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Original Article

Evaluation of body composition and its association with cardio respiratory fitness in south Indian adolescents

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Abstract

Anthropometry is generally considered as the single most easily obtainable, inexpensive, and noninvasive method that reflects body composition and VO_2max is an indication of the physical fitness of the subject. There is a paucity of data on t3he age related changes in the body composition parameters and VO_2max, and the association between them in the Indian adolescent population. Hence, the present study was conceived to assess and find the association between these parameters in the students in the age group of 12-17 years. Body composition was assessed using anthropometric measures (Height, weight, BMI, waist circumference, hip circumference and skin fold thickness) and cardiorespiratory fitness (CRF) was assessed using estimated VO_2max from Rockport Walk Fitness Test. We observed that the anthropometric measures were normal for the respective age groups and VO_2max (mL/kg/min) in all the age groups in both the genders were in superior category according to Heywood classification. We observed higher body fat percentage (BF%) in girls of all the age groups compared to the boys and higher fat free mass (FFM) and VO_2max in the boys of all age groups when compared to girls. VO_2max showed a strong correlation with FFM ($r=0.891$, $P<0.001$) and a weak correlation with BF% ($r=-0.322$, $P<0.0001$). Optimal body composition and CRF can be attributed to the regular structured physical activity of one hour duration daily and the provision of adequate nutrition. FFM can be put forth as a stronger determinant of CRF than BF% in the adolescents.

Introduction

Physical inactivity and obesity in children and adolescents are considered as independent risk factors for the development of lifestyle related disorders like coronary artery disease, diabetes, hypertension in later life. Anthropometry is generally considered as the single most easily obtainable, inexpensive, and noninvasive method that reflects body composition (1). Body composition measures like height, weight, BMI, waist and hip circumference, body fat percentage (BF%) and fat free mass (FFM) are also accepted globally amongst the sensitive indicators of health status of children and adolescents (2). Cardiorespiratory fitness (CRF) or VO_2max reflects the functional capabilities of the heart, blood vessels, blood, lungs, and relevant muscles during various types of exercise demands. CRF is related to the ability to perform large muscle, dynamic, moderate-to-high intensity exercise for prolonged periods (3). With growth of children and adolescents, there is a change in body composition measures

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and the gender difference in these measures are more evident from adolescence onwards (4).

Previous studies have given conflicting reports from strong correlation (5-7) to no correlation (8-10) between BF% and VO_2max. There is a paucity of data on the assessment of age related growth changes in the body composition parameters and its association with VO_2max in the Indian adolescents in the age group of 12 to 17 years. Also, in the previous studies, while measuring body composition parameters and CRF, school students were not categorized into day scholars and school campus residents, therefore, it would have been difficult to control the effect of socioeconomic and cultural difference, environmental exposure and nutritional status of the subjects (11-13).

BF% estimated through skin fold thickness measurements has been validated in adolescents in previous studies (14, 15). Rockport Walk Fitness Test (RWFT) is the maximal paced 1-mile walk test, which is an acceptable field test to measure CRF through the estimation of maximal oxygen consumption (VO_2max) for school aged individuals in large groups and is easy to administer with minimal requirements (16, 17).

Therefore, the present study has been conceived, on adolescent subjects of both genders studying in the co-educational residential school set up provided with fully subsidized school mess with the following objectives:

- To evaluate the body composition and CRF in terms of VO_2max of adolescents of different age groups
- To find the association of age with the body composition and CRF in adolescents
- To find the effect of gender difference on the body composition and CRF in adolescents in all age groups
- To find the association, if any, between the body composition parameters and CRF

Materials and Methods

This is a cross sectional study done by the Department of Physiology, Jawaharlal Institute of Postgraduate Medical Education & Research (JIPMER), Pondicherry, India in collaboration with a residential school Jawahar Navodaya Vidyalaya, Pondicherry, India. The study was approved by JIPMER scientific advisory committee and JIPMER institute ethics committee for human studies. Written informed consent from the parents or the local guardians and written assent from the volunteer students were taken after explaining the experimental protocol.

Participants

All the volunteered students recruited (n=335, Boys = 188, Girls = 147) were in the age group of 12-17 years. Age of the students was recorded from the date of birth specified in school records. The students were full time school residents. This could help us to control the confounding effects of socioeconomic difference, environmental exposure and nutritional status of the subjects of both genders. Food was provided to them from fully subsidized school meals and our study included both vegetarian and non-vegetarian students. Subjects with any co-morbidity in which exercise is contra-indicated, were excluded from the study. All the subjects were participating in the monitored structured physical activity for one hour duration as a part of their school curriculum on six days a week. Physical activity was structured based on the recommendations for Asian Indians into aerobic exercise, muscle and bone strengthening exercises (18).

