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RESEARCH ARTICLE

Estimation of aerobic fitness levels and its determinants among the school going undernourished Indian children – A field-based study

Rajesh Jeniton Fernando[1], Maria Pauline[2], Tinku Thomas[3], Mario Vaz[2]

[1]Department of Physiology, Pondicherry Institute of Medical Sciences, Kalapet, Pondicherry, India, [2]Department of Physiology, St. Johns National Academy of Health Sciences, Bengaluru, Karnataka, India, [3]Division of Epidemiology and Biostatistics, St. Johns Research Institute, Bengaluru, Karnataka, India

Correspondence to: Rajesh Jeniton Fernando, E-mail: oshonrajesh@yahoo.com

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ABSTRACT

Background: Higher aerobic fitness in children has many physical and cognitive health benefits and can track into adulthood preventing non-communicable diseases later in life. Data on the levels of aerobic fitness among Indian undernourished children are sparse. **Aims and Objectives:** The aim of the present study is to perform a field-based study to estimate the levels of aerobic fitness and its determinants among the undernourished Indian children. **Materials and Methods:** Three hundred clinically healthy children, 50% boys, 7–10.5 years between the body mass index (BMI) Z score of −3 and 0 were recruited. Their anthropometry, lung function, handgrip strength were determined, and their physical activity levels were ascertained. Their aerobic fitness was estimated using 20-m multistage shuttle run test (20-mMSRT) and modified Harvard's step test (MHST). **Results:** The estimated aerobic fitness levels were 32.25 ± 4.21 and 37.29 ± 5.96 (ml/kg/min) using 20-mMSRT and MHST, respectively. Body composition (fat-free mass), nutritional level (BMI Z scores), and hemoglobin explained 37% and 44% of the variance in whole-body aerobic fitness (ml/min) using 20-mMSRT and MHST, respectively. Gender difference in the predicted aerobic fitness was not apparent in this undernourished group of children. BMI Z scores were positively correlated with the whole-body aerobic fitness among undernourished Indian children. **Conclusion:** The estimated levels of aerobic fitness among the Indian undernourished children were found to be low for their age. Improvement in nutrition can positively influence on whole-body aerobic fitness among this group of undernourished children.

KEY WORDS: Aerobic Fitness; Body Composition; Children; Lung Function; Nutrition; Physical Activity Levels

INTRODUCTION

Aerobic fitness or cardiorespiratory fitness (CRF) refers to the maximum ability of the circulatory, respiratory, and muscular system to supply oxygen to sustain exercise until exhaustion and to eliminate fatigue products after supplying fuel.[1] Higher aerobic fitness prevents against insulin resistance, higher systolic blood pressure, and dyslipidemia in children which are risk factors of cardiovascular disease later in adults.[2] Children with higher aerobic fitness also have better cognitive abilities[3] and a greater hippocampal volume.[4] Hence, higher aerobic fitness has both physical and mental health benefits in children.

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In India with a population of 1.3 billion non-communicable diseases (NCDs) accounts for 60% (5.86 million) of all-cause mortality.[5] WHO world health statistics report 2017 estimates that a reduction of 2% of national-level NCD death rate in

