consists of shuttle running at increasing speeds between two markers placed 20 m apart. A portable compact disc (Sony CFD-V7) dictated the pace of the test by emitting tones at appropriate intervals. The children were required to be at one of the ends of the 20 m course at the signal. A starting speed of 8.5 km/hour was maintained for one minute, and thereafter the speed was increased every minute by 0.5 km/hour. The test was terminated when the child withdrew voluntarily from the exercise, or failed to arrive within 3 meters of the end line on two consecutive tones. The aerobic fitness of each participant was calculated as the total distance achieved during the test.

Repeated Sprint Test

The RST included a series of short maximal runs with short rest periods between runs. The protocol consisted of 12 X 20 m runs starting every 20 s. A 20 m all-out sprint was performed at the end of the warm-up by each participant. The time for the 20 m sprint was used as the criterion score for the subsequent RST. Participants had rested for five minutes between the criterion sprint and the RST. In the first sprint of the RST, participants were required to achieve at least 95% of their criterion score. This requirement was achieved by all participants.

A photoelectric cell timing system (Alge-Timing Electronic, Vienna, Austria) linked to a digital chronoscope was used to record each sprint and rest interval time with an accuracy of 0.001 s. During the recovery period between sprints, participants tapered down from the sprint they had just completed and slowly walked back to the next starting point. Two sets of timing gates were used, working in opposite directions, to allow participants to start the next run from the end-point of the preceding sprint. A standing start, with the front foot placed 30 cm behind the timing lights, was used for all sprints. Timing was initiated when the participants broke the light beam. An experimenter was placed at each end of the track to give strong verbal encouragement to each participant at each sprint. Participants were instructed prior to the test to produce maximal effort and to avoid pacing themselves.

The three measures of the RST were the fastest 20 m sprint time (FS), the total sprint time (TS) of the 12 sprints, and the performance decrement (PD) during the test. Total sprint time was calculated as the sum of all sprints times of the test. Performance decrement was used as an indication of fatigue and was calculated as (Total sprint time/Fastest sprint time x 12 x 100) – 100 [13]. The test-retest reliability of the RST is 0.942 for total running time, and 0.75 for performance decrement [13].

Heart rate was measured using a Polar heart rate monitor (Polar Accurex Plus, Polar Electro, Woodbury, NY) immediately after completion of each run in the RST. Rate of perceived exertion (RPE) was determined using the modified Borg scale [8] at the end of the RST.

Statistical analyses

A two-way repeated measure ANOVA with bonferroni adjustments was used to compare differences (total distance 20 m shuttle run, RST's FS, TS, PD, heart rate, RPE) between the normal weight and overweight children. Pearson correlations were computed between the calculated distance during the shuttle run aerobic test and performance indices of the 12 x 20 m RST. Data are presented as mean±SD. Significance level was set at $p<0.05$.

RESULTS

Anthropometric characteristics, performance indices of the RST and the results of the 20 m shuttle run aerobic test of the study participants are presented in Table 1. Overweight children had a significantly greater body weight, BMI and BMI percentiles compared to the normal weight children. The total distance in the 20 m shuttle run was significantly greater in the normal weight compared to the overweight children. Fastest sprint time and TS were significantly faster in the normal weight children, and RPE at the end of the RST was significantly lower. There were no significant differences in PD and heart rate between the groups.

Table 1. Anthropometric measures, performances indices of the 12 x 20 m RST and total distance during the 20 m shuttle run of the normal weight and overweight pre-pubertal children (Mean ± SD).

Parameters	Normal weight (n=18)	Overweight (n=14)
Age (yrs)	10.4±1.2	10.6±1.5
Pubertal Stage (Tanner)	1.1±0.3	1.2±0.4
Body Height (m)	141.0±9.9	143.5±7.9
Body Weight (kg)	36.3±6.6	52.5±10.0*
BMI (kg/m^2)	18.1±1.5	25.1±4.7*
BMI Percentile (%)	59.8±12.9	96.4±1.9*
Fastest Sprint (sec)	4.10±0.34	4.71±0.65*
Total Sprint Time (sec)	52.99±4.95	60.03±9.05*
Performance Decrement (%)	7.74±3.55	6.36±3.62
Maximal Heart Rate (beats/min)	197.2±8.9	191.0±7.1
RPE Score	3.8±1.4	5.1±1.5*
Distance-20m Shuttle Run (m)	752.6±401.7	468.6±107.4*

* $p<0.05$, normal versus overweight

The correlations between the 20 m shuttle run aerobic test and performance indices of the RST are presented in Figure 1. Significant negative correlations were found between the distance in the 20 m shuttle run aerobic test and the TS (r=–0.802), FS (r=–0.762) and the PD (r=–0.670) of the RST in the normal weight children. Similarly, significant negative correlations were found between the distance in the 20 m shuttle run aerobic test and the TS (r=–0.767) and the FS (r=–0.738) of the RST in the overweight children. There was no significant correlation between the distance in the 20 m shuttle run aerobic test and the PD in the RST in the overweight children.

