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Physical Characterstics of Junior Athletes in India Across Training Phase and Sports

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Abstract

Introduction: Adolescent athletes are at a crucial age, requiring energy for training, apart from growth and young athletes need to maintain a positive energy balance. Changes in physical characteristics, particularly body composition are also a part of the growing phase and may reflect on energy balance. Therefore, the present study aimed to understand the physical characteristics of junior athletes across the different phases of training. **Methods:** In this longitudinal study, 79 junior athletes (Athletics: Boys=19, Girls=17; Football: Boys=13, Girls=16; Weightlifting: Boys=9, Girls=5 at PC-rest phase and sample size varies across the phases) aged 10-17 years were recruited from a State Sports School, with majority participating at the national-level and training for a minimum of 24-hours per week for a minimum period of 3-years. Physical characteristics including circumferences and body composition (using sum of 4-skinfolds) was assessed across post-competitive rest (PC-rest, January), preparatory (PP, July) & competition phase (CP, December) in a calendar year. The differences in physical characteristics across phases of training within sports was assessed using the mixed-method ANOVA and across events using univariate ANOVA. **Results:** Across training phases, the boys in athletics event, showed a decrease in circumferences like neck, waist, thigh, and calf from PC-rest to CP phase, however, male football players showed a significant increase in neck, waist, thigh, calf, and Mid-Upper Arm Circumferences (MUAC), along with supra-spinale skinfold. Further, weightlifting boys also exhibited a significant increase in Chest, MUAC and fat-free mass, with a significant decline in bicep and supra-spinale skinfold across PC-rest to CP phase. Across events, body fat percent was lower among athletic group and fat-free mass was higher among weightlifters, while footballers exhibited a higher fat percentage at CP. MUAC was higher in weightlifters, irrespective of training phase and event. **Conclusion :** Physical characteristics, particularly circumferences and body composition varied across events and phases of training, with weightlifters exhibiting a greater improvement in fat-free mass, while track athletes exhibiting lower fat percentage at CP-phase. Further studies on larger data-sets are warranted for exploring normative standards for Indian athletes.

Keywords: Junior Athletes, Physical Characteristics, Body composition, Fat %

Resumen

Introducción: Los atletas adolescentes se encuentran en una edad crucial, requiriendo energía para entrenar, además del crecimiento, y los atletas jóvenes necesitan mantener un balance energético positivo. Los cambios en las características físicas, particularmente en la composición corporal, también son parte de la fase de crecimiento y pueden reflejarse en el balance energético. Por lo tanto, el presente estudio tuvo como objetivo comprender las características físicas de los atletas juveniles en las diferentes fases de entrenamiento. **Métodos:** En este estudio longitudinal, 79 atletas juveniles (Atletismo: Niños=19, Niñas=17; Fútbol: Niños=13, Niñas=16; Halterofilia: Niños=9, Niñas=5 en fase de descanso de PC y el tamaño de la muestra varía según las fases) de 10 a 17 años fueron reclutados de una Escuela Estatal de Deportes, con la mayoría participando a nivel nacional y entrenando durante un mínimo de 24 horas por semana durante un período mínimo de 3 años. Las características físicas, incluyendo circunferencias y composición corporal (usando la suma de 4 pliegues cutáneos) se evaluaron a través del descanso postcompetitivo (PC-descanso, enero), preparatoria (PP, julio) y fase de competencia (CP, diciembre) en un año calendario. Las diferencias en las características físicas a través de las fases de entrenamiento dentro de los deportes se evaluaron usando el ANOVA de método mixto y a través de eventos

usando ANOVA univariante. **Resultados:** A través de las fases de entrenamiento, los niños en el evento de atletismo, mostraron una disminución en circunferencias como cuello, cintura, muslo y pantorrilla de PC-descanso a la fase CP, sin embargo, los jugadores de fútbol masculino mostraron un aumento significativo en el cuello, cintura, muslo, pantorrilla y circunferencias del brazo medio superior (MUAC), junto con el pliegue cutáneo supraespinal. Además, los niños de levantamiento de pesas también exhibieron un aumento significativo en el pecho, MUAC y masa libre de grasa, con una disminución significativa en el bíceps y el pliegue cutáneo supraespinal a través de PC-descanso a la fase CP. En todos los eventos, el porcentaje de grasa corporal fue menor en el grupo atlético y la masa libre de grasa fue mayor en los levantadores de pesas, mientras que los futbolistas mostraron un mayor porcentaje de grasa en la fase de entrenamiento. El MUAC fue mayor en los levantadores de pesas, independientemente de la fase de entrenamiento y el evento. **Conclusión:** Las características físicas, en particular la circunferencia y la composición corporal, variaron entre los eventos y las fases de entrenamiento; los levantadores de pesas mostraron una mayor mejora en la masa libre de grasa, mientras que los atletas de pista mostraron un menor porcentaje de grasa en la fase de entrenamiento. Se requieren estudios adicionales con conjuntos de datos más amplios para explorar los estándares normativos para los atletas indios.

Palabras Clave: Atletas júnior, Características físicas, Composición corporal, % de grasa

Introduction

Assessing physique and physical characteristics is considered important for regular monitoring for health and fitness of any population and it is crucial specially for athletes to improve their competence at the international level. Anthropometric factors like body mass and height has been reported to influence performance in individual and team sports and is particularly vital for weight-dependent sports like weightlifting, gymnastics, wrestling etc (Perroni et al., 2015; Reilly et al., 2000a; Reilly et al., 2000b). Body Mass Index (BMI) though useful for the standard healthy population, has not been considered beneficial for sports persons, with studies reporting misclassification of athletes as “overweight”, while having a lower percentage of body fat (Etchison et al., 2011; Garrido-Chamorro et al., 2009; Jacobson et al., 2003). However, body composition for athletes not only reflects their fitness levels, but also becomes a primary and easy measure of assessing the balance between the quantum of food consumed and training undergone. Fat-free mass (FFM) has gained popularity among sports persons, with studies reporting its role in improving force-generation and involvement in energy production which supports sporting performance (Alburquerque et al., 2005; Douda et al., 2008; Takai et al., 2018).

