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ORIGINAL ARTICLE

Anthropometry, body composition and hand grip strength of select female athletes from Chennai, India

EXERCISE IS MEDICINE

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Joseph Amanda[1], **Dr. Ramesh Gowri**[2]
1 Senior Research Scholar, Department of Home Science, Women's Christian College, Chennai, India
2 Associate Professor, Department of Home Science, Women's Christian College, Chennai, India

Abstract

This was a cross-sectional study, conducted from March to December 2021. Purposive sampling was used

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to select 154 female athletes aged 18 to 23 years from various colleges and sports organisations. The participants were involved in athletics, ball sports, racquet sports, field sports and other sports such as boxing, fencing, kho-kho, taekwondo and swimming. Height, body weight, body mass index, waist and calf circumferences, waist to height ratio, total fat, subcutaneous fat and visceral fat percentages, muscle mass percentage, resting metabolic rate, and hand grip strength of all participants were recorded. Height (163.1 ± 8.0 cm; $p<0.01$) and body weight (60 ± 10 kg; $p<0.05$) of ball sport athletes was significantly higher compared to other participants. Highest calf circumference (34.5 ± 3.2 cm) was seen among racquet sport players. Participants involved in athletics had significantly higher muscle mass percentage (28.6 ± 2.2; $p<0.01$), lower total body fat percentage (24.7 ± 4.7; $p<0.01$) and lower subcutaneous fat percentage (21.1 ± 4.6; $p<0.05$). All athletes showed normal hand grip strength values. Regular assessment of these parameters is important for athletes to ensure their fitness for training, thereby improving performance and delaying the onset of fatigue during competitions.

Résumé

Cette étude transversale été menée de mars à décembre 2021, analysant un échantillon de convenance de 154 athlètes féminines âgées de 18 à 23 ans dans divers collèges et organisations sportives. Les participantes pratiquaient l'athlétisme, les sports de balle et de raquette, les sports de terrain ou encore la boxe, l'escrime, le kho-kho, le taekwondo et la natation. La taille, le poids corporel, l'indice de masse corporelle, le tour de taille et des mollets, le rapport taille/hauteur, les pourcentages de masse graisseuse, de graisse sous-cutanée et de graisse viscérale, le pourcentage de masse musculaire, le métabolisme basal et la force de préhension de toutes les participantes ont été enregistrés. La taille (163,1 ± 8,0 cm; $p<0,01$) et le poids corporel (60 ± 10 kg; $p<0,05$) des athlètes de sport de balle étaient significativement plus élevés que ceux des autres participantes. La circonférence du mollet la plus élevée (34,5 ± 3,2 cm) a été observée chez les joueuses de sports de raquette. Les participantes pratiquant l'athlétisme avaient un pourcentage de masse musculaire significativement plus élevé (28,6 ± 2,2; $p<0,01$), un pourcentage de graisse corporelle totale plus faible (24,7 ± 4,7 ; $p<0,01$) et un pourcentage de graisse sous-cutanée plus faible (21,1 ± 4,6; $p<0,05$). Toutes les athlètes présentaient des valeurs normales de force de préhension. L'évaluation régulière de ces paramètres est importante pour les athlètes afin de s'assurer de leur aptitude à l'entraînement, ce qui permet d'améliorer les performances et de retarder l'apparition de la fatigue pendant les compétitions.

Introduction

Female athletes are a vulnerable population, due to their susceptibility to various conditions such as relative energy deficiency in sport (RED-S), anorexia athletica, iron and vitamin B12 deficiencies, lower energy intake and expenditure [1]. Such conditions often lead to inconsistent training levels and sub-optimal performance during competition.

Based on the sport, certain parameters are required to be within a specific range in order to positively impact performance. Training and performance standards are not only dependant on body weight and body mass index (BMI), but works in correlation with other body composition parameters such as body fat and muscle mass [2]. Consistent low body weight, if not corrected, can lead to unfavourable consequences such as eating disorders, amenorrhoea and osteoporosis [3]. Both body weight and BMI are greatly

