Assessment of Fat Mass Index and Fat-Free Mass Index in Young Athletes

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Abstract

Fat mass (FM) and percentile body fat (% BF) is commonly used as an assessment tool, especially to evaluate nutrition status of children. As the body mass index is linked with height, it is possible to calculate fat mass index (FMI) and fat-free mass index (FFMI). FMI or FFMI can be used to assess changes in fat-free mass linked to growth; whether there is a change due to shorter height or to a change in body composition.

The data presented were gathered as part of health check-ups by specially-trained medical team of the State Sport Medicine Centre between 2008 and 2012. The study population comprised 6,048 young athletes (4,249 boys and 1,799 girls) aged 10–17 years. During the study period, 13,788 measurements were taken (9,813 on boys and 3,975 on girls). The athletes represented 27 different sports divided into three groups according to weight control practices. Body mass and total body fat was measured using multi frequency 8-polar bioelectrical impedance analyser (X-Scan pluss II, Korea).

Mean of FFMI varies from 17.33 kg/m^2 at 10 years of age to 19.52 kg/m^2 at 17 years of age for males in group I; from 16.44 kg/m^2 to 18.51 kg/m^2 in group II; and from 16.77 kg/m^2 to 19.05 kg/m^2 in group III, accordingly. Mean of FFMI for female varies from 15.73 kg/m^2 to 17.17 kg/m^2 in group I; from 14.20 kg/m^2 to 16.07 kg/m^2 in group II; and from 15.30 kg/m^2 to 16.50 kg/m^2 in group III, accordingly.

Mean of FMI in young male athletes varies from 5.84 kg/m^2 at 10 years of age to 4.57 kg/m^2 at 17 years of age for males in group I; from 4.02 kg/m^2 to 3.69 kg/m^2 in group II; and from 4.59 kg/m^2 from to 4.07 kg/m^2 in group III, accordingly. In female young athletes' population, FMI varies from 8.69 kg/m^2 to 7.59 kg/m^2 in group I; from 6.40 kg/m^2 to 6.81 kg/m^2 in group II, and from 7.63 kg/m^2 to 7.37 kg/m^2 in group III, accordingly.

Developed assessment scales of FMI and FFMI for young athletes can be used in daily practice to evaluate height-independent fat and fat-free (lean) mass to prevent negative impact on health linked with nutritional status and physical load.

Keywords: young athletes, fat mass index, fat-free mass index.

Introduction

Every competitive athlete needs maintenance of good health with optimal weight and body composition (Rodriguez et al., 2009). Based on Joint Position Statement, various attributes of physique (body size, shape and composition) are considered to contribute to success in various sports. Of these, body mass ("weight") and body composition are often focal points for athletes since they are most able to be manipulated, and the assessment and manipulation of body composition may assist in progression of an athletic career (AND, DC, ACSM, 2016). Body weight can influence an athlete's speed, endurance, and power, but body composition can affect an athlete's strength, agility, and appearance. To improve body profile, athletes typically use a weight-loss strategy by increasing activity, reducing energy intake, or doing both. This strategy results in an undesirable change in body composition. Risks include changes in the hormonal milieu that are associated with higher risk of skeletal problems, including higher stress fracture risk, and modifications in metabolic rate. Poorly achieved weight loss nearly always reduces muscle mass and increases fat mass, making it more difficult for an athlete to achieve top performance.

Commonly FM and % BF is used as assessment tool, especially to evaluate nutrition status of children. In this case it is difficult to assess if the changes are linked with weight loss or with growth. For this reason body composition parameters have to be evaluated linked with height. Height-independent body composition parameters (FMI, FFMI) allow height-independent interpretation of nutrition status. With an inadequate caloric intake, a body catabolises the metabolic (lean) mass to lower the need for energy so survival is assured (Baumgartner et al., 1998; Kyle et al., 2003; Eissa et al., 2009; Rodriguez et al., 2009; Sundgot-Borgen et al., 2013; Meleleo et al., 2017). Evaluating FFMI regularly allows to maintain desirable body composition of young athletes without losing lean mass, therefore, prevent negative impact on health linked with nutritional status and physical load.

Aim

The aim of this study was to establish age- and sex-stratified reference values for young athletes' fat mass index and fat-free mass index in Latvia.