Physical characteristics, including circumferences and body composition have been found to differ across age groups, level of training experience, training seasons or phases and type of sport, including playing positions. Researchers have found that across various types of events the elite level athletes often have lower body fat percent as compared to amateur athletes (Fry et al., 2006; le Gall et al., 2010) and their sedentary counterparts (Lutoslawska et al., 2014) or non-athletic counterparts (Quiterio et al., 2011). Very limited studies have focussed on longitudinal changes among athletes across different events world-wide (Trexler et al., 2017). Stanforth et al. (2014) monitored Division-I athletes involved in different sporting disciplines for three years and found volleyball players to show an increase in lean mass, while the soccer players and track athletes exhibited no changes in their fat percentages across three years. Most studies were carried out on athletes above 18 years and limited studies are conducted on adolescent athletes in their growth spurt period of 10 to 17 years (Aerenhouts et al., 2015). Such data is scanty even among Indian junior athletes.

Indian sports are yet to make a mark at the Olympic level, although Hosting Junior FIFA 2017, Junior Hockey 2021, and the consistent performance of Indian contingents in Commonwealth games 2022, have certainly put India in the limelight. However, efforts are made in improving sports sciences and raising the competency of athletes on par with the international level. Thus, the primary purpose of this study was to serially quantify the physical characteristics and body composition of junior athletes across a one-year-period, involving three phases of training. Secondly, to determine the differences in physical characteristics and body composition across athletics, football, and weightlifting.

Methods

In this longitudinal observation design, all measurements were made across the Competitive rest phase (PC-rest phase or “Initial”), Preparatory phase (PP or “Mid-point”) and Competition phase (CP or “Final”).

Study Participants

A total of 79 participants across athletics (sprinters and middle-distance runners together termed as “track athletes”), football (known as soccer in America) and weightlifting of the State Sports School were recruited for the study based on age-category (10-17 years), training for over 3-yrs with a minimum of 24-hours training per week, apparently healthy, not suffering from any illness or injury. The sample size varies across the phases of training.

Study Procedure

Anthropometric measurements were carried out by a Level I ISAK (International Society of the Advancement of Kinanthropometry) accredited investigator, following the guidelines provided by ISAK (Marfell-Jones et al., 2012). All measurements were made early in the morning, in an empty stomach, after voiding the bladder and before the morning training session.

Body weight and height

For measuring body mass and height, participants were made to stand upright with shoulders relaxed and arms at the sides suspended freely. Body mass was measured by each participant standing near the centre of the digital weighing scale with 100g accuracy (SECA-882, Germany). Stature (Height) was measured using an anthropometric rod (SECA-242, Germany). For measurement, the participant’s head was placed in the Frankfort horizontal plane and instructed to stand upright with heels together and toes apart (pointing outwards at a 60° angle).

Body Circumferences

Circumferences were measured at neck, arm, chest, waist, hip and calf using a non-stretchable measuring tape (SECA 201, Germany) with 0.1cm accuracy. The measurements at arm, thigh and calf were carried out on the right side of the body.

Body Composition

Body composition of the participants was determined using the two-compartment model (i.e. fat and fat free mass) by employing the skinfold technique. This model divides the body into fat mass and fat free mass or lean body mass and works on the principle similar to that of hydro densitometry, wherein, the body density is determined first using age and gender dependent empirical models (Durnin & Rahaman, 1967) considering sum of the skinfolds. Further, the equation of Siri (1956) which assumes a density for fat as 0.9007 g/cm^3 and fat free mass as 1.1000 g/cm^3 (Brožek et al., 1963) was used to determine Percent body fat. The fat component minus the body mass will provide the fat free mass.

Measurement of Skinfolds

The skinfold thicknesses at Tricep, Bicep, Subscapular and Supra-spinale were measured using Holtain callipers (U.K.) with 0.2 mm accuracy. At all four sites in the exact position, skin fold was firmly held by the investigator, without grasping any underlying muscle. The authors have published the procedure elsewhere (Cherian et al., 2018).

Statistical Analyses

Descriptive statistics were carried out and data were presented as mean and standard deviation, unless specified otherwise in Tables. For comparing differences in physical characteristics across three phases of training (PC-rest, PP, CP) within each event, the mixed method model of analysis of variance (ANOVA) was employed. Athletes were included if data was available in at least two phases. For assessing differences of physical characteristics in a given phase across various events (Athletics, Football and Weightlifting) the General Linear Model of ANOVA was used. Association between age and differences in body mass and height between PC-rest and CP were obtained using linear regression. Further, physical characteristics of athletes in this study were compared with athletes from other countries using unpaired t-test (GraphPad Software, CA, USA) by considering the mean, standard deviation and sample size. Comparison of physical characteristics of study participants were made using the data from CP only, since most studies from other countries have not mentioned the season and majority of them were carried out in CP. The level of significance was considered at $P<0.05$.

Table 1. Physical Characteristics of Junior Track Athletes (Boys) aged 10-16 years