India over the next 10 years would result in an economic gain of 15 billion dollars. These NCDs are partially programed in early childhood (critical period), even in-utero based on the fetal origin of adult diseases (- Barker's hypothesis), and due to epigenetic phenomenon called "programming."[6] Hence, poor nutrition during intrauterine and early life is an early marker of NCDs in later life.[7] The Indian National Family Health Survey of 2015–2016 showed that 36% of children under age of 5 are underweight compared to the WHO global standards and 38% of them are stunted. Hence, a sizable proportion of Indian children are undernourished and therefore are at risk for future NCDs. Childhood aerobic fitness (CRF) can track into adulthood[8,9] and higher levels of CRF in adults prevent the risk of NCDs and mortality.[10] It is, therefore, important to improve aerobic fitness among the undernourished children for their immediate and future health benefits. Essential to this is to document the levels of aerobic fitness among them. Direct measurement of inspired and expired gas while exercising is the gold standard technique to measure aerobic fitness.[11] They are, however, difficult to administer in the large group. One of the places where we can easily administer an aerobic fitness test in large groups is school. Hence, we used two field-based tests, which could be performed at school, to estimate aerobic fitness which are reasonably reliable and valid in the age group of children from 6 to 10 years.[12-14] Although the determinants of aerobic fitness are partially explained in children, they are all performed in normal nourished children.[15] The gender difference in aerobic fitness is small yet apparent among children[16] and even evident in predicted aerobic fitness using field-based study.[14] However, gender difference in aerobic fitness among the nutritionally challenged children is not clearly documented. Hence, the aim of this present study is to evaluate the levels of the aerobic fitness among the clinically healthy yet nutritionally compromised school going Indian children and to elucidate its determinants and gender differences.

MATERIALS AND METHODS

Ethical clearance was obtained from the institutional ethics committee Ref no: IERB 1/303/08. The children were briefed in detail about the study and gave their assent in addition to written parental or legal guardian consent. Their nutritional status was assessed using the body mass index (BMI) Z score based on the WHO standard charts.[17] Children within the BMI Z score of −3 to 0 were included in the study. Children from 1st to 6th grade, in the age group of 7–10.5 years, from three different schools in the urban districts of Bengaluru, India, were randomly selected for this study (eligible $n = 1155$; screened $n = 379$; enrolled $n = 300$). Their age was confirmed from the school registry. Equal number of boys and girls were enrolled (150 boys and 150 girls). The children belonged to three socioeconomic groups (i.e., upper-lower, 236; lower-middle, 56; and upper-middle, 8) based on the modified Kuppuswamy scale.[18] Children who were apparently healthy over the past 3 months before the study, as reported by the parents or guardians, were examined by the study physician for any cardiovascular, respiratory, and musculoskeletal disorders, which could refrain them from performing the tests. After the physical examination, anthropometric parameters were measure by trained research assistants. Height was measured to the nearest 0.1 cm, standing barefoot with heels, buttocks, and back touching the custom made calibrated stadiometer and head in Frankfurt plane. Weight was measured to the nearest 0.1 kg with school uniforms, standing barefoot using a calibrated digital weighing scale (Salter-9016, Kent, U.K). BMI Z scores for the age of the children were calculated using the WHO standard charts.[17] Skin-fold thickness and midarm circumference (MAC) were performed by well-trained nutritionist. Triceps and calf skin-fold thickness of the children were measured using a standardized skinfold caliper to the nearest 0.2 mm (Holtain Ltd., Crymych, UK). The MAC was measured using a non-stretchable tape to the nearest 0.1 cm, midway between the acromion and the olecranon process, while the subject was standing with the elbow flexed at 90°. The body fat percentage was calculated using gender-specific prediction equations.[19] The fat mass and fat-free mass (FFM) were calculated using the fat percentage and body mass. Lung function test (LFT) was performed while the children were standing using a calibrated mobile spirometer (Micro GP, Spirometer, Micro Medical Ltd., U.K) by the study physicians. Grip strength was assessed, after adjusting the grip width to comfortable level for each child, three times and the best of the readings was noted in both non-dominant and dominant hand, using the Jamar hydraulic hand dynamometer (SI instruments, Hilton, Australia). Since arm length was not measured, height was used for the standardization of grip strength. Following the anthropometry, the LFTs, and the handgrip strength measurements, blood was drawn from the anterior cubital vein and the hemoglobin (Hb) levels were asserted using spectrophotometer measurement of cyanmethemoglobin on the ABX Pentra 60 C+ (Horiba Medica) within 4 h of collection. After confirming the Hb levels of the children to be more than 8 gm%, they were administered with a modified physical activity questionnaire, developed by our research team before this study,[20] for the estimation of physical activity levels (PAL) among children. Activities with metabolic equivalent MET >3 were considered as moderate to vigorous physical activity (MVPA).[21] After these preliminary measurements, the aerobic fitness was estimated using the 20-m multistage shuttle run test (20-mMSRT) and the modified Harvard's step test (MHST)[12] on two separate days on their respective school grounds with 48 hours rest in between the tests.