Material and Methods

The data presented were gathered as part of health check-ups by specially-trained medical team of the State Sport Medicine Centre between 2008 and 2012. The study population comprised 6,048 young athletes (4,249 boys and 1,799 girls) aged 10–17 years from a representative mix of urban and rural areas and sports disciplines throughout Latvia. During the study period, 13,788 measurements were taken (9,813 on boys and 3,975 on girls). The athletes represented 27 different sports divided into three groups according to weight control practices (Sundgot-Borgen et al., 2013): group I, weight-class sports in which short-term weight control practices are used; group II, aesthetic sports in which leanness is preferred; and group III, weight control is not highlighted. Respondents' mean training load was 4.18 (standard deviation (SD) 1.29) sessions per week, each session lasting approximately 1.5 hours.

Height was measured to the nearest 0.1 cm with an ultrasonic height meter (UHM-101, Korea) with children standing bare feet. Body mass and total body fat was measured using multi frequency 8-polar bioelectrical impedance leg-to-hand analyser (X-Scan pluss II, Korea). The subjects were required to adhere to standard BIA testing guidelines, as given in the manufacturer's manual and measured in light clothes.

The study was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki (6^{th} revision, 2008). The study design was approved by Rīga Stradiņš University Ethics Committee before the data collection was initiated. Participation was based on written applications filed by sport organisations and clubs. Individual athletes and their parents received information about the study before the tests, and their consent was obtained before the data collection. All data stratified by chronological age groups were computed as the mean ± 1SD. Eight chronological age groups were used for analysis, ranging from 10 years (10.0–10.9 years) to 17 years (17.0–17.9 years).

Results

Fat mass index is a height-adjusted assessment of fat mass. The percentile distributions of FMI for young athletes, categorised by gender and age, are shown in Table 1 and 2. Mean of FMI in young male athletes in the current study varies from 5.84 kg/m^2 at 10 years of age to 4.57 kg/m^2 at 17 years of age for males in group I; from 4.02 kg/m^2 to 3.69 kg/m^2 in group II; and from 4.59 kg/m^2 to 4.07 kg/m^2 in group III, accordingly. Median of FMI (50 percentile) decreasing in age groups from 10 years old to 14 years old in group I and III. Median in group II (aesthetic sports) is lower compared to group I and II. According to female young athletes' population, FMI varies from 8.69 kg/m^2 to 7.59 kg/m^2 in group I; from 6.40 kg/m^2 to 6.81 kg/m^2 in group II, and from 7.63 kg/m^2 to 7.37 kg/m^2 in group III, accordingly. Median of FMI (50 percentile) decreases mainly in the first year after being involved in sport.

Table 1. Tabulated fat mass index (kg/m^2) percentile values by exact age in young male athletes