Athletics	**Boys**				**P-value**
	PC-rest (n=19)	PP (n=19)	CP (n=16)	Combined	Training Phase*
Age (years)	12.6 ± 1.04	12.9 ± 1.04	13.2 ± 1.09	12.9 ± 1.06	
Body mass (kg)	50.0 ± 5.56	51.2 ± 5.38	51.8 ± 5.36	51.0 ± 5.39	0.969
Height (cm)	166.2 ± 7.51	167.0 ± 7.09	168.6 ± 6.77	167.2 ± 7.08	0.919
BMI (kg/m^2)	18.1 ± 1.14	18.3 ± 1.12	18.2 ± 1.20	18.2 ± 1.14	0.839
BSA (kg/sqm)	1.543 ± 0.118	1.563 ± 0.112	1.582 ± 0.108	1.562 ± 0.112	0.982
Circumferences					
Neck (cm)	31.1 ± 1.74^a	30.7 ± 1.58^{a,b}	30.5 ± 1.49^b	30.8 ± 1.60	0.027
Chest (cm)	77.8 ± 3.43	78.1 ± 3.15	77.7 ± 3.38	77.8 ± 3.26	0.609
Waist (cm)	67.6 ± 3.12^a	69.2 ± 2.79^a	66.8 ± 2.67^b	67.9 ± 3.00	0.002
Hip (cm)	80.8 ± 3.64	81.4 ± 3.39	80.6 ± 3.42	80.9 ± 3.44	0.248
Thigh (cm)	47.1 ± 2.68^a	46.6 ± 2.7^{a,b}	46.2 ± 2.65^b	46.7 ± 2.65	0.095
Calf (cm)	32.1 ± 1.51	32.9 ± 4.95	31.8 ± 1.59	32.3 ± 3.17	0.576
MUAC (cm)	23.1 ± 1.44^a	22.8 ± 1.57^{a,b}	22.6 ± 1.43^b	22.8 ± 1.47	0.077
Skinfolds					
Tricep (mm)	6.0 ± 1.13	6.0 ± 1.34	5.6 ± 1.15	5.9 ± 1.21	0.528
Bicep (mm)	3.7 ± 0.68	3.8 ± 0.72	3.7 ± 0.70	3.7 ± 0.69	0.758
Sub-scapular (mm)	5.9 ± 0.76	6.1 ± 0.93	6.1 ± 0.51	6.1 ± 0.76	0.758
Supra-spinale(mm)	4.8 ± 0.77	4.9 ± 0.95	4.8 ± 0.62	4.8 ± 0.79	0.840
Sum SKF (mm)	20.3 ± 2.86	21.0 ± 3.45	20.2 ± 2.60	20.5 ± 3.00	0.708
Density (g/cm^3)	1.069 ± 0.004	1.069 ± 0.005	1.070 ± 0.003	1.069 ± 0.004	0.765
Body composition					
Fat (%)	12.9 ± 1.77	13.2 ± 2.00	12.8 ± 1.53	13.0 ± 1.77	0.762
Fat mass (kg)	6.4 ± 1.19	6.8 ± 1.39	6.6 ± 1.09	6.6 ± 1.22	0.736
FFM (%)	87.1 ± 1.77	86.8 ± 2.00	87.2 ± 1.53	86.8 ± 2.57	0.998
FFM (kg)	43.6 ± 4.77	44.4 ± 4.50	45.2 ± 4.66	44.3 ± 4.60	0.762
FFM:Fat	6.9 ± 1.27	6.8 ± 1.26	6.9 ± 0.94	6.9 ± 1.16	0.869

Note: *Age adjusted P-values; a, a or b, b or no values assigned = No significant differences across phases of training; a, b = Significant differences exists across phases of training; PC-rest = Post-Competitive rest phase; PP = Pre-competition phase; CP = Competition phase; BMI = Body Mass Index, BSA = Body Surface Area, MUAC = Mid-Upper Arm Circumference, Sum SKF = Sum of Skinfolds, FFM = Fat-free Mass

Results

Physical characteristics were compared across the different phases of training after adjusting for age, within each event and sex (Table 1-6). In Athletics, there were no significant changes in body mass, height, and body composition within a competitive year among boys and girls. Only athletic boys exhibited a significant decline in circumferences like neck, waist, thigh and MUAC from the first phase (PC-rest) to last phase (CP), with PP and PC-rest. This decline in circumferences during competition did not reflect in significant changes in body composition. Only a mean decline in fat mass, with increase in fat-free mass was observed, and were not significant. Among football players, boys exhibited a significant increase in all circumferences (neck, waist, hip, thigh, calf and MUAC), except chest, while the PP was not significantly different from either PC-rest or CP. Considering body composition, male footballers showed a significant increase in fat mass. Among girls, there was no significant differences in physical characteristics across the phases of training.

Among weightlifting boys, there was a significant increase in chest circumference between PC-rest and CP, with PP not significantly different from PC-rest. While, MUAC exhibited a significant decline from PC-rest to PP, with a consequent increase in CP. The skinfold measurements like biceps and supra-spinale decreased from PC-rest to CP (*P<0.05*), consequently, the fat-free mass significantly increased from PC-rest to CP. However, no such differences were observed among girls.

Table 2. Physical Characteristics of Junior Track Athletes (Girls) aged 10-16 years

Athletics	**Girls**				***P-value***
	PC-rest (n=17)	PP (n=18)	CP (n=17)	Combined	Training Phase*
Age (years)	12.2 ± 1.16	12.6 ± 1.13	13.0 ± 1.14	12.6 ± 1.16	
Body mass (kg)	43.7 ± 4.04	44.0 ± 4.74	44.6 ± 4.28	44.1 ± 4.30	0.923
Height (cm)	155.7 ± 4.44	156.2 ± 4.39	156.7 ± 4.22	156.2 ± 4.29	0.981
BMI (kg/m^2)	18.0 ± 1.46	18.0 ± 1.79	20.7 ± 11.06	18.9 ± 6.46	0.403
BSA (kg/sqm)	1.390 ± 0.075	1.395 ± 0.082	1.408 ± 0.073	1.397 ± 0.076	0.915
Circumferences					
Neck (cm)	28.8 ± 1.35	28.3 ± 1.33	28.5 ± 1.31	28.5 ± 1.32	0.467
Chest (cm)	76.9 ± 4.63	76.2 ± 5.01	77.3 ± 4.76	76.8 ± 4.74	0.691
Waist (cm)	64.1 ± 3.35	65.5 ± 5.11	65.7 ± 4.73	65.1 ± 4.45	0.750
Hip (cm)	82.3 ± 3.77	81.4 ± 4.73	82.4 ± 4.03	82.0 ± 4.15	0.544
Thigh (cm)	48.5 ± 2.72	46.8 ± 3.42	47.7 ± 3.26	47.6 ± 3.17	0.148
Calf (cm)	30.2 ± 2.97	30.2 ± 1.86	29.9 ± 2.38	30.1 ± 2.39	0.590
MUAC (cm)	21.8 ± 1.46	21.4 ± 1.71	21.8 ± 1.73	21.7 ± 1.62	0.729
Skinfolds					
Tricep (mm)	10.1 ± 1.99	9.6 ± 2.46	9.4 ± 2.57	9.7 ± 2.33	0.765
Bicep (mm)	4.4 ± 0.85	4.4 ± 0.90	4.1 ± 0.94	4.3 ± 0.89	0.844
Sub-scapular (mm)	7.5 ± 1.30	7.7 ± 1.73	7.6 ± 1.69	7.6 ± 1.56	0.851
Supra-spinale(mm)	6.0 ± 1.60	6.1 ± 2.01	5.4 ± 1.79	5.8 ± 1.80	0.532
Sum SKF (mm)	27.7 ± 4.68	27.5 ± 6.34	26.2 ± 6.02	27.2 ± 5.66	0.770
Density (g/cm^3)	1.051 ± 0.004	1.052 ± 0.006	1.053 ± 0.006	1.052 ± 0.005	0.670
Body composition					
Percent fat (%)	21 ± 1.93	20.8 ± 2.72	20.3 ± 2.55	20.7 ± 2.4	0.675
Fat mass (kg)	9.2 ± 1.37	9.2 ± 1.95	9.1 ± 1.83	9.2 ± 1.7	0.814
FFM (%)	79.0 ± 1.93	79.2 ± 2.72	79.7 ± 2.55	79.3 ± 2.4	0.956
FFM (kg)	34.5 ± 3.04	34.8 ± 3.16	35.5 ± 2.82	34.9 ± 2.98	0.675
FFM:Fat	3.8 ± 0.44	3.9 ± 0.66	4.0 ± 0.61	3.9 ± 0.58	0.550

