ORIGINAL RESEARCH PAPER

Volume-8 | Issue-8 | August - 2019 | PRINT ISSN No. 2277 - 8179

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

COMPARISON OF CARDIOPULMONARY FUNCTION, PREDICTED VO2MAX, AND EUROPEAN FITNESS TESTS BETWEEN ADOLESCENT ATHLETE AND NON-ATHLETE BOYS - A CROSS-SECTIONAL STUDY

Physiology

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ABSTRACT

Components of health-related physical fitness that includes cardiorespiratory endurance, muscular strength, flexibility, speed of movement and coordination were found to have a positive association with health outcomes. This cross-sectional study aimed to compare the cardiopulmonary function and physical fitness parameters assessed by EUROFIT among adolescent athletes and nonathlete schoolboys aged between 10 -19 years. Thirty boys representing their school at state or national or international level aerobic sports and have undergone physical conditioning for at least one year, were recruited as athletes and 30 age-matched non-athlete students were recruited as controls. Their height, weight, blood pressure, maximal expiratory and inspiratory pressures, peak expiratory flow rate, European fitness test battery were recorded and VO2max was predicted using submaximal treadmill exercise testing. Participants in both groups were of normal weight and were within normal range of BMI. Predicted VO2max from submaximal exercise testing was significantly higher in athletes. Participants had normal blood pressure in both groups. Respiratory rate was significantly lower in athletes. PEFR, MIP and MEP were higher in athletes but not statistically significant. All the parameters of European fitness test battery was better in athletes. However, it was not statistically significant in stork balance and sit up. We conclude that athletic level physical training improves overall health of the adolescents in terms of strength, flexibility, endurance, agility, balance and speed.

KEYWORDS

Aerobic fitness, Cardiorespiratory fitness, VO2max, Peak expiratory flow rate, PEFR, Maximum Inspiratory Pressure, Maximum Expiratory Pressure. Eurofitness test

INTRODUCTION

Cardiorespiratory fitness (CRF), an important component of physical fitness, is widely accepted as an essential indicator of overall health status among children and adolescents (1). Children with higher CRF had lower BMI as reported by several studies, hence the risk of metabolic syndrome (2) and cardiovascular comorbidities were reduced (3). Since direct measurement of maximum rate of oxygen uptake (VO2 max) has a limitation of high cost and requirement of sophisticated equipment, several submaximal exercise tests are used to predict VO2 max (1).

Several studies have reported the beneficial effects of sports activities and high physical activity level among children and adolescents on cardiovascular and metabolic risk factors (4–7). Components of health-related physical fitness that includes cardiorespiratory endurance, muscular strength, flexibility, speed of movement and coordination were found to have a positive association with health outcomes (8). While most of the physical fitness test assesses the skills, European fitness tests assess the strength, flexibility and endurance of children (9). Physical fitness of children were found to be an important determinant of performance and success in sports such as football, hockey and athletic performance. It enables the coach and parents to follow up the physical fitness levels of the sportsmen after adequate training (10).

This study aimed to compare the cardiopulmonary function and physical fitness parameters assessed by EUROFIT among adolescent athletes and nonathletes.

MATERIALS AND METHOD

Study design:

This was a cross-sectional collaborative study conducted between Department of Physiology, JIPMER, Puducherry, India and CBSE board residential school in Puducherry. The students were approached for data collection after obtaining approval from the Institute ethics committee for human studies.

Participants:

Schoolboys aged between 10 -19 years studying in CBSE school in Puducherry were considered for the study. Students with a history of cardiovascular, respiratory or organic disorder which prevents subjects from doing maximal exercise, or on any drugs that affect cognitive test were excluded from the study. We obtained informed written consent from the guardians/parents and written assent from the boys who had met the inclusion criteria. By convenience sampling thirty boys representing their school at state or national or international level aerobic sports and have undergone physical conditioning for at least one year, were recruited as athletes and 30 age-matched non-athlete students (not participated in any inter-school athletic events for at least one year and only participating in recreational sports activities) were recruited as controls.

Parameters measured:

Boys were asked to report to the Department of Physiology, JIPMER and following parameters will be recorded.