Age (full years)	N	Mean	SD	FMI Percentiles									
				5	10	20	40	50	60	80	85	90	95
Group I – weight-class sports													
10	170	5.84	2.99	1.68	1.92	3.01	4.48	5.52	6.36	8.99	9.60	10.55	11.06
11	212	4.70	2.58	1.20	1.49	2.20	3.71	4.38	5.14	7.03	7.34	7.96	9.61
12	210	4.49	2.69	1.06	1.30	2.00	3.37	4.03	4.49	6.73	7.39	8.54	9.83
13	191	4.58	2.72	1.26	1.70	2.44	3.33	3.95	4.55	6.34	7.32	8.80	10.65
14	201	3.65	2.24	1.10	1.30	1.70	2.70	3.20	3.70	5.26	5.83	6.89	8.20
15	184	4.00	2.04	1.33	1.80	2.39	3.24	3.49	4.02	5.54	5.83	6.82	8.65
16	194	4.28	1.99	1.70	2.05	2.63	3.62	4.00	4.50	5.71	6.03	6.71	8.38
17	151	4.57	1.96	2.06	2.30	2.96	3.71	4.12	4.82	5.96	6.56	7.40	8.94
Group II – aesthetic sports													
10	31	4.02	2.56	0.56	0.92	1.76	2.94	3.97	4.18	5.93	6.31	7.57	9.74
11	33	4.14	2.49	1.48	1.74	2.06	3.03	3.42	4.01	5.85	6.27	7.15	10.04
12	44	3.11	1.73	0.68	1.05	1.64	2.30	2.76	3.01	4.33	4.37	5.77	7.16
13	40	3.24	1.89	0.70	0.93	1.60	2.80	3.15	3.45	4.29	5.00	5.55	6.85
14	33	3.36	1.84	0.90	1.00	1.57	2.77	3.55	3.90	4.52	4.81	5.66	7.14
15	32	3.18	1.34	1.47	1.68	1.86	2.48	2.88	3.56	4.40	4.80	5.25	5.81
16	19	3.32	1.71	0.60	1.00	1.60	3.10	3.30	3.60	4.34	4.43	5.61	6.01
17	18	3.69	1.24	1.90	2.02	2.48	3.28	3.56	4.09	4.90	5.17	5.71	6.12
Group III – non–weight-sensitive sports													
10	848	4.59	2.69	1.20	1.50	2.11	3.40	4.10	4.81	6.87	7.52	8.52	9.88
11	1128	4.32	2.55	1.10	1.50	2.09	3.20	3.76	4.43	6.37	7.21	8.18	9.42
12	1220	4.00	2.29	1.10	1.43	1.97	2.97	3.51	4.16	5.92	6.55	7.23	8.52
13	1461	3.63	2.05	1.10	1.40	1.93	2.78	3.19	3.63	5.07	5.59	6.40	7.95
14	1066	3.52	1.83	1.20	1.50	1.93	2.74	3.20	3.64	4.87	5.38	5.91	7.24
15	1055	3.58	1.75	1.30	1.69	2.10	2.93	3.30	3.74	4.76	5.19	5.67	6.61
16	910	3.77	1.56	1.54	1.95	2.50	3.20	3.62	4.03	4.94	5.32	5.87	6.60
17	568	4.07	1.60	1.81	2.20	2.70	3.50	3.90	4.31	5.24	5.66	6.02	6.96

Fat-free mass index is a height-adjusted assessment of fat-free mass. The percentile distributions of FFMI for young athletes, categorised by gender and age, are shown in Table 3 and 4. FFMI increases (50 percentile) in male population approximately by 1.99 kg/m^2 in group I and 1.89 kg/m^2 in group II and, by 2.83 kg/m^2 in group III. It means, that adolescent males gain more muscle mass in non-weight sensitive sports.

In young female athletes' population, FFMI (50 percentile) increases by 1.69 kg/m^2 in group I and 1.53 kg/m^2 in group II and, by 1,15 kg/m^2 in group III. There is no big difference in gaining fat-free mass between these three sport groups as it is seen in male population.

Table 2. Tabulated fat mass index (kg/m^2) percentile values by exact age in young female athletes