Note: *Age adjusted P-values; a, a or b, b or no values assigned = No significant differences across phases of training; a, b = Significant differences exists across phases of training; PC-rest = Post-Competitive rest phase; PP = Pre-competition phase; CP = Competition phase; BMI = Body Mass Index, BSA = Body Surface Area, MUAC = Mid-Upper Arm Circumference, Sum SKF = Sum of Skinfolds, FFM = Fat-free Mass.

Table 3. Physical Characteristics of Junior Football Players (Boys) aged 10-16 years

Football	Boys				*P-value*
	PC-rest (n=13)	PP (n=15)	CP (n=16)	Combined	Training Phase*
Age (years)	11.9 ± 1.15	12.6 ± 1.56	13.2 ± 1.64	12.6 ± 1.56	
Weight (kg)	46.8 ± 9.66	50.1 ± 10.67	52.0 ± 10.95	49.8 ± 10.46	0.192
Height (cm)	159.6 ± 10.42	162.9 ± 10.45	164.3 ± 9.95	162.4 ± 10.21	0.710
BMI (kg/m^2)	18.2 ± 2.05	18.6 ± 2.02	19.1 ± 2.34	18.7 ± 2.13	0.164
BSA (kg/sqm)	1.455 ± 0.190	1.519 ± 0.206	1.553 ± 0.202	1.512 ± 0.199	0.353
Circumferences					
Neck (cm)	30.1 ± 2.71^a	29.9 ± 2.20^{a,b}	30.3 ± 2.51^b	30.1 ± 2.42	0.045
Chest (cm)	69.0 ± 18.24	76.2 ± 5.72	77.2 ± 6.90	74.4 ± 11.53	0.568
Waist (cm)	65.8 ± 4.73^a	68.2 ± 5.87^a	67.4 ± 5.60^b	67.2 ± 5.43	0.026
Hip (cm)	78.8 ± 7.89^a	79.6 ± 6.92^a	80.9 ± 8.51^b	79.8 ± 7.68	0.120
Thigh (cm)	46.8 ± 4.43^a	47.0 ± 4.38^b	48.1 ± 4.49^b	47.3 ± 4.37	0.043
Calf (cm)	31.6 ± 2.85^a	31.8 ± 2.68^{a,b}	32.2 ± 2.78^b	31.9 ± 2.72	0.033
MUAC (cm)	22.5 ± 2.49^a	22.6 ± 2.75^{a,b}	23.0 ± 2.79^b	22.7 ± 2.64	0.031
Skinfolds					
Tricep (mm)	7.6 ± 2.21	7.7 ± 2.14	7.3 ± 2.08	7.5 ± 2.09	0.538
Bicep (mm)	4.3 ± 0.95	4.6 ± 1.15	4.6 ± 1.73	4.5 ± 1.32	0.674
Sub-scapular (mm)	6.5 ± 1.30	7.3 ± 2.54	7.2 ± 2.23	7.1 ± 2.11	0.283
Supra-spinale(mm)	5.1 ± 0.98^a	6.0 ± 1.86^b	5.4 ± 1.33^b	5.5 ± 1.46	0.076
Sum SKF (mm)	23.5 ± 4.66	25.7 ± 7.13	24.5 ± 6.68	24.6 ± 6.24	0.292
Density (g/cm^3)	1.066 ± 0.006	1.064 ± 0.007	1.065 ± 0.007	1.065 ± 0.007	0.322
Body composition					
Percent fat (%)	14.5 ± 2.45	15.4 ± 3.27	14.9 ± 3.07	15.0 ± 2.93	0.319
Fat mass (kg)	6.8 ± 2.17^a	7.9 ± 3.01^b	7.9 ± 3.00^b	7.6 ± 2.76	0.062
FFM (%)	85.5 ± 2.45	84.6 ± 3.27	85.1 ± 3.07	85.0 ± 2.93	0.462
FFM (kg)	40 ± 7.94	42.2 ± 8.25	44.1 ± 8.56	42.3 ± 8.26	0.319
FFM:Fat	6.1 ± 1.25	5.8 ± 1.48	6.0 ± 1.38	5.9 ± 1.35	0.408

Note: *Age adjusted P-values; a, a or b, b or no values assigned = No significant differences across phases of training; a, b = Significant differences exists across phases of training; PC-rest = Post-Competitive rest phase; PP = Pre-competition phase; CP = Competition phase; BMI = Body Mass Index, BSA = Body Surface Area, MUAC = Mid-Upper Arm Circumference, Sum SKF = Sum of Skinfolds, FFM = Fat-free Mass.

Physical characteristics after age-adjustment were compared across events and the age adjusted values are shown in Figure 1. Across events, within each phase of training, the body mass exhibited no significant difference in the PC-rest and CP, while in PP the male weightlifters showed lowest body mass. Among girls, body mass was similar across event in PC-rest and PP with significant increase among weightlifters at CP. Among boys, track athletes were significantly taller and weightlifters were shortest, while no significant differences observed among girls. Among boys, the circumferences like neck, hip and thigh were lower in weightlifters at PP and by CP, they were similar to athletics and football. During CP, the MUAC of junior male weightlifters was significantly higher than track athletes and football players, while, the junior female weightlifters showed higher MUAC, irrespective of the phase of training.