A.Anthropometric Parameters:

Anthropometric parameters were measured by the International Society for the Advancement of Kinanthropometry (ISAK) certified investigator. A wall-mounted stadiometer (V M Electronics Hardware Ltd) accurate to the nearest 0.1 cm is used to measure the height. We measured weight using a digital weighing scale (Charder Electronic Co. Ltd Taichung, Taiwan 2013) accurate to the nearest 0.1 kg. *Body mass index (BMI)* was calculated by using the Quetelet formula (11).

B.Cardiovascular and pulmonary parameters:

1.Cardiovascular parameters: Blood pressure (BP) and heart rate (HR) were measured after 10 minutes of rest in the sitting position. HR was assessed manually from the radial artery. The BP (mm Hg) was recorded from the right arm using mercury sphygmomanometer (Diamond, Industrial Electronic & allied product Maharashtra, India). BP recordings were taken thrice with two minutes rest intervals and the average was considered as the final reading. All measurements were recored by the same investigator.

2.Pulmonary function parameters:

a.Respiratory rate (RR) was recorded manually after 5 minutes of rest.

b.Respiratory pressures (mmHg) - Aneroid sphygmomanometer (Smart Care SCH- 200A, India) connected to a 50 mL syringe using non-expandable polyvinyl tube was used. Participants were given a demonstration of the maneuver. It was ensured that there was no air leakage during the measurement and the subject did not use oral muscles to develop pressure or tongue to block the tubing.

Maximum expiratory pressure (MEP): The participants were asked to take a deep inspiration and blow forcefully into the mouthpiece and sustain the peak pressure for 3 seconds. This was noted as MEP in mmHg.

Maximum inspiratory pressure (MIP): After a full expiration the participants were asked to take deep inspiration and sustain the peak pressure for 3 seconds. This was noted as MIP in mmHg.

c.Peak expiratory flow rate: The procedure for PEFR in standing position was demonstrated to the boys using Mini-Wright Peak Flow Meter. They were asked to take a deep breath and blow into the meter as hard and fast as possible without any leak between the lips and disposable mouthpiece. Best of the three measurements was considered as the final reading.

3.Cardiorespiratory fitness: We followed the procedure and test termination criteria recommended by the American college of sports medicine. Participants were briefed about the test and were told that they could terminate at any point of the test. Rate of perceived exertion was assessed using Borg's perceived exertion scale which has rating 6 to 20 (12). Participants were asked to stand for five minutes on the automated treadmill (T2100 treadmill system, General Electricals) and their HR and BP was measured. Three minutes of warm-up at 1.7 mph speed and grade 0% was given followed by Bruce protocol. HR, BP, ECG and perceived exertion were continuously monitored. The requirements for the test were to complete two separate stages that result in HR values between 110 and 150 bpm. At each 3-min work stage, a steady-state HR is required. If steady state HR is not reached the stage would be continued for another minute. All the participants were able to achieve two steady-state HR. After completion of the submaximal exercise test, we monitored the participant's HR and BP for five minutes for recovery. VO2max is estimated using the equation - VO2max (mL/kg/min) = a (HRmax - HR2) + VO22 where a = VO22 - VO21 / (HR2 - HR1), VO21 is submaximal predicted VO2 from stage 1 in mL/kg/min, VO22 is submaximal predicted VO2 from stage 2 in mL/kg/min, HR1 is steady state HR from stage 1 in bpm, HR2 is steady state HR from stage 2 in bpm, HRmax = 220 – age. VO2 for each stage was calculated using the equation - VO2 (mL/kg/min) = [(0.1 X S) + (1.8 X S X G)] + 3.5; where s (speed) = mph X 26.8 m/min/mph, G (grade) = % elevation/100.

4.European fitness test battery: The Eurofit Physical Fitness Test Battery is a set of nine physical fitness tests covering flexibility, speed, endurance and strength. The standardized test battery was devised by the Council of Europe, for children of school age. The following 8 tests are the standard tests recommended for testing school-age children- Stork balance stand test, plate tapping test, sit and reach test, Broad jump, handgrip strength test, Euro fit sit-up test, Bent arm hang test and 10 X 5 shuttle test. These recordings were done in their respective school premises. The procedure was done as per the protocol explained in Annexure I.

RESULTS

Anthropometric data (Table 1): Height, Weight and BMI were comparable between the two groups. There was no significant difference between the two groups.