Age (full years)	N	Mean	SD	FMI Percentiles									
				5	10	20	40	50	60	80	85	90	95
Group I – weight-class sports													
10	31	8.60	3.69	1.56	2.88	6.92	7.79	8.62	9.29	10.46	11.86	12.72	17.39
11	36	6.52	2.93	2.27	2.87	3.48	5.36	5.97	6.98	9.09	9.80	11.44	11.85
12	39	6.42	2.82	1.90	2,60	4.00	5.80	6.29	6.59	9.17	9.76	10.34	11.93
13	33	7.42	2.50	3.41	3.66	5.35	6.54	7.20	8.23	9.37	9.93	10.13	13.08
14	35	6.89	2.42	2.72	3.78	4.71	6.25	6.89	7.67	8.64	9.05	10.60	11.38
15	45	7.72	2.15	3.73	5.66	5.99	7.29	7.69	7.97	9.33	9.77	10.67	12.06
16	53	8.03	2.08	4.43	5.58	6.13	7.57	7.90	8.60	9.60	10.49	10.82	12.08
17	28	7.59	2.60	3.31	3.98	5.58	6.70	7.00	8.31	10.10	10.53	11.13	13.04
Group II – aesthetic sports													
10	178	6.40	2.74	1.70	1.90	3.38	6.18	6.81	7.60	8.71	9.01	9.70	10.46
11	174	5.57	2.63	1.50	1.85	2.50	5.17	5.85	6.44	7.85	8.10	8.76	10.12
12	175	5.27	2.32	1.48	2.06	2.92	5.09	5.52	5.96	7.06	7.46	8.20	9.08
13	156	5.41	2.30	1.97	2.20	2.80	5.09	5.74	6.36	7.23	7.72	8.24	9.08
14	122	5.92	2.12	2.43	3.03	4.00	5.51	6.03	6.55	7.87	8.13	8.73	9.55
15	97	6.16	2.08	3.00	3.30	4.20	5.69	6.40	6.82	8.04	8.59	9.16	9.45
16	58	6.19	2.00	2.97	3.20	4.26	5.79	6.38	6.73	7.82	8.05	8.62	8.85
17	47	6.81	2.13	2.92	4.00	4.76	6.68	7.05	7.33	8.49	8.83	9.22	10.34
Group III – non-weight-sensitive sports													
10	251	7.63	3.61	2.10	2.62	4 47	6.59	7.74	8.59	10.34	10.97	12.43	13.98
11	396	6.63	2.95	2.20	2.70	4 00	5.79	6.43	7.11	9.13	9.82	10.49	11.37
12	485	6.37	2.65	2.33	2.80	4 01	5.54	6.19	6.97	8.51	9.09	9.93	10.90
13	542	6.58	2.49	2.60	3.10	4.19	6.00	6.62	7.30	8.76	9.24	9.75	10.48
14	503	7.01	2.42	3.10	3.70	4.80	6.40	7.15	7.70	9.19	9.56	10.03	10.73
15	421	7.18	2.03	3.55	4.26	5.44	6.65	7.40	7.89	8.91	9.30	9.79	10.30
16	326	7.18	2.18	3.52	4.27	5.29	6.66	7.26	7.90	9.08	9.43	9.83	10.68
17	225	7.37	1.96	3.95	4.50	5.72	7.00	7.45	7.87	8.96	9.29	9.83	10.62

Table 3. Tabulated fat-free mass index (kg/m^2) percentile values by exact age in young male athletes

Age (full years)	N	Mean	SD	FFMI Percentiles									
				5	10	20	40	50	60	80	85	90	95
Group I – weight-class sports													
10	170	17.33	1.23	15.29	15.70	16.29	17.06	17.31	17.62	18.32	18.51	18.70	19.53
11	212	17.20	1.29	15.18	15.54	16.06	16.80	17.09	17.45	18.22	18.50	18.90	19.64
12	210	17.48	1.38	15.37	15.79	16.26	17.01	17.40	17.63	18.63	18.90	19.50	19.95
13	191	18.07	1.41	15.61	16.29	16.82	17.80	18.11	18.35	19.16	19.50	19.80	20.48
14	201	18.15	1.34	16.22	16.60	17.07	17.78	18.21	18.31	19.16	19.45	19.80	20.71
15	184	18.81	1.29	16.88	17.32	17.93	18.41	18.68	18.86	19.62	19.98	20.54	21.53
16	194	19.19	1.37	17.25	17.56	18.13	18.80	19.08	19.47	20.21	20.56	20.76	21.60
17	151	19.52	1.34	17.67	18.01	18.45	19.03	19.30	19.70	20.40	20.61	21.49	22.20
Group II – aesthetic sports													
10	31	16.44	1.25	14.67	15.28	15.61	15.98	16.38	16.46	17.13	17.20	17.73	19.41
11	33	16.99	1.25	15.22	16.01	16.20	16.62	16.76	16.90	17.41	18.06	18.26	20.33
12	44	16.79	1.01	14.98	15.50	16.00	16.57	16.74	17.00	17.65	18.00	18.15	18.67
13	40	17.49	1.20	15.72	16.20	16.64	17.08	17.30	17.68	18.15	18.47	18.91	19.78
14	33	17.94	1.36	15.95	16.28	16.79	17.53	17.87	18.10	18.60	19.07	19.60	20.87
15	32	18.11	0.89	16.33	16.94	17.35	17.94	18.12	18.41	18.77	19.02	19.23	19.74
16	19	18.59	0.96	16.40	16.70	17.90	18.43	18.60	19.03	19.47	19.50	19.70	20.10
17	18	18.51	0.94	16.80	17.53	17.74	18.07	18.27	18.52	19.36	19.54	20.15	20.11
Group III – non–weight-sensitive sports													
10	848	16.77	1.11	15.15	15.45	15.80	16.41	16.66	17.00	17.65	17.90	18.17	18.72
11	1128	16.82	1.11	15.21	15.53	15.83	16.44	16.74	17.01	17.68	17.97	18.33	18.78
12	1220	17.11	1.15	15.50	15.78	16.18	16.74	17.00	17.25	18.01	18.35	18.67	19.20
13	1461	17.62	1.21	15.87	16.20	16.61	17.26	17.50	17.78	18.51	18.76	19.10	19.78
14	1066	17.97	1.20	16.14	16.50	17.01	17.60	17.86	18.19	18.91	19.16	19.50	20.00
15	1055	18.42	1.16	16.64	17.10	17.49	18.10	18.36	18.60	19.27	19.50	19.78	20.23
16	910	18.74	1.06	17.18	17.43	17.83	18.44	18.67	18.91	19.60	19.80	20.09	20.54
17	568	19.05	1.03	17.47	17.81	18.19	18.77	19.00	19.27	19.83	20.02	20.33	20.70