Table 4. Physical Characteristics of Junior Football Players (Girls) aged 10-16 years

Football	Girls				*P-value*
	PC-rest (n=16)	PP (n=16)	CP (n=12)	Combined	Training Phase*
Age (years)	12.6 ± 1.56	12.7 ± 1.36	13.2 ± 1.70	12.8 ± 1.52	
Weight (kg)	46.3 ± 6.41	46.5 ± 6.83	46.7 ± 4.42	46.5 ± 5.97	0.999
Height (cm)	154.5 ± 3.82	154.3 ± 4.47	155.8 ± 4.16	154.8 ± 4.11	0.825
BMI (kg/m^2)	19.4 ± 2.39	19.5 ± 2.75	19.2 ± 1.49	19.4 ± 2.28	0.954
BSA (kg/sqm)	1.414 ± 0.095	1.415 ± 0.098	1.430 ± 0.079	1.419 ± 0.09	0.979
Circumferences					
Neck (cm)	29.0 ± 1.10	28.7 ± 1.16	28.4 ± 0.86	28.7 ± 1.06	0.361
Chest (cm)	78.9 ± 5.55	78.2 ± 5.47	78.1 ± 3.76	78.4 ± 4.99	0.890
Waist (cm)	70.3 ± 6.85	70.2 ± 7.57	71.2 ± 5.23	70.5 ± 6.60	0.956
Hip (cm)	85.5 ± 5.80	84.9 ± 5.88	85.1 ± 3.64	85.2 ± 5.22	0.905
Thigh (cm)	50.9 ± 4.44	49.1 ± 4.29	50.1 ± 2.98	50.0 ± 4.02	0.482
Calf (cm)	31.4 ± 2.10	33.5 ± 10.99	31.0 ± 1.88	32.0 ± 6.77	0.595
MUAC (cm)	22.4 ± 2.20	22.0 ± 2.60	22.3 ± 1.42	22.2 ± 2.15	0.840
Skinfolds					
Tricep (mm)	13.2 ± 4.15	12.3 ± 4.83	11.8 ± 2.95	12.5 ± 4.08	0.797
Bicep (mm)	6.1 ± 1.98	6.1 ± 2.60	5.8 ± 1.66	6.0 ± 2.11	0.985
Sub-scapular (mm)	11.3 ± 5.47	9.4 ± 3.38	9.0 ± 2.68	10.0 ± 4.16	0.315
Supra-spinale(mm)	8.9 ± 3.47	8.3 ± 3.73	7.1 ± 2.70	8.2 ± 3.39	0.444
Sum SKF (mm)	39.5 ± 13.67	36.0 ± 13.44	33.6 ± 8.26	36.6 ± 12.30	0.567
Density (g/cm^3)	1.043 ± 0.008	1.045 ± 0.008	1.046 ± 0.006	1.045 ± 0.008	0.539
Body composition					
Percent fat (%)	24.8 ± 3.60	23.6 ± 3.75	23.1 ± 2.73	23.9 ± 3.44	0.541
Fat mass (kg)	11.7 ± 3.39	11.2 ± 3.58	10.9 ± 2.10	11.3 ± 3.12	0.842
FFM (%)	75.2 ± 3.60	76.4 ± 3.75	76.9 ± 2.73	76.1 ± 3.44	0.813
FFM (kg)	34.7 ± 3.31	35.3 ± 3.50	35.9 ± 2.82	35.2 ± 3.22	0.541
FFM:Fat	3.1 ± 0.55	3.3 ± 0.61	3.4 ± 0.5	3.3 ± 0.56	0.508

Note: *Age adjusted P-values; a, a or b, b or no values assigned = No significant differences across phases of training; a, b = Significant differences exists across phases of training; PC-rest = Post-Competitive rest phase; PP = Pre-competition phase; CP = Competition phase; BMI = Body Mass Index, BSA = Body Surface Area, MUAC = Mid-Upper Arm Circumference, Sum SKF = Sum of Skinfolds, FFM = Fat-free Mass.

The body fat percent was significantly higher among male football players in CP, as compared to athletics and weightlifters, while fat-free mass did not show significant difference across events (Exhibited in Figure 1a and b). The lean-to-fat ratio was higher among male weightlifters, compared to other events. Among girls, the fat percent was significantly lower and FFM:Fat was significantly higher among athletics, compared to other events. While, the fat-free mass was significantly higher among weightlifters, compared to other events.

Table 5. Physical Characteristics of Junior Weightlifters (Boys) aged 11-17 years