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influenced by total energy intake, level of carbohydrate intake and phases of the menstrual cycle [1].
Due to the fluctuation of female hormones oestrogen and progesterone, body fat and muscle mass are altered continuously [4]. Studies have indicated a lower body fat to be desirable for endurance in runners while a higher body fat is preferred to maintain 'buoyancy and thermal regulation' in swimmers. In case of muscle mass regulation, age, gender, level of training, good nutrition and genes play an influential role [5].
Research has shown that a higher subcutaneous adipose tissue increases gravitational pull thereby decreasing agility during performance [6]. Studies have also revealed that a higher visceral fat level could result in arterial hypertension and insulin resistance, thereby affecting athletes' health in the long term [7].
A higher waist circumference (WC) may be indicative of obesity-related disorders and an extremely low calf circumference (CC) may suggest the onset of sarcopenia [3,8].
Resting metabolic rate (RMR) is evaluated in athletic people to give an estimate of the energy needs required daily and for training. Body weight, muscle mass, level of activity, exercise intensity and duration are factors that influence RMR [1].
Assessing hand grip strength (HGS) among athletes could assist in either increasing the quality of dietary protein or improving strength training [9].
Since there is insufficient literature available on female athletes in India, data obtained from this study can be used to plan proper dietary interventions and thereby reduce the incidence of RED-S and other related conditions. Therefore, with this focus, the present study was undertaken to assess anthropometric, body composition and HGS parameters in select female athletes from various colleges and sports organisations in Chennai, India.

Methods

Design of the study: This was a cross-sectional study, and was conducted over a period of 10 months from March to December 2021 during the COVID-19 pandemic.
Selection of Sample: Five colleges and two sports organisations were selected based on permission granted by the respective authorities. Purposive sampling was used to select 154 female participants aged 18 to 23 years involved in different sports. Criteria for selection was training ≥5 days a week and representation at the collegiate, state, national and international levels. Athletics (n=25) included participants involved in sprinting, mid- and long-distance running, high jump, long jump and triple jump. Ball sports (n=63) included basketball, volleyball, handball and throwball. Racquet sport players (n=18) were involved in badminton, ball badminton and table tennis. Field sports (n=40) included cricket, hockey, and football players. The 'other sports' category (n=8) included participants involved in boxing, fencing, kho-kho, taekwondo and swimming. Participants below 18 years of age, pregnant or lactating women, and those with health conditions were excluded. The study was approved by the Institutional Ethics Committee of Women's Christian College, Chennai. Written informed consent was obtained from willing participants.
Tools used: A questionnaire was used to collect information on socio-demographic details. A staturemeter was used to measure the height of all participants. For body composition measurements, participants were asked to assemble between 6-8 am in an overnight-fasted, euhydrated, pre-exercise state. A digital body composition analyser (Karada Scan HBF-701, Omron Healthcare Pvt Ltd, India) using bioelectrical impedance analysis (BIA) technology was used to record body weight, BMI, percentages of total body fat,

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subcutaneous fat, visceral fat, muscle mass, and RMR. BIA is a method whereby an electric current (50 kHZ) flows through the body and voltage is checked to measure its resistance (impedance) to the current. A taut measuring tape was used to measure WC and CC. WHtR was obtained by dividing height by WC. An electronic hand dynamometer (EH101-67, CAMRY, China) was used to measure HGS of the athletes' dominant hand. Grip width was adjusted by turning the silver knob located below the screen of the dynamometer. All equipment was sanitised after each use to ensure the safety of both participants and researcher.

Statistical analysis: Arithmetic mean, standard deviation (SD), and one-way analysis of variance (ANOVA) were used to analyse the data. Statistical Package for Social Sciences (SPSS v.22, IBM, United States of America) was used for analysis.

Results

Socio-Demographic Information

The female participants were aged between 18 to 23 years. Most of the participants had completed high school education (85.1%), while 14.3% and 0.6% had completed their undergraduate and postgraduate education respectively. 11.05% of participants were collegiate athletes, while 45.5% and 39.6% of them were state and national-level athletes respectively. 3.9% of them were at the international level. 40.3% of participants came from a family with prior sports background.

Anthropometric and Circumference Measurements

Mean anthropometric and circumference measurements of the female participants involved in different sports is presented in Table 1. As expected, due to sample selection, a significant difference was observed in the height and body weight of participants. Participants playing ball sports had the highest mean height and body weight. There was no significant difference in BMI, waist and calf circumferences, and waist-to-height ratio of participants involved in different sports.

Body Composition Parameters

Mean body composition parameters of female participants involved in different sports is presented in Table 1. A significant difference was observed between groups for total body fat, subcutaneous fat, and percentage of muscle mass. Participants involved in athletics were observed to have the lowest total body fat, subcutaneous fat, and visceral fat percentages, while percentage of muscle mass was the highest. RMR was observed to be the lowest among field sport players, and highest among ball sport players.

Hand Grip Strength

Mean HGS of female participants involved in different sports is presented in Table 1. There was no significant difference in the HGS of participants involved in the different sports. A majority (81.2%) of them showed normal HGS, while 9.7% and 9.1% showed weak and strong HGS respectively.