20-mMSRT

The participants ran back and forth around two cones kept 19 m apart, completing one 20 m shuttle. They must touch the 20-m line at the same time that a sound signal is emitted by a pre-recorded tape. The pace of the signal increased by 0.5 km/h every minute, starting with an initial speed of

4 km/h. There were two lines marked (markers) 1 m from the cones making them 17 m apart. The participant ran until exhaustion or until they were unable to cross two consecutive markers along with the pace. The speed of the last stage and the age of the child were used to estimate the aerobic fitness level.

$$VO_{2peak1} = 31.025 + (3.328\times \text{speed}) - (3.248\times \text{age}) \text{ (ml/kg/min)}$$[12]

The test was administered in groups of three to five to maximize the effort by the participants, since the end of the test is effort dependent, and to motivate the children. The test was supervised by trained personnel to maintain a standardized protocol.

MHST

The participants claimed on a platform (height – 30.48 cm) at the rate of 22 steps per minute for 3 min paced using a metronome. The immediate radial arterial pulse was manually recorded, within 5 s of the cessation of test, for 15 s. The aerobic fitness was estimated using the step height, stepping rate, age of the child, and observed heart rate at the end of the test.

$$VO2 = (2.2\times \text{stepping rate}) + (2.4\times \text{step height} \times \text{stepping rate}) + 3.4$$

HRmax =220-age

VO_{2peak2}= VO2× HRmax/HR observed (ml/kg/min)[12]

This study used data from a double-blinded, placebo-controlled, and randomized trial that examined the impact of multiple micronutrient supplementation on physical performance in school-going children in Bengaluru, Karnataka, India.[22]

Statistical Analysis

The data are expressed as means with standard deviations. Independent sample "*t*-test" was performed to examine the gender difference in anthropometric parameters, LFTs, handgrip strength, and the aerobic capacity (assessed by 20mMSRT [VO_{2peak1}] and MHST [VO_{2peak2}]). The association of gender with involvement in MVPA was analyzed using χ^2 test. The factors associated with VO_{2peak1} and VO_{2peak2} were identified using separate simple followed by multiple linear regression analyses. Age, lung function parameters, anthropometry, body composition, MVPA levels, Hb levels, and forearm muscle strength apart from gender were considered as predictors in regression analyses.

RESULTS

The descriptive statistics of the study population are given in Table 1. Age, weight, and Hb levels were comparable between boys and girls. Boys were taller and had lesser MAC than girls though statistically insignificant. Boys had a significantly higher FFM ($P < 0.001$) and a lower fat percentage of about 50% ($P < 0.001$) when compared to girls. Boys had a significantly lower BMI Z scores for their age than girls (−1.46 ± 0.86 vs. −1.04 ± 84, $P < 0.001$). Within the similar BMI Z scores, boys had conceivably even greater difference (60%) in FFM compared to girls (β =1.6, $P < 0.001$).

Table 2 summarizes the LFTs, PALs, and local muscle strength, measured as handgrip strength. All the measured lung function parameters were significantly higher in boys than in girls. Forced expiratory volume (FEV_1) was approximately 9% higher while forced vital capacity (FVC) and peak expiratory flow rate (PEFR) were 10% and 7% higher, respectively, in boys than girls. The reported habitual physical activities were comparable between the genders. However, the proportion of boys reported to have engaged in MVPA was higher than girls (88 vs. 36, $P < 0.001$). Boys had significantly higher handgrip strength ($P < 0.001$) both in the dominant and non-dominant hand, and it remained so even after standardizing for height ($P < 0.001$).