Weightlifting	**Boys**				***P-value***
	PC-rest (n=9)	PP (n=6)	CP (n=7)	Combined	Training Phase*
Age (years)	15.1 ± 1.25	15.3 ± 1.30	15.6 ± 1.22	15.3 ± 1.22	
Weight (kg)	56.5 ± 3.67	55.7 ± 4.40	59.7 ± 4.41	57.3 ± 4.27	0.242
Height (cm)	164.3 ± 3.43	164.2 ± 3.27	166.6 ± 3.05	165.0 ± 3.30	0.437
BMI (kg/m^2)	20.9 ± 1.15	20.6 ± 1.46	21.5 ± 1.19	21.0 ± 1.24	0.554
BSA (kg/sqm)	1.611 ± 0.062	1.600 ± 0.068	1.665 ± 0.070	1.625 ± 0.069	0.218
Circumferences					
Neck (cm)	32.7 ± 1.66	31.2 ± 1.16	32.9 ± 1.30	32.4 ± 1.54	0.103
Chest (cm)	82.3 ± 2.10^a	81.1 ± 0.22^a	84.3 ± 1.96^b	82.6 ± 2.10	0.014
Waist (cm)	70.1 ± 2.07	68.6 ± 2.27	68.9 ± 3.03	69.3 ± 2.45	0.241
Hip (cm)	85.7 ± 2.92	83.4 ± 3.04	84.8 ± 3.12	84.8 ± 3.02	0.150
Thigh (cm)	52.3 ± 3.14	49.2 ± 6.55	52.4 ± 2.75	51.5 ± 4.27	0.266
Calf (cm)	33.6 ± 1.98	32.3 ± 1.51	33.5 ± 1.74	33.2 ± 1.80	0.339
MUAC (cm)	26.5 ± 1.01^a	25.7 ± 1.17^b	27.0 ± 1.02^a	26.5 ± 1.12	0.013
Skinfolds					
Tricep (mm)	8.3 ± 2.06	7.2 ± 1.36	6.4 ± 1.58	7.4 ± 1.85	0.192
Bicep (mm)	4.5 ± 0.96^a	4.4 ± 0.61^a	3.4 ± 0.42^b	4.1 ± 0.87	0.025
Sub-scapular (mm)	7.5 ± 0.98	7.0 ± 1.25	7.3 ± 0.92	7.3 ± 1.00	0.418
Supra-spinale(mm)	5.5 ± 0.58^a	6.8 ± 1.82^b	4.7 ± 0.47^a	5.6 ± 1.30	0.008
Sum SKF (mm)	25.0 ± 4.73	24.3 ± 5.67	20.8 ± 3.76	23.5 ± 4.87	0.193
Density (g/cm^3)	1.064 ± 0.006	1.065 ± 0.007	1.069 ± 0.006	1.066 ± 0.006	0.219
Body composition					
Percent fat (%)	15.2 ± 2.59	14.9 ± 2.91	13.1 ± 2.5	14.4 ± 2.71	0.217
Fat mass (kg)	8.7 ± 1.77	8.3 ± 2.01	7.9 ± 1.8	8.3 ± 1.79	0.537
FFM (%)	84.8 ± 2.59	85.1 ± 2.91	86.9 ± 2.5	85.6 ± 2.71	0.217
FFM (kg)	47.8 ± 2.54^a	47.3 ± 3.14^a	51.8 ± 3.07^b	48.9 ± 3.4	0.020
FFM:Fat	5.8 ± 1.53	6.0 ± 1.46	7.0 ± 2.17	6.2 ± 1.75	0.292

Note: *Age adjusted P-values; a, a or b, b or no values assigned = No significant differences across phases of training; a, b = Significant differences exists across phases of training; PC-rest = Post-Competitive rest phase; PP = Pre-competition phase; CP = Competition phase; BMI = Body Mass Index, BSA = Body Surface Area, MUAC = Mid-Upper Arm Circumference, Sum SKF = Sum of Skinfolds, FFM = Fat-free Mass.

Discussion

This study aimed to determine the physical characteristics and body composition of 10-17-year-old junior Indian athletes across three phases of training. The height of male track athletes in this study, were similar to the height observed among sprinters in Belgium (Aerenhouts et al., 2015) and that of Australian male distance runners (Greene et al., 2006). On the other hand, female track athletes showed a similar height as the middle distance runners from Australia (Greene et al., 2006) and Kenya (Muia et al., 2016). The body mass of Indian junior male track athletes in this study were significantly lower than the sprinters (Aerenhouts et al., 2015), middle distance runners (Greene et al., 2006), endurance runners (Barrack et al., 2017) and cross country runners (Loprinzi et al.,

2011) in the age range of 13-17 years. The body mass of female track athletes in this study were similar to the high school athletes from USA (Barrack et al., 2010b) and middle distance runners from Kenya (Muia et al., 2016).

Table 6. Physical Characteristics of Junior Weightlifters (Girls) aged 11-17 years

Weightlifting	**Girls**				***P-value***
	CP-rest (n=5)	PP (n=6)	CP (n=6)	Combined	Training Phase*
Age (years)	14.4 ± 2.64	14.1 ± 2.42	15.1 ± 2.34	14.5 ± 2.32	
Weight (kg)	49.9 ± 4.62	50.3 ± 5.08	52.0 ± 4.38	50.8 ± 4.50	0.852
Height (cm)	153.2 ± 5.26	153.5 ± 4.31	154.2 ± 3.75	153.7 ± 4.08	0.938
BMI (kg/m^2)	21.2 ± 1.16	21.3 ± 1.32	21.9 ± 1.89	21.5 ± 1.46	0.883
BSA (kg/sqm)	1.452 ± 0.089	1.460 ± 0.089	1.486 ± 0.066	1.468 ± 0.077	0.874
Circumferences					
Neck (cm)	30.3 ± 0.71	30.0 ± 0.71	29.6 ± 0.65	29.9 ± 0.72	0.124
Chest (cm)	80.8 ± 2.70	81.5 ± 2.80	80.3 ± 2.05	80.9 ± 2.40	0.726
Waist (cm)	69.0 ± 6.53	69.8 ± 4.87	68.6 ± 5.39	69.2 ± 5.14	0.855
Hip (cm)	87.3 ± 4.77	87.7 ± 3.42	86.5 ± 3.72	87.1 ± 3.65	0.870
Thigh (cm)	54.2 ± 2.49	52.9 ± 3.78	53.0 ± 1.81	53.3 ± 2.73	0.747
Calf (cm)	32.3 ± 1.36	31.8 ± 2.29	31.6 ± 1.67	31.8 ± 1.77	0.859
MUAC (cm)	24.8 ± 1.45	25.0 ± 0.82	24.7 ± 0.63	24.8 ± 0.89	0.385
Skinfolds					
Tricep (mm)	14.8 ± 4.07	13.6 ± 2.8	12.1 ± 2.23	13.3 ± 2.97	0.224
Bicep (mm)	6.4 ± 2.37	5.6 ± 1.03	5.4 ± 0.92	5.7 ± 1.39	0.496
Sub-scapular(mm)	10.4 ± 4.06	9.8 ± 2.62	9.4 ± 2.05	9.8 ± 2.67	0.771
Supra-spinale(mm)	9.3 ± 3.34	7.8 ± 2.08	7.1 ± 1.69	7.9 ± 2.32	0.273
Sum SKF (mm)	40.8 ± 11.29	36.8 ± 5.17	34.0 ± 5.01	36.8 ± 7.07	0.169
Density (g/cm^3)	1.041 ± 0.007	1.043 ± 0.004	1.046 ± 0.004	1.044 ± 0.005	0.201
Body composition					
Percent fat (%)	25.4 ± 3.2	24.4 ± 1.66	23.4 ± 1.77	24.3 ± 2.15	0.199
Fat mass (kg)	12.7 ± 2.43	12.3 ± 1.88	12.2 ± 1.85	12.4 ± 1.88	0.778
FFM (%)	74.6 ± 3.2	75.6 ± 1.66	76.6 ± 1.77	75.7 ± 2.15	0.472
FFM (kg)	37.1 ± 2.93	38.0 ± 3.35	39.8 ± 2.65	38.5 ± 3.01	0.199
FFM:Fat	3.0 ± 0.49	3.1 ± 0.28	3.3 ± 0.34	3.1 ± 0.36	0.239

Note: *Age adjusted P-values; a, a or b, b or no values assigned = No significant differences across phases of training; a, b = Significant differences exists across phases of training; PC-rest = Post-Competitive rest phase; PP = Pre-competition phase; CP = Competition phase; BMI = Body Mass Index, BSA = Body Surface Area, MUAC = Mid-Upper Arm Circumference, Sum SKF = Sum of Skinfolds, FFM = Fat-free Mass.