Data collection

Anthropometric measurements : All the anthropometric and skinfold thickness measurements were made by anthropometrist certified by the International Society for the Advancement of Kinanthropometry (ISAK). While wearing light clothing and bare feet, the subjects were weighed on a digital weighing scale to the nearest 0.1 kg and height was recorded on vertical stadiometer to the nearest 0.1 cm. Body mass index (BMI) was calculated by using Quetelet formula (BMI = body weight (kg)/height^2 (m)). By using anthropometric tape (CESCROF Sports Equipment Limited, Porto Alegre – Rio Grande do Sul, Brazil), waist circumference (WC) was measured at the midpoint between lower rib margin and iliac crest, at the end of expiration and hip circumference (HC) was measured at the maximal circumference over the buttocks.

Estimation of BF% and FFM: To calculate BF%, skin fold thickness was measured from four sites (biceps, triceps, subscapular and suprailiac) using clinical plicometer innovare (CESCROF Sports Equipment Limited, Porto Alegre – Rio Grande do Sul, Brazil). Measurements were taken in triplicate to the nearest 0.1 mm by the same investigator and the average measurement was used in the data analysis. Body density was calculated using Durnin and Rahaman equation for boys (14) and Durnin and Womerley equation for girls (15). BF% was calculated using the Siri's equation (19). Body fat mass (in kg) was obtained by multiplying BF% by weight and then dividing by 100. Fat free mass (FFM) was calculated by subtracting body fat mass (FM) (in kg) from body weight (kg).

Estimation of VO_2max: Subjects were asked to refrain from any vigorous intensity physical activity, 24 hours prior to the day of RWFT. Subjects reported in the 400 meters track two hours after taking light breakfast. They were instructed to walk as fast as possible on the track for 1 mile. Time for completion of one mile walk was recorded by stopwatch up to a hundredth of a second. Heart rate (HR) was recorded from the brachial artery for 15 seconds and then it was multiplied by four to record one minute recovery HR (beats/min). VO_2max score was calculated using the following equation (16, 17):

Girls : VO_2max = 139.168 – (0.88 X age in years) – (0.077 X weight in lbs.) – (3.265 X walk time in minutes) – (0.156 X heart rate).

Boys : 139.168 – (0.88 X age in years) – (0.077 X weight in lbs.) – (3.265 X walk time in minutes) – (0.156 X heart rate) + 6.318.

Statistical analysis

The mean difference between boys and girls was analyzed using unpaired Students' 't' test. Comparison between successive age groups was done using unpaired Students' 't' test. The relationship between FFM, BF% and VO_2max (mL/min) was assessed using Karl Pearsons' correlation and linear regression. All statistical analysis was carried out for two-tailed significance at the 5% level using SPSS version 19 (SPSS Inc, Chicago, USA).

Results

Table I shows comparative data of anthropometric measures including, height (in cm), weight (in kg), waist circumference (in cm) and hip circumference (in cm) in the adolescents from the age groups of 12-17 years of both genders.

Table II shows comparative data on BF%, FFM (in kg) and VO_2 max (mL/kg/min) between girls and boysfrom the age group of 12-17 years.

Table III shows the partial correlation of absolute VO_2max (mL/min) with BF%, fat mass (FM) and FFM after adjusting for age and gender. The results demonstrate that VO_2max had significantly negative correlation ($r=-0.102$, $p=0.062$) with BF% whereas, there was significantly positive correlation ($r=0.777$, $P<0.0001$) with FFM and no correlation with FM.

Figure 1 and 2 shows age wise trend in FFM, BF% and VO_2max. VO_2max followed FFM trend in both genders.

There was significant positive and strong correlation between VO_2max and FFM ($r=0.891$, $P<0.001$, Figure 4) whereas, significant but comparatively less stronger and negative correlation ($r=-0.322$, $P<0.001$, figure 4) was seen between VO_2max and BF%. There was no significant correlation between FM and VO_2max ($r=0.101$, $p = 0.065$).

Age and gender classified correlation analysis showed that FFM had a stronger correlation with VO_2max than BF% (Figure 5 and 6).

TABLE I: Comparison of anthropometric measures between girls and boys.