Table 4. Tabulated fat-free mass index (kg/m^2) percentile values by exact age in young female athletes

Age (full years)	N	Mean	SD	FFMI Percentiles									
				5	10	20	40	50	60	80	85	90	95
Group I – weight-class sports													
10	31	15.73	1.59	13.31	13.80	14.30	15.07	15.47	15.81	17.49	18.05	18.40	18.74
11	36	15.57	1.29	13.58	13.94	14.24	15.24	15.54	15.71	16.62	16.89	17.01	18.56
12	39	15.87	1.17	13.90	14.62	14.77	15.30	15.79	16.30	16.95	17.00	17.30	18.69
13	33	16.50	1.10	14.99	15.38	15.76	15.95	16.40	16.69	17.44	17.57	17.87	18.74
14	35	16.13	0.88	14.47	14.64	15.56	15.82	16.15	16.53	16.80	16.90	17.10	17.60
15	45	16.79	0.95	14.93	15.43	16.04	16.52	16.78	17.13	17.67	17.82	17.88	18.39
16	53	17.21	1.29	15.39	15.61	16.01	16.72	17.16	17.42	17.94	18.20	19.37	20.08
17	28	17.17	1.27	14.99	15.77	16.31	16.77	17.16	17.28	18.03	18.36	18.76	20.33
Group II – aesthetic sports													
10	178	14.20	0.91	12.88	13.15	13.42	13.89	14.19	14.37	14.79	15.16	15.41	15.85
11	174	14.41	0.96	12.89	13.28	13.66	14.10	14.30	14.54	15.15	15.38	15.61	16.22
12	175	14.80	1.06	13.25	13.48	13.84	14.44	14.69	15.04	15.70	15.90	16.24	16.45
13	156	15.16	1.02	13.47	13.80	14.30	14.97	15.17	15.36	16.00	16.17	16.49	16.80
14	122	15.42	0.97	13.89	14.25	14.67	15.13	15.30	15.45	16.32	16.42	16.69	17.50
15	97	15.58	0.97	14.02	14.44	14.78	15.31	15.51	15.66	16.44	16.59	16.77	17.00
16	58	15.53	0.94	14.10	14.47	14.70	15.34	15.46	15.62	16.22	16.39	16.89	17.42
17	47	16.07	1.15	14.34	14.77	15.18	15.70	15.90	16.15	17.14	17.36	17.62	18.64
Group III – non–weight-sensitive sports													
10	251	15.30	1.33	13.44	13.71	14.10	14.85	15.24	15.51	16.30	16.54	17.07	17.85
11	396	15.43	1.26	13.42	13.93	14.39	15.08	15.31	15.66	16.40	16.71	17.12	17.59
12	485	15.63	1.27	13.64	14.20	14.62	15.22	15.50	15.81	16.66	16.90	17.24	17.75
13	542	15.94	1.10	14.30	14.62	15.00	15.60	15.90	16.13	16.82	17.08	17.30	17.76
14	503	16.22	1.16	14.60	14.83	15.30	15.89	16.13	16.39	17.10	17.33	17.73	18.25
15	421	16.36	1.01	14.88	15.10	15.49	16.03	16.30	16.58	17.20	17.47	17.80	18.20
16	326	16.51	1.12	14.90	15.25	15.61	16.17	16.40	16.69	17.32	17.52	17.82	18.59
17	225	16.50	1.11	14.87	15.15	15.60	16.13	16.39	16.61	17.37	17.50	17.90	18.54