Figure 1: predicted VO2max from submaximal exercise testing was significantly higher in athletes.

Cardiovascular data (Table 2): Their basic cardiovascular parameters (HR, SBP, and DBP) were comparable.

Pulmonary function data (Table 3): Respiratory rate was significantly lower in athletes. PEFR, MIP and MEP were higher in athletes but not statistically significant.

European fitness test batter (Table 4): All the parameters of European fitness test battery was better in athletes. However, it was not statistically significant in stork balance and sit up.

DISCUSSION

We assessed the health-related physical fitness components such as predicted VO2 max, grip strength, speed, endurance, balance and flexibility among athletes. The level of physical fitness is known to predict the current and future cardiovascular (13), skeletal and mental health status of an individual (14). Participants in both groups were of normal weight and were within normal range of BMI. Participants had normal blood pressure in both groups.

VO2max is the maximum amount of oxygen consumed while the intensity of exercise increases. It is a measure of cardiorespiratory fitness and hence helps to assess cardiovascular health (15). Higher level of physical fitness and daily physical activity has been known to protect all-cause mortality (15). Among athletes, it is a useful indicator to assess the change in the aerobic capacity as a measure to the improvement of physical fitness after physical training (16). In our study, VO2max was predicted by submaximal treadmill test. Predicted VO2max was significantly higher in athletes compared to non-athletes. The previous study by Smita et al., also reported higher VO2max among young female athletes compared to non-athletes (17). Regular physical training of athletes is generally attributed to the higher cardiorespiratory fitness (18). Increase in cardiac output secondary to an increase in stroke volume leads to an increase in arteriovenous difference. This increase in arteriovenous difference contributes to the increase in VO2 max (19).

The respiratory rate was less among athletes compared to non-athletes. Lung ventilation and homeostasis of blood carbon dioxide, oxygen and pH is interlinked. To uphold this homeostasis minute ventilation has to be maintained by increasing the tidal volume in case of decrease in respiratory rate. A decrease in respiratory rate alone would lead to hypercapnia and activation of central chemoreceptors leading to forced increase in respiratory rate (20). However, it has been shown that controlled respiration at the rate of 6 per minute could reduce chemoreflex response to hypercapnia (21). We have not measured the tidal volume in this study; hence we would not be able to discuss whether the athletes were able to achieve lesser respiratory rate by increasing the tidal volume or by other mechanisms while maintaining the tidal volume. Breathing at a lower rate reduced dead space ventilation and thereby improves ventilatory efficiency (22). A metanalysis on the respiratory rate of children from birth to 18 years has shown that the 50^{th} percentile of respiratory rate was around 20 at 10 years and around 15 at 18 years of age (23). Considering this value respiratory rate was less in both the athlete and non-athlete groups in our study. We hypothesize that this might be due to higher physical activity levels in both these groups as compared to the study population of the metanalysis. Previous studies have shown that respiratory pattern could affect VO2 (24). However, a recent study by Nalbandian et al have shown that respiratory rate has no influence over VO2 in an incremental exercise (25).

Maximal inspiratory pressure and maximal expiratory pressure could be used as marker of athlete's performance as physical training tends to improve these parameters (27,28). In our study, MEP was increased among athletes however not significant. MIP was similar between the two groups. This might be because the control group was also physically active. Similar results were reported by Eastwood et al., there was no significant difference in MIP between athletes and sedentary adult population (29).

Peak expiratory flow rate (PEFR) is the maximal flow rate generated from full lung during a forceful exhalation. PEFR reflects large airway flow and depends on the voluntary effort and respiratory muscle strength. Maximal airflow occurs during the effort-dependent portion of the expiratory maneuver; thus, low values may be caused by a less than maximal effort rather than by airway obstruction. Even though Maximal inspiratory and expiratory pressures were comparable between athletes and non-athletes, PEFR was higher in athletes in our study. This shows that higher PEFR in athletes is not only due to higher muscular strength. This observation requires further exploration. Vignesh et al., assessed the pulmonary function of the athletes and reported that there was significance increase in PEFR in athletes compared to sedentary individuals (26).