Parameters	Gender	Age (years)					
		12 *G = 26* *B = 26*	*13* *G = 29* *B = 33*	*14* *G = 29* *B = 29*	*15* *G = 29* *B = 27*	*16* *G = 11* *B = 28*	*17* *G = 23* *B = 45*
Height (m)	Girls	1.43±0.08	1.49±0.08*	1.51±0.05*	1.55±0.06	1.61±0.08*	1.64±0.07*
	Boys	1.40±0.08	1.47±0.09*	1.55±0.08	1.59±0.09*	1.64±0.08*	1.68±0.06*
	P value	0.159	0.538	0.061	0.079	0.268	0.016
Weight (kg)	Girls	38.85±8.94	42.00±5.85*	43.76±3.83*	45.00±6.60	50.36±5.57*	48.13±5.37
	Boys	34.73±3.18	40.09±5.42	44.48±5.92*	47.81±7.58*	56.00±6.97	55.51±6.83
	P value	0.035	0.187	0.582	0.144	0.022	<0.0001
BMI	Girls	18.93±2.95	18.96±1.45	19.14±1.94	20.31±2.04	19.40±2.16*	20.30±2.39*
	Boys	17.85±1.32	18.46±1.48	18.52±1.64	18.92±1.87*	20.69±1.78	19.72±1.97
	P value	0.093	0.187	0.199	0.010	0.062	0.287
Waist circumference (cm)	Female	56.81±5.83	54.86±3.43	57.86±3.71	60.72±11.49	61.18±4.02	59.65±6.15
	Male	55.72±5.39	54.64±3.50	54.36±3.80	56.31±5.02	66.51±6.20	67.67±4.57
	P value	0.488	0.804	0.001	0.072	0.012	<0.0001
Hip circumference(cm)	Female	68.50±8.46	70.24±10.00	77.16±5.38	82.28±15.16	83.18±5.25	83.35±5.07
	Male	65.32±5.31	66.48±5.17	68.16±5.38	71.70±7.27	81.18±7.06	85.31±5.56
	P value	0.110	0.063	<0.0001	0.002	0.401	0.163

Data are expressed as mean±SD. Comparison between boys and girls in each age group is done using unpaired Students' 't' test and the p value is mentioned in written format in the table. Comparison between one age group values with the immediate next age group values was done using unpaired Students' 't' test and the P value is denoted as *. *P<0.05. P<0.05 has been considered as statistically significant. *P<0.05.

TABLE II: Comparison of body composition parameters and VO_2max between girls and boys.

Parameters	Gender	Age (years)					
		12 *G = 26* *B = 26*	*13* *G = 29* *B = 33*	*14* *G = 29* *B = 29*	*15* *G = 29* *B = 27*	*16* *G = 11* *B = 28*	*17* *G = 23* *B = 45*
Body fat percentage	Girls	26.35±3.42	28.06±3.28	28.87±3.86	32.95±2.55	30.17±2.98*	30.46±3.50*
	Boys	17.21±4.81	19.76±5.28	19.23±5.12	18.86±5.13*	13.936±4.60*	14.43±4.25
	P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fat free mass (kg)	Girls	28.43±5.44	30.21±4.44*	31.08±2.72*	32.77±3.83	35.16±4.12*	33.34±2.76
	Boys	31.48±5.3	34.38±4.30	37.61±4.61	40.14±5.38	49.15±5.13	49.21±4.88
	P value	0.0813	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VO_2max (mL/kg/ min)	Girls	52.08±4.99	50.97±5.33	52.88±4.47	50.86±3.27*	49.91±3.40*	49.13±3.82
	Boys	59.04±5.35	59.44±5.78	60.16±4.24	55.04±3.03	58.12±4.12	59.86±3.78
	P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VO_2max absolute (mL/min)	Girls	2016.04±454.18	2141.84±391.48*	2310.52±245.55*	2485.59±324.27	2508.67±297.57*	2358.44±275.29
	Boys	2051.53±271.70	2380.55±390.77	2667.86±342.49	2821.34±370.61*	3238.490±334.96	3315.98±399.16
	P value	0.734	0.020	<0.0001	0.0007	<0.0001	<0.0001

Data are expressed as mean±SD. Comparison between boys and girls in each age group is done using unpaired Students' 't' test and the P value is mentioned in written format in the table. Comparison between one age group values with the immediate next age group values was done using unpaired Students' 't' test and the P value is denoted as *. *P<0.05. P<0.05 has been considered as statistically significant. *P<0.05.

TABLE III: Partial correlation of Cardiorespiratory fitness (VO_2max mL/min) with Body fat percentage, fat mass and fat free mass after adjusting for age and gender.

VO_2 max mL/min	*r value*	*P value*	*N*
Body Fat percentage	0.102	0.062	335
Fat free mass	0.777	<0.0001	335

Discussion

While evaluating body composition parameters (Table I), we observed that mean height and weight measurements in our study were significantly higher in all the age groups when compared with previous studies done in south India (20) and other Indian states (21-24). But, the anthropometric values (height, weight, waist and hip circumference) of both boys and girls were within normal limits for the respective age groups according to the available national studies (25, 26). BMI values and BF% values of both boys and girls were within the 5th to 85th percentile of the available national reference data (25, 27). Further, based on International obesity task force cut off points for BMI, none of the students were underweight or overweight (28). There are no available national reference data for VO_2max values in south Indian adolescents. However, in reference to international values our subjects from both genders were found to be in the superior category (29, 30). Previous study done in Indian adolescents in the age group of 7-14 years reported that VO_2max values in girls were lesser as compared to western counterparts (31), while the values of the boys were comparable. They have attributed this difference to the lesser physical activity and the preference to stay indoor seen in Indian girls. But in our study, students of both the genders were exposed to regular structured physical activity of one hour duration and were provided with balanced meals from the school. This may have helped the students of both genders to attain an optimal body composition and CRF which is comparable to western peers.