Table 3 summarizes the gender difference in aerobic fitness. The whole-body aerobic fitness and relative to the body weight

Table 1: Descriptive statistics of the study population

Variables	Pooled (*n*=300)	Boys (*n*=150)	Girls (*n*=150)	*P*-value
Age (years)	8.6±1.0	8.7±1.0	8.6±1.0	0.46
Height (cm)	122.6±6.5	123.2±5.8	121.3±7.0	0.09
Weight (kg)	21.5±3.2	21.4±2.8	21.5±3.5	0.93
Fat percentage (%)	13.1±3.5	10.6±2.1	15.6±2.7	<0.001
FFM (kg)	18.7±2.5	19.2±2.4	18.1±2.6	<0.001
MAC (cm)	16.8±1.5	16.6±1.5	17.0±1.5	0.06
BMI Z score for age	–1.25±0.88	–1.46±0.86	–1.04±0.84	<0.001
Hb (g/dl)	12.8 ±9.1	12.9±9.7	12.8±0.8.4	0.49

Data expressed as mean±standard deviation, *P* value obtained from Student's "*t*-test" between boys and girls, FFM: Fat-free mass, MAC: Mid arm circumference, Hb: Hemoglobin. BMI: Body mass index

Table 2: Gender difference in lung function tests, physical activity levels, and handgrip strength

Variables	Pooled (*n*=300)	Boys (*n*=150)	Girls (*n*=150)	*P*-value
FEV_1 (L)	1.05±0.24	1.09±0.22	1.00±0.25	0.001
FVC (L)	1.14±0.30	1.20±0.32	1.09±0.28	0.003
PEFR (L/min)	180.3±36.0	186.3±36.6	174.3±34.4	0.003
PAL (met min/week)	10724±1830	10617±1308	10823±2208	0.51
Number of children reported to have involved in moderate to vigorous physical activity (MET >3)*[a]	126	88	38	<0.001[#]
Dominant hand muscle strength (kg)	9.6±3.7	10.4±3.6	8.8±3.5	<0.001
Non-dominant hand muscle strength (kg)	8.6±3.4	9.3±3.7	7.8±3.2	<0.001

Data expressed as mean±standard deviation, *P* value obtained from Student's "*t*-test" between boys and girls, *Data expressed as number of children who reported to involved in moderate to vigorous physical activity. [a]Report obtained from total 295 children (149 boys and 146 girls), [#]*P*-value for χ^2 test of association between gender and number of children reported to have involved in moderate to vigorous physical activity. FEV_1: Forced expiratory volume in 1[st] s, FVC: Forced vital capacity, PEFR: Peak expiratory flow rate. PAL: Physical activity level

Table 3: Gender differences in aerobic fitness and whole-body endurance

Variables	Pooled (*n*=300)	Boys (*n*=150)	Girls (*n*=150)	*P*-value
VO_{2peak1} (ml/kg/min)[#]	32.25±4.21	32.51±4.43	32.00±3.98	0.29
VO_{2peak2} (ml/kg/min)*	37.21±5.39	37.65±5.17	36.77±5.59	0.16
Whole body VO_{2peak1} (ml/min)[#]	687.4±97.4	693.3±98.9	681.6±95.7	0.29
Whole body VO_{2peak2} (ml/min)*	800.8±162.9	810.0±154.7	791.5±170.8	0.32

Data expressed as mean±standard deviation, *P* value obtained from Student's "*t*-test" between boys and girls. [#]VO_{2peak1} – Aerobic fitness predicted from 20-meter multistage shuttle run test (20-mMSRT). *VO_{2peak2} – Aerobic fitness predicted from modified Harvard's step test (MHST)

predicted using 20-mMSRT and MHST did not show gender differences using Student's "*t*-test." Whole-body aerobic fitness estimated using 20-mMSRT (r = 0.48, $P < 0.001$) and MHST (r = 0.28, $P = 0.001$) were positively correlated with BMI Z scores. Multiple linear regression analysis indicated that FFM, BMI Z score, and Hb concentration explained 37% and 44% of the variance in whole-body aerobic fitness predicted using 20-mMSRT and MHST, respectively.