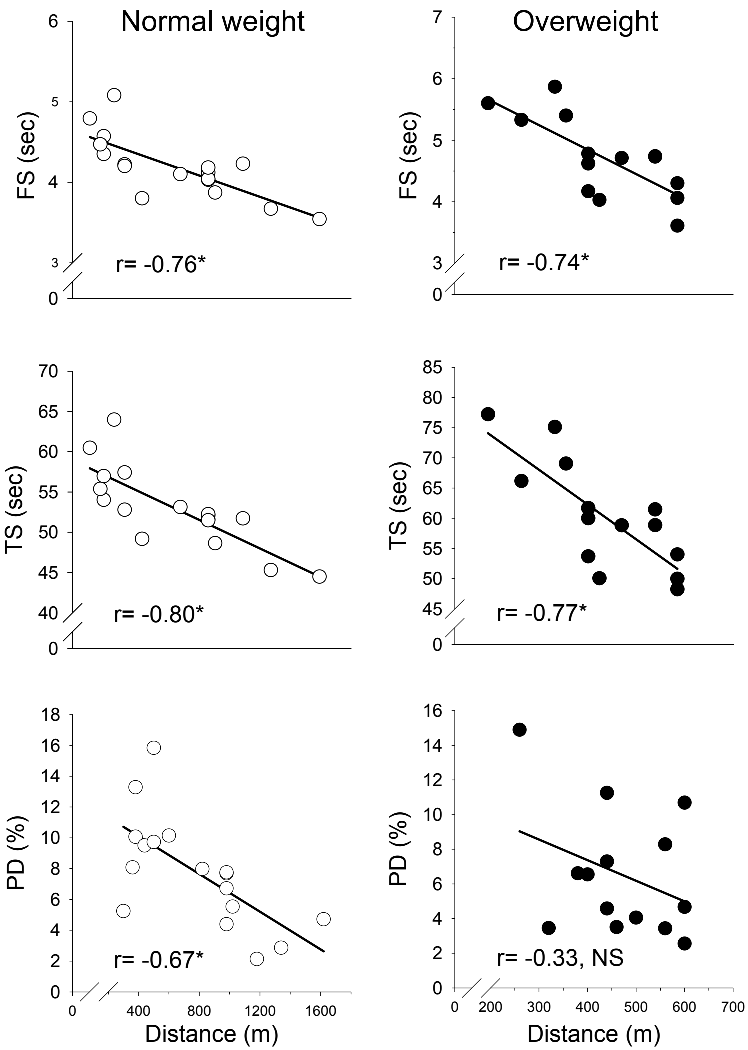

Figure 1. Relationships between the total distance in the 20 m shuttle run and performance indices of the 12 x 20 m RST in normal weight (left panel) and overweight (right panel) children. FS: fastest sprint time; TS: total sprint time; PD: performance decrement; NS: non-significant; * $p<0.05$.

DISCUSSION

The present study examined the relationship between aerobic fitness (measured by distance in 20 m Shuttle Run) and performance indices of 12 X 20 m RST in normal weight and overweight pre- and early-pubertal children. The results clearly indicated that the aerobic fitness of the normal weight children is higher than overweight children (Table 1). Our findings are in agreement with the results of Marinov et al. [20] who demonstrated that the aerobic fitness of non-obese children was significantly higher than obese children. Consistent also with our findings, the RPE of the obese children, in their study, was significantly higher than controls despite a standard workload. It seems therefore, that the aerobic fitness of obese children is reduced and they tend to perceive exertion higher than non-obese children. Both factors may interfere with their ability to sustain prolong physical activity.