As expected, the trend towards increase in height and weight was seen from the age group of 12 year onwards till 17 years in both the boys and girls (Table I). The gender comparison showed that height and weight were lesser in the boys in the age group of 12 and 13 years but from 14 years onwards, height and weight were more in the boys than girls. This may have occurred due to the earlier onset of puberty in the girls than boys. We observed an increasing trend in the BF% in girls from 12–17 years while boys showed a decreasing trend (Figure 1 and 2). Further, BF% values were significantly higher in girls in all the age groups. We observed that even though FFM showed an increasing trend in both boys and girls, boys had a significantly higher FFM in all the age groups. Our findings are similar to previous studies which found that FFM and VO_2max are higher in males than females whereas, BF% and Body fat mass was higher in females (32-35). These finding suggest that an increase in body weight seen in boys is primarily because of FFM, while in girls it is due to both fat mass and FFM. Absolute VO_2max values showed an increasing trend in both boys and girls but the increase was more in boys (66.30%) than girls (16.98%) from 12-17 years. Further, absolute VO_2max values were significantly higher in boys than in girls. By figure 1 and 2 we were able to show that the trend in absolute VO_2max values followed the trend in FFM values irrespective of the change in BF% trend. The correlation between body composition parameters and VO_2max was further analyzed.

Weight adjusted VO_2max (mL/Kg/min) cannot reveal the actual association between FFM and VO_2max as FFM forms the part of body weight. Therefore, we used absolute VO_2max values to study these correlation analyses. We observed that FFM had significantly stronger positive correlation with VO_2max ($r=0.777$) than BF% ($r=0.102$) and by linear regression analysis FFM explained 79% of variation in VO_2max while BF% explained only 10% variation. These observations suggest that FFM is a stronger determinant of CRF than BF%. But, as we discussed above, body composition and CRF value changes with age and gender. From age and gender adjusted partial correlation analysis, we also observed a stronger correlation between FFM and VO_2max than between BF% and VO_2max. Further to find the exact relation between body composition and CRF, age and gender classified correlation analysis was done. We observed that correlation between FFM and VO_2max was stronger than the correlation between BF% and VO_2max in each age group in both the gender. On further observation BF% showed no correlation with VO_2max in boys while it showed significant correlation in girls and FFM showed stronger correlation with VO_2max in boys than girls. These findings suggest that FFM is the only determinant of CRF for boys while BF% plays no role. In girls both FFM and BF% has an influence on CRF but FFM is a stronger determinant. The overall correlation between VO_2max and fat mass was very less and insignificant ($n = 335$, $r = 0.101$, $p = 0.065$). Hence, in normal weight for age category adolescents, BF% is a more important determinant of CRF rather than body fat mass. Our findings are similar to previous studies which have found that BF% is negatively correlated to VO_2max (36, 37) but contradictory to other studies which have found that BF% is not related to VO_2max (38, 39). Our findings are similar to previous studies which also concluded that FFM is the main factor that explains the effect of weight on VO_2max and FM does not have a significant effect on VO_2max (40). Therefore, our study demonstrates that although CRF depends on both FFM and BF%, FFM is the strongest determinant of CRF in adolescents. Since there are no national reference data available for FFM for adolescents of both genders, our data can be considered for pooling towards baseline normative values for FFM in the respective age group from 12-17 years. The relationship of BF%, FFM and FM with absolute VO_2max (mL/min was assessed using partial correlation after adjusting for age and gender distribution.

Conclusion

To conclude, our study demonstrates that CRF of Indian adolescents from the residential school in all age groups was in the superior group according to Heywood's classification and was comparable to the western adolescents. All studied body composition parameters were normal for the respective age groups. Girls had higher BF% in all age groups compared to boys but boys had higher FFM and CRF in all age groups when compared to girls.FFM is stronger determinant of CRF than BF% in the adolescents.

Strengths and Limitations

One of the limitations of our study was that a direct assessment of VO_2max was not done. Since data has been collected from one rural school in Pondicherry, India, it cannot be considered as a representative sample of whole population. In future studies, we are planning to extend our findings to the adolescents from other schools in and around Pondicherry.

The strength of the study is that students are recruited from the same campus of a co-educational residential school, had similar exposure to the school environment and were given adequate nutrition through fully subsidized school meals, therefore, confounding effect of variations of socioeconomic, cultural differences and probability of malnutrition amongst the subjects could be controlled.

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