DISCUSSION

The nutritional status of the study children was determined by BMI Z scores using WHO standard charts[23] and its mean value was less than zero. Hence, our study participants were predominantly undernourished; however, there could be well nourished yet small-sized children. Our study estimated the levels of aerobic fitness among these undernourished Indian children the data of which is scarce in literature. We have performed a maximal effort test, 20-mMSRT[24] and a sub-maximal test, step test[25] to estimate the levels of aerobic fitness, which are validated and reliable for field study among children. The absolute mean value of the aerobic fitness predicted using 20-mMSRT was found to be lower for age among the undernourished children (32.25 ± 4.21 vs. 48.7 ± 4.7 ml/kg/min) compared to their well-nourished counterparts.[14] Similarly, MHST also predicted a lesser mean value of aerobic fitness among the pooled data (37.21 ± 5.39).

Boys performed better than girls in CRF in field-based studies among the well-nourished prepubertal children.[26] Direct measure of aerobic fitness among the prepubertal children elucidated that FFM[27,28] and the difference in muscle fiber type between boys and girls[29] as the primary determinant of gender difference in CRF. Among our study children, despite boys having greater levels of FFM compared to girls, the gender difference was not apparent in the estimated levels of CRF (ml/kg/min). This could be due to the limitation that aerobic fitness and body composition were estimated rather than measured in our study. Furthermore, boys had significantly lower BMI Z scores compared to girls and the whole-body aerobic fitness was positively correlated with BMI Z score in our study children. Therefore, gender differences in aerobic fitness could have been plausibly negated since boys were undernourished compared to girls. Our study elucidated that FFM, BMI Z scores, and Hb were partial determinants of the estimated levels of whole-body aerobic fitness. FFM being the primary determinant is been well established in earlier studies since it the oxygen demand of the working muscle which determines the rate of consumption.[11,16] BMI Z score had positive effect over and above the FFM on the estimated whole-body aerobic fitness. We could only speculate that an increase in BMI Z scores, reflecting better nutrition, would have changed the muscle fiber type enhancing CRF[30] since muscle function is an early indicator of nutrition status. However, this needs further studies to substantiate our claim. Higher levels of Hb having a positive effect on aerobic fitness is logical since erythrocytes carry oxygen to the exercising muscle. MVPA is positively associated with aerobic fitness among children[31] and it was not observed in our study since PAL was estimated using questionnaire, albeit reliable could not obtain valid reading like accelerometer. Like the previous studies on well-nourished children, lung function parameters and local muscle strength did not show any impact on aerobic fitness.[11,16]

Low levels of aerobic fitness among these undernourished children could have a negative impact on their physical[32-34] and mental health[35,36] and persistence of low CRF into adolescence can have detrimental health effects.[37] It is, therefore, important to improve aerobic fitness early among these undernourished children. Our primary randomized double-blinded placebo-controlled study suggested that micronutrient supplementation could improve aerobic fitness in this group of children.[22] Further prospective studies are needed to optimize their aerobic fitness through appropriate macro and micro nutrition support with exercise.

Limitation of the Study

Our study estimated aerobic fitness, body composition, and physical activity rather than direct measurement which is a limitation of the study.

CONCLUSION

The estimated levels of aerobic fitness among the Indian undernourished children were found to be profoundly low. Improvement in nutritional status, as reflected by a higher BMI Z score, can improve aerobic fitness levels among the undernourished children. Nutritional status of the children should be considered while elucidating gender differences in aerobic fitness among children.

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