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Parameter	Female participants involved in different sports (n=154)					F value	p value
	Athletics (n=25)	Ball sports (n=63)	Racquet sports (n=18)	Field sports (n=40)	Other sports (n=8)		
	Mean ± SD						
Height (cm)	160.7 ± 5.7	163.1 ± 8.0	160.5 ± 4.2	158.0 ± 4.7	157.6 ± 6.2	4.250	0.003**
Body weight (kg)	54.4 ± 8.8	60.0 ± 10.6	58.1 ± 13.4	54.1 ± 9.7	55.0 ± 12.2	2.478	0.047*
BMI (kg/m²)	20.9 ± 2.6	22.5 ± 3.3	22.6 ± 4.7	21.7 ± 3.5	21.7 ± 4.3	1.078	0.370
WC (cm)	70.2 ± 6.0	74.3 ± 8.6	72.3 ± 10.8	71.4 ± 8.2	70.1 ± 9.3	1.498	0.206
CC (cm)	32.8 ± 3.2	34.2 ± 2.7	34.5 ± 3.2	32.7 ± 3.2	33.1 ± 3.7	2.294	0.062
WHtR	0.4 ± 0.03	0.4 ± 0.03	0.4 ± 0.06	0.4 ± 0.05	0.4 ± 0.06	1.418	0.231
Total body fat (%)	24.7 ± 4.7	28.8 ± 4.5	28.6 ± 5.8	27.9 ± 4.2	28.7 ± 2.5	3.826	0.005**
Subcutaneous fat (%)	21.1 ± 4.6	25.1 ± 4.4	24.8 ± 6.0	23.9 ± 4.3	24.2 ± 4.6	3.398	0.011*
Visceral fat (%)	2.7 ± 2.0	3.4 ± 2.1	3.8 ± 2.9	3.1 ± 2.1	3.5 ± 2.4	0.790	0.533
Percentage of muscle mass	28.6 ± 2.2	26.9 ± 2.0	26.6 ± 1.9	26.7 ± 1.7	26.5 ± 0.9	4.505	0.002**
RMR (Kcal)	1223.0 ± 138.5	1278.7 ± 156.0	1246.6 ± 187.4	1189.7 ± 142.7	1201.0 ± 182.1	2.235	0.068
HGS (kg)	25.8 ± 6.0	25.4 ± 4.8	24.8 ± 4.0	24.7 ± 4.2	26.5 ± 6.1	0.431	0.786

BMI – body mass index; WC – waist circumference; CC – calf circumference; WHtR – waist to height ratio; RMR – resting metabolic rate; HGS – hand grip strength

* ($p < 0.05$)
** ($p < 0.01$)

Table 1: Anthropometric and circumference measurements, body composition parameters and HGS of female participants involved in different sports

Discussion

Significant differences were observed in height and body weight of the participants, with the ball sport athletes showing maximum values, as expected. A study among female netball players in England showed differing heights and body weights depending on their playing position on the court. Fat and muscle mass also differed between 'goal circle' and 'mid court' players [10]. In a similar study, basketball players had an increased average height and body weight compared to lacrosse players in the United States [11].

BMI for participants was within the normal range of 18.5-22.9 kg/m2 for Asian Indians [12]. Studies conducted among volleyball players in Bosnia and Herzegovina [6], table tennis players in Spain (13) and elite athletes in Japan [2] have also shown normal BMI. In contrast, BMI was observed to be higher among Ghanian athletes involved in nine different sports [14] than participants in the present study. Research among Iranian athletes showed a strong association between body weight, BMI and body fat percentage. As body weight increased, so did BMI and body fat percentage [15]. Increased physical activity is associated with decreased body weight which is beneficial in maintaining normal BMI and body fat among athletes.

Similar to the results of this study, it was found that Japanese female track and field athletes showed a lower whole-body percentage of fat and higher percentage of lean muscle [2]. Track and field athletes are

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required to maintain their muscle mass and body fat percentages to be able to shoulder the demands of training, and perform better at the competitive level.

Intensity and duration of physical activity have a tremendous effect on subcutaneous fat tissue and vice versa [16]. Subcutaneous fat tissue among female volleyball players in Bosnia and Herzegovina was seen to be lower than the present study results. As per the 'movement structure' of the game, a lesser body weight and subcutaneous fat were beneficial for greater athletic achievement [6]. However, there was a difference in the instrument used to calculate the subcutaneous fat percentage. The study involving volleyball players used the skinfold callipers at seven sites of the body, while the present study used a digital body composition analyser.