The results of the present study also show that FS and TS in the 12 x 20 m RST were significantly faster among the normal weight compared to the overweight children (Table 1). This indicates that anaerobic capacities are reduced in overweight compared to normal weight children as well. Our findings are in agreement with the results of Unnithan et al. [34] who found that anaerobic peak power and total work of normal weight children were significantly higher than overweight children when performing the Wingate Anaerobic Test. The authors concluded that their findings reflect a deficit in anaerobic capacity among children with relatively large body size for their age. This conclusion is in line with the findings of Armstrong et al. [1] who observed a significant negative correlation between skin-fold thickness and peak power or total work of children. The significantly higher body weight and BMI percentile of the overweight children in the present study may have lowered their running efficiency and contributed to the differences in aerobic fitness and RST performance indices between the two groups. The reduced performance among overweight participants might also be related to hypoactivity and muscle contraction characteristics. Cross sectional studies have shown that obese children are less physically active than non-obese children, particularly in spontaneous activities [29]. Although it is unclear whether this hypoactivity can directly influence anaerobic capacity, studies have shown that high-intensity, intermittent training led to improvement in the Wingate Test performance in normal weight children [28]. In contrast, similar type of training did not result in an increase anaerobic capacity in 12–16 years old obese boys [11]. In addition, evidence exist that obese adolescents have a lower percentage of motor unite activation during knee extension compared to leaner adolescents [7]. This finding implies that, for a given muscle mass, less power can be generated. The contributing role of hypo-activity and reduced muscle unit characteristics for the reduced pereformance of overweight children in the present study remains speculative since we did not determine these factors.

The present study also examined the relationships between the aerobic fitness and the performance indices of the 12 X 20 m RST. Significant strong negative correlations were found between the aerobic fitness and the TS and PD of the normal weight children and between aerobic fitness and the TS of the overweight children (Fig. 1). Although PCr resynthesis appears to be controlled by the rate of oxidative metabolism within the muscle [32], previous studies have found that correlation analyses between VO_2 max and performance indices of RST have been inconsistent, and while some authors reported significant moderate correlations between the two [10, 14], others have failed to do so [23]. However, previous studies found a higher muscle oxidative activity [6, 15], a greater relative volume density of mitochondria [5] and a faster adaptation of the oxygen transport system [35] in children compared to adults. These experimental data have been supported by Taylor et al. [32] who showed that the rate of PCs resynthesis after maximal exercise were two-fold higher in children aged 6–12 y compared with adults aged 20–29 y. In accordance with these, Ratel et al. [27] found boys (11.7±0.5 y) to maintain more easily running performance than adults (22±2.9 y) during repeated treadmill sprints separated by 15 s rest. The greater reliance of children on oxidative metabolism is consistent with the finding of significant high correlations between the aerobic fitness and the TS and PD in the RST of the normal weight children and between the aerobic fitness and the TS in the RST of the overweight children in the present study. The lack of significance in the relationship between aerobic fitness and PD of the overweight children may be explained by the remarkable overall slow running speed of the overweight children, and/or by the great heterogeneity of running skills and running efficiency among the overweight children. Reduced running efficiency may affect performance mainly during all out sprints [22], as was required in the RST of the present study, and could have masked the relationship between aerobic capacity and PD during RST in the overweight children.

The aerobic fitness was also significantly correlated with the FT in the RST of the normal weight and the overweight children in the present study. These findings are in contrast to previous reports indicating that the aerobic components of a single short sprint (≤10 sec) are very small (<10%) in adults subjects [3, 25]. However, as seen in normal weight boys [17], the results of the present study may suggest that oxidative metabolism plays an important role, and serves as an energy source, even during a single sprint in normal and in overweight pre-pubertal children. This finding is consistent with the notion of greater reliance of children on oxidative metabolism, and with the theory that the metabolic specialization phenomenon (aerobic versus anaerobic preference) occurs in adults but not in pre- and early-pubertal children [4].

In summary, in prepubertal children the aerobic fitness and the anaerobic capabilities, as reflected by RST performance indices, of normal weight children are significantly higher than overweight children. The results also indicate that aerobic fitness plays an important role in intense intermittent activity in normal weight and in overweight children. Finally, the results of the present study suggest that oxidative metabolism may serve as an energy source, even during a single sprint in normal and in overweight children. Further studies are needed to clarify the relationships between the aerobic and the anaerobic capabilities in normal and overweight children and to determine the relative contribution of the aerobic and the anaerobic energy systems to short all-out exercise in pre- and early-pubertal children.

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