Speed, Flexibility, endurance and muscle strength were found to be significantly higher among the athletes. This could be due to their specific sports activity. Components of physical fitness were found to be increased among athletes based on the sports activity they perform. Sports specific characteristics are seen among athletes of different sports, for instance, soccer players have higher upper and lower body strengths compared to other players. Improvement in these parameter vary based on the intensity and duration of training in their sports activity (30). A 25 year follow up study has shown adolescent flexibility, endurance, strength, and physical activity as predictors of adult tension neck, low back pain, and knee injury (31). Further it has been shown that low back pain is common in adolescents with low hip mobility (32). It is well proven in older age that physical activity improves quality of life in them by increasing agility, balancing, endurance and muscle strength (33). However, in children where agility and balancing are not the limiting factor for day to day life, these parameters find their importance in specific group of children with motor incoordination (34).

Balancing ability was longer in athletes compared to non-athletes however not significant. Similar results were reported by Moraru et al., that balancing abilities among athletes was longer but not significant. Even though other parameters were increased, balancing abilities were not up to the expected level which recommends the athletes to get trained more to improve the balancing abilities which help in better performance in sports and to prevent injury (11). SEVINC et al., showed that balancing abilities were better in children performing sports activities such as badminton, swimming and football (12).

It has been shown that improvement in muscle strength, muscle endurance, balancing, agility and aerobic capacity is specific to the type of training a person undergoes. Erickoglu et al., reported that Soccer players had better cardiorespiratory fitness and balancing abilities compared to their sedentary counterpart while Sit and reach, sit-ups and vertical jump were similar between the two groups (10). In our study, athlete group population belonged to a variety of sports such as football, basketball, running, and kho kho. The lack of statistical difference in some of the measured parameters in our study might be because of this limitation. European fitness test battery assesses the overall Physical health of the children and athletes tend to have better values in all the parameters of the test battery.

Table 1: Comparison of anthropometric data between Non-athlete (n=30) and athlete boys (n=30)

Parameters	Non-athlete	Athlete	P value
	Mean ± SD	Mean ± SD	
Height (cm)	160.55 ± 6.21	159.26 ± 5.66	.407
Weight (kg)	47.81 ± 5.06	48.33 ± 5.09	.693
Body mass index	18.51 ± 1.19	19.05 ± 1.83	.175

Table 2: Comparison of Cardiovascular data between Non-athlete (n=30) and athlete boys (n=30)

Parameters	Non-athlete	Athlete	P value
	Mean ± SD	Mean ± SD	
Heart rate (beats per minute)	72.50 ± 3.45	71.20 ± 2.44	.098
Systolic blood pressure (mm Hg)	109.60 ± 4.75	108.83 ± 5.12	.550
Diastolic blood pressure (mm Hg)	87.83 ± 5.68	87.67 ± 5.74	.910

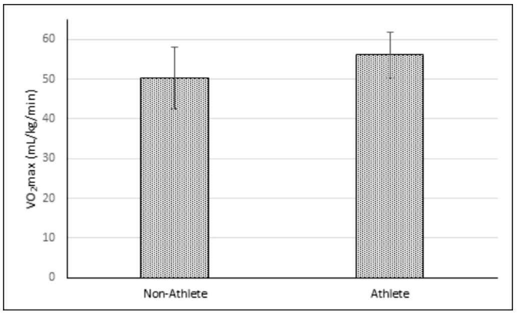
Table 3: Comparison of pulmonary function data between Non-athlete (n=30) and athlete boys (n=30)

Parameters	Non-athlete	Athlete	P value
	Mean ± SD	Mean ± SD	
Respiratory rate (breaths per minute)	16.3 ± 1.64	15.2 ± 1.78	.018
Peak Expiratory flow rate (L/min)	310.50 ± 140.30	350.75 ± 135.56	.263
Maximal Inspiratory pressure (mm Hg)	63.25 ± 16.54	67.73 ± 15.01	.277
Maximal Expiratory pressure (mm Hg)	40.25 ±9.96	45.56 ± 11.25	.058

Table 4: Comparison of European fitness test battery data between Non-athlete (n=30) and athlete boys (n=30)