Participants in the present study had a normal visceral fat percentage, between 0.5-9% [17]. A study conducted among 'healthy, non-athletic' Indian adolescent females showed that normal visceral fat level was found to have a positive effect on cardiorespiratory fitness and physical activity [18]. Subcutaneous and visceral fat tissue have a 'cushioning effect' in training athletes; they prevent sports-related injuries. However, studies have also indicated that a marked increase in the above parameters will impede performance [6,1].

A study conducted among Ghanian female athletes (14) participating at the university level in various sports found that mean WC values were closely matched with the results of the racquet sport players in the present study. Frequent physical activity at moderate to vigorous intensity decreases abdominal adiposity thereby maintaining WC at an acceptable level [19].

Mean CC in Ethiopian female runners was lower compared to participants in this study. Having a lesser CC and thigh circumference proved to benefit African athletes in terms of performance. For long-distance runners, maintenance of healthy CC is crucial to support running economy [20].

Participants showed a normal WHtR of <0.50 [21]. An increased WHtR leads to risk of developing CVD and is also related inversely to cardiorespiratory fitness and physical activity [22]. Research showed that across a timespan of four years in a non-athletic Finnish population, a marked increase was observed in BMI and WHtR for those who did not increase their yearly step count by a minimum of 2,000 steps [23].

Studies on American female athletes competing at the Division III NCAA level reported a higher RMR owing to higher body weight (24,25) than those in the present study. RMR and resting energy expenditure (REE) are used interchangeably at times; the former affected by body weight, while the latter influenced by increasing BMI. Another study showed that REE was found to be higher among young adult Chinese women [26], than the RMR seen in participants of this study.

A study on HGS among Indian non-athletic females between the age group of 21-30 years [9] showed a mean grip value which was lower than that of the participants in the present study. Research has shown that female Spanish table tennis players had a higher dominant HGS than participants of this study. Due to the repetitive action of hitting the ball back and forth, racquet sport players are seen to possess a significantly stronger grip value [13]. Studies have shown that HGS values are associated with improved physical fitness levels, and are highest among post-pubertal elite female athletes [27].

Low energy intake and/or inadequate energy availability is likely to lead to RED-S which can translate into risk of lower-than-normal body fat. Eating disorders may stem from prolonged incidence of RED-S and chronic low fat mass, requiring medical intervention. Further complications such as metabolic, physiological, immunity, bone, menstrual, reproductive and psychological disorders can occur which could greatly hinder the female athlete from performing to their maximum potential [28]. Hence,

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maintaining a normal range of anthropometric and body composition parameters will not only improve an athlete's training and performance but also contribute to overall health.
Strengths of the study included a wide variety of sports from which players were selected, and a sufficient sample size which helped draw conclusive results. The first limitation was the utilisation of BIA technology to measure body composition. BIA is usually a highly criticised method and validity of the measures are questionable. However, protocols were followed to standardise these measures that would significantly reduce error percentage. Even though it is not the gold standard, it is more affordable and easier to use for large sample studies compared to DEXA and BodPod machines. Second limitation was the inability to determine serum haemoglobin levels, and correlate with muscle mass and hand grip strength due to stringent safety procedures followed during the COVID-19 pandemic and the city facing periodic lockdowns.

Conclusion

A key finding in this study was the significant difference in total body fat, subcutaneous fat and muscle mass of athletics participants compared to others. Further research conducted during training and competitive seasons supported by biochemical data would be helpful in addressing any gaps in the training schedule and nutrition periodization of athletes. A combination of anthropometric and body composition parameters, and macronutrient and micronutrient intake assessment at regular intervals can be used as a reference for improvement and would warrant an athlete's future development in their particular sport.

Practical implications

– The need arises to assess anthropometric and body composition parameters on a regular basis, provide world-class training and prescribe specific diets, which will equip female athletes in the Indian subcontinent to develop and maintain a desirable physique for performance.
– Planning specialised training sessions and tailor-made diets will not only help female athletes perform better, but also maintain high energy levels during competitions and delay the onset of fatigue.
– Suitable body composition parameters and proper nutrition intervention will also help them lead a healthier lifestyle.

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Conflict of interest

None declared.

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Corresponding author

Amanda Joseph
Women's Christian College,
51 College Road, Chennai – 600 011, India
Tel: +91-9600116710
Email: amanda_joseph95@yahoo.com

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BODY FAT CALF CIRCUMFERENCE HAND GRIP MUSCLE MASS