Discussion

Sports dieticians have important opportunities to work with athletes to help promote a healthy body composition, to minimise their reliance on rapid-weight loss techniques and other hazardous practices that may result in performance decrements, loss of fat-free mass, and chronic health risks (AND, DC, ACSM, 2016). This study proposes reference values for FFMI and FMI that are developed by exact age on young athletes aged between 10 and 17 years old using BIA – multi frequency 8-polar bioelectrical impedance leg-to-hand analyser. FMI and FFMI can be used to assess changes in fat mass or fat-free mass linked to growth; whether the changes are due to shorter height or to changes in body composition.

According to research (Loenneke et al., 2012), there was a tendency for the BIA to underestimate FFMI compared to DEXA: 98 % of the estimates were within plus or minus 2 kg/m^2. Therefore, while slightly biased, BIA may provide a reasonable (± 2 kg/m^2) estimate of nutritional status for practitioners who cannot afford more expensive equipment. DEXA is more precise but has issues of cost, accessibility, and its utility is affected by exposure to small radiation dose limit; therefore, BIA is a good alternative, especially when reference values are made for a specific population and device. BIA can give reliable details on body composition differences in competitive and non-competitive adolescents, outlining a progressive decline in ECW and increase in ICW without affecting TBW composition of athletes (Meleleo et al., 2017). A study using eight-mode BIA and DEXA determined no significant difference in body-fat estimation between these methods when applied to children (Yu et al., 2010).

There is little data on FMI and FFMI in athletes' population. In a study (Trexler et al., 2016) in NCAA Division I and II on Collegiate American Football Players it was found that football practitioners may use FFMI to evaluate an individual's capacity for additional FFM accretion, suitability for a specific position, potential for switching positions, and overall recruiting assessment.

According to the current study, young female athletes gain less fat-free mass and loose less fat mass during puberty compared to male athletes. According to this, special attention has to be paid to males' population to assess fat and fat-free mass avoiding unhealthy weight loss and inappropriate nutritional and physical load recommendations since many of them can be classified as overweight using BMI.

In healthy USA non-black adolescents (Eissa et al., 2009), mean of FFMI at the age of 11 and 14 years for boys were 14.2 (SD 1.6) and 16.7 (SD 1.7) kg/m^2 and for girls – 13.4 (SD 1.1) and 15.4 (SD 1.3) kg/m^2, accordingly. From this study, mean of FFMI at the age of 11 and 14 years for non-weight sensitive sports athletes were 16.82 (SD 1.1) and 17.9 (SD 1.2) kg/m^2 for boys and 15.63 (SD 1.3) and 16.22 (SD 1.2) kg/m^2 for girls, accordingly. FFMI in young athletes is higher compared to healthy adolescents from the USA. Analysing FMI mean value from the current study at the age group of 11 and 14 years, it is higher for girls (6.63 (SD 2.9) and 7.01 (SD 2.4) kg/m^2) compared to healthy adolescent girls from the USA (5.0 (SD 2.5) and 4.0 (SD 2.1) kg/m^2) and lower for boys (4.3 (SD 2.5) and 3.52 (SD 1.8) kg/m^2) compared to healthy adolescent boys from the USA (5.0 (SD 2.5) 4.0 (SD 2.1) kg/m^2). Taking into account that the research from the USA uses different BIA device (50 kHz, single frequency) from ours (5 to 500 kHz, multi-frequency), results can be slightly biased; therefore, the data do not differ significantly.

Conclusions

In Latvia we have developed fat mass index and fat-free mass index percentile scales for young athletes for assessment of height-independent body composition parameters. Using developed reference values, health care providers can set norms and maintain optimal body composition for athletes in three different sport groups to prevent a negative impact on health linked changes in the hormonal milieu that are associated with higher risk of skeletal problems, including higher stress fracture risk, and modifications in metabolic rate, avoid relative energy deficiency in sport (RED-s) and optimise physical load.

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