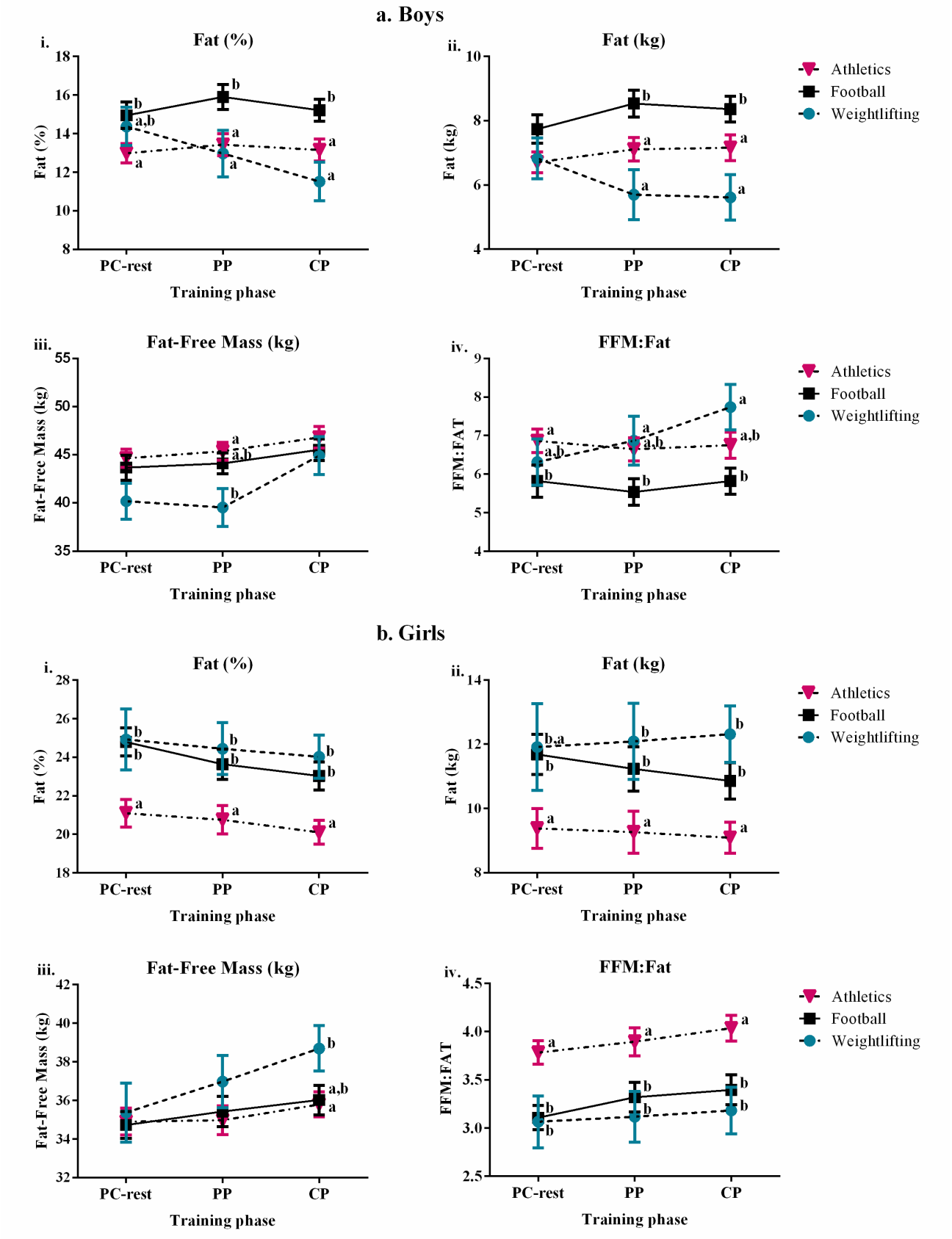

Figure 1. Comparison of Body Composition across Athletics, Football and Weightlifting

Note: PC-rest = Post Competitive rest phase; PP = Preparatory phase; CP = Competition phase. a,a or b,b or no values assigned as superscripts = No significant differences across events. a,b or a,b,c = Significant differences across events

While considering body composition, junior male track athletes in this study had a similar fat mass as the Australian middle-distance runners (Greene et al., 2006) with the fat-free mass significantly lower than them. The female track athletes in this study had similar height, body mass, BMI and fat percent as the elite Kenyan distance runner (Muia et al., 2016), while having significantly lower fat-free mass. They also had a similar fat percent as the high school cross-country runners (Barrack et al., 2010a) and high school athletes (Rauh et al., 2014) from USA. Fat-free mass of Indian Junior female track athletes in this study was similar to that of high school athletes from USA (Barrack et al., 2010b), however, having significantly higher fat percent. In order to achieve physical characteristics in line with the elite international athletes for better competence, an increase in fat-free mass is warranted, especially among short to middle distance junior athletes in India, which in turn would result in an increase in the lean-to-fat ratio.