Parameters	Non-athlete	Athlete	P value
	Mean ± SD	Mean ± SD	
Stork balancing test (seconds)	14.40 ± 11.51	18.88 ± 9.91	.112
Plate tapping (seconds)	10.13 ± 0.81	9.54 ± 1.34	.044
Sit and reach (cm)	7.68 ± 6.86	10.82 ±2.73	.016
Broad jump (cm)	190.58 ± 20.91	201.53 ±19.72	.041
Hand grip strength (kg)	20.5 ± 5.6	24.1 ± 5.8	.018
Sit up (30 sec)	20.79 ± 5.63	23.04 ± 5.88	.136
Bent arm hand (seconds)	21.82 ± 8.83	28.37 ± 7.55	.003
10X5 m shuttle (seconds)	18.56 ± 1.23	17.86 ± 0.96	.017

Figure 1: Comparison of Cardiorespiratory fitness between non-athletes (n=30) and athletes (n=30)



Vo_2max - Predicted VO_2max using submaximal treadmill exercise testing using Modified Bruce protocol. Comparison was done using Unpaired Student's t test. * $p < .05$, ** $p < .01$, *** $p < .001$

ANNEXURE I – EURO FITNESS TEST BATTERY

i.Stork Balance Stand Test: Boys were asked to remove their foot wears and stand on one leg on a flat non-slip mat with hands on the hips, and the non-supporting foot was asked to place against the supporting leg knee. They were given 1 minute to practice. When the boys raise the heel to balance on the ball of the foot stopwatch was started. Stopwatch was stopped if the hands came off the hips, non-supporting foot loses contact with the knee, heel of the supporting foot touches the floor, supporting foot swivels or moves. The total time in seconds is recorded. The score is the best of three attempts.

ii.Plate tapping test: Two yellow coloured circular papers were pasted on a table of suitable height for the boys with their centres 60 cm apart and with a rectangular paper in the middle. While placing their non-preferred hand over the rectangle, boys were asked to move their preferred hand back and forth for 25 full cycles (50 taps) between the two yellow discs as quickly as possible passing the rectangle. The time taken to complete 25 cycles is recorded using stopwatch. Best of two trials is considered.

iii.Sit and reach test: boys were made to sit on the floor with legs out straight placing their bare soles flat against the sit and reach box, shoulder width apart. With their hands-on top of each other and palms facing down, boys were asked to bend forward without any jerky movement as far as possible along the measuring line on the box while their knees were held flat against the floor by an investigator. After one practice reach, the second reach is asked to hold for two seconds and the distance is recorded.

iv.Broad jump: This was tested on the long jump ground. Boys were asked to stand behind a line marked on the ground with feet shoulder apart. They were asked to jump as far as possible with swinging of the arms and bending of both the knees to provide forward drive. The distance between the take-off and landing on both feet without falling backwards is measured. Best of the two is considered final.

v.Handgrip strength test: The boys were asked to squeeze the hand-held dynamometer (Inco, Ambala) with maximum effort for about 5 seconds, using their dominant hand while the arm is at right angle and the elbow by their side. Best of the two trials were taken.

vi.Euro fit sit up test: Boys were lying on a mat with knees bent at right angles, with the feet flat on the floor and held down by a partner.

With their fingers interlocked behind the head, they were asked to raise their chest so that their upper body is vertical and then return to the floor with the back touching the floor. Repeat this as fast as possible for 30 seconds. The number of correctly performed sit-ups is counted. The sit up is not counted if the upper body does not reach vertical position, interlocking of the fingers are released, knees are extending beyond 90 degrees or back arches.

vii.Bent arm hang test: We used pull-up horizontal bars in the school gym. Boys stood on a chair to position themselves, where their chin is at level with the horizontal bar. They were asked to grasp the bar using overhand grip, with hands shoulder with apart. Stopwatch was started when the supporting chair was removed and stopped when the chin falls below the level of the bar or the head is tilted backward to make the chin stay at level with the bar.

viii.10 X 5 shuttle test: marker cones were kept five meters apart on the basketball court in the school. Boys were instructed to start with one foot at one marker and run to the opposite marker when instructed and return to the starting line. Repeat the same five times without stopping (total 50 meters covered). At each marker it was instructed that both feet must fully cross the marking cones. The time to complete the task is recorded.

CONCLUSION:

We conclude that athletic level physical training improves overall health of the adolescents in terms of strength, flexibility, endurance, agility, balance and speed.

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