In case of football/soccer players, nine studies showed a similarity in age with the Indian junior football players in this study. Out of the nine studies, at least six studies (Deprez et al., 2014; Koury et al., 2014; le Gall et al., 2010; Lozano Berges et al., 2017; Teixeira et al., 2015; Vänttinen et al., 2011) showed no significant difference in their mean body mass, height and/or BMI with that of the study group. In addition, the National-level Brazilian soccer players (Teixeira et al., 2015) showed no significant difference even in the body composition (fat mass and fat-free mass) compared to Indian players. However, Teixeira et al. (2015) determined body composition by the skinfold technique using the equation of Slaughter et al. (1988) as against the equation of Durnin and Rahaman (1967) in this study. At similar age, the U13/14 elite English premier league players from Liverpool had lower body mass than soccer players in this study. The Flemish players from Portugal (Deprez et al., 2014) and the players from Finland (Vänttinen et al., 2011) had lower fat percent, compared to players in this study. Both these studies have employed the bioelectrical impedance analyser (Tanita and InBody) for estimating body composition. Among female players, there were two studies showing similar age as the Indian players in this study. One study was carried out on Iranian players (Hosseinzadeh et al., 2017), who had similar body mass, BMI and body fat percent (as per Bioelectrical impedance analyser), but were taller than players in this study. The other research was carried out among the Spain club football players (Lozano Berges et al., 2017), who showed similarity in height, BMI and body fat percent (as per air-displacement plethysmography), while weighing higher compared to Indian players in this study. Thus, similarity in age among soccer players, resulted in similar physical characteristics and body composition, especially in terms of the percent body fat.

Nine other studies of football players (Amorós et al., 2015; Caccialanza et al., 2007; Chamari et al., 2005; García-Pinillos et al., 2015; Gioldasis et al., 2014; Hosseinzadeh et al., 2017; Iglesias-Gutiérrez et al., 2008; Naughton et al., 2016; Valente-dos-Santos et al., 2015) showed significantly higher age (in terms of mean and standard deviation) than players in our study. These studies also reported a significantly higher body mass, height and BMI compared to this study group. Among these, the players from Norway (Chamari et al., 2005), Spain (Iglesias-Gutiérrez et al., 2008) and Iran (Hosseinzadeh et al., 2017) exhibited a lower fat percent than the study group. Another study on 13-15-year-old Portuguese players (Valente-dos-Santos et al., 2015) showed similar fat percent as football players in this study with a higher fat-free mass. The German female players (Braun et al., 2018) exhibited a lower fat percent and higher fat-free mass compared to Indian female players in our study. A study on 8-12-year-old players from Portugal (Valente-dos-Santos et al., 2015) and 11-year-old had players from Spain (Plaza-Carmona et al., 2016) exhibited a significantly lower age, height, body mass and BMI compared to players in this study, while having higher fat percent. Thus, reinforcing the importance of age specificity in understanding similarities in physical characteristics across soccer/football players. Also, the soccer players across the globe though having a higher body mass and height, maintained a fat percent lower than the players in this study.

Among weightlifters, very scanty research exists at the junior level in the age-group of 11 to 17 years. Out of the three studies (Bellew & Gehrig, 2006; Fry et al., 2006; Koşar, 2016) on junior weightlifters, all had similar age as the Indian junior weightlifters in this study. The study of Fry et al. (2006) showed differences in physical characteristics across elite and non-elite weightlifters from USA. Junior weightlifters from this study exhibited a similar mean height and body mass as the elite and non-elite weightlifters, however, their body fat percent and fat-free mass were similar only to the non-elite weightlifters. Our participants also had similar height and BMI as the Olympic weightlifters from USA (Bellew & Gehrig, 2006) and adolescent weightlifters from Turkey (Koşar, 2016). This places an emphasis on decreasing the fat percent of junior weightlifters in this study, while improving the muscle mass to achieve the body composition in line with elite-level weightlifters.

Perroni et al. (2015) reported that pubertal changes begin in male soccer players at 12 years of age, where they observed a sitting height of 78.7 cm, which has been corresponded to puberty and growth spurt. Opposing to this, Malina et al. (2004b) projected pubertal changes at 14 years in soccer players. Though our study has not assessed the pubertal changes, however, we found that between 11-12 years of age, both male football players and male track athletes exhibited maximum difference in height, and it decreased as the age advanced. However,

among male weightlifters this difference in height was highest at 14 years. This could be related to differences in maturity status observed among male athlete (early vs. late maturing within the same chronological age) (Malina, 2006; Malina et al., 2004b) or differences in the type of training which needs to be explored further. Female athletes in this study did not show any association of body mass and height with age, this may be attributed to the early onset of maturation and pubertal changes in females compared to males.

This study did not account for positional or event specific differences and was limited by the sample size within each category or position or event. However, positional difference in adolescent football players were reported after training for over 4.5 years (Malina et al., 2004b). While, another study reported changes in body mass and height with no physiological differences (Wong et al., 2009). Profound positional differences start to occur with greater years of experience in a sport. However, the athletes in this study, would have a training experience of not more than 3 years in a particular sport and it would at least take 10 years of training, to attain an elite or professional level experience to exhibit more profound positional differences (Helsen et al., 2000).

Conclusion

Physical characteristics, though not conclusive, will be crucial to understand the initial fitness levels and form a reflection of the nutritional status. The athletes in this study though not exhibiting significant differences in body mass and height across the various phases of training, did show a reduction among boys in certain circumferences and body fat percent from PC-rest towards CP. Male weightlifters exhibited an increase in fat-free mass from PC-rest to CP, such an increase was not found in track athletes and football players, attributing to the explosive strength training during CP. Across events, the track athletes were tallest and weightlifters were shortest among boys, with no significant differences among girls. MUAC was higher among weightlifting boys at CP and girls at all phases. Across events in boys, body fat percent of football players were higher at CP, while, FFM:Fat ratio was highest among weightlifters. Whereas, in girls, track athletes showed lower body fat percent and higher FFM:Fat ratio compared to other events.

Though reference standards exist for normal healthy Indian population, it might not be suitable and/or useful for athletes who are involved in professional high intensity training. Therefore, a comparison of basic physical characteristics was made between the study participants and international counterparts based on the existing literature. Such a comparison also holds some relevance since the study participants compete against the international elite athletes, enabling an overview of the similarities or differences in physique among them. In comparison with players from various countries, Indian junior track athletes and weightlifters did show a similarity in body mass and height but needed to improve the muscle mass and reduce fat percent, while footballers showed similarity in percent body fat with their international counterparts.

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Informed Consent Statement

All the adolescent athletes included in the study provided assent and written informed consent was obtained from their parents/gaurdians.

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