Baltic Journal of Health and Physical Activity

Volume 10 | Issue 2 Article 5

2018

Assessment of body water spaces & mineral content in trained athletes of different sports using bioelectrical impedance analysis

Abhishek Bandyopadhyay
Human Performance Laboratory, Sports Authority of India, Netaji Subhas Eastern Center, Salt Lake City, Kolkata, India

Subhra Chatterjee
Human Performance Laboratory, Sports Authority of India, Netaji Subhas Eastern Center, Salt Lake City, Kolkata, India

Sujata Jana
Human Performance Laboratory, Sports Authority of India, Netaji Subhas Eastern Center, Salt Lake City, Kolkata, India

Swapan K. Dey
Human Performance Laboratory, Sports Authority of India, Netaji Subhas Eastern Center, Salt Lake City, Kolkata, India, drsk_dey@rediffmail.com

Recommended Citation

Bandyopadhyay A, Chatterjee S, Jana S, Dey SD. Assessment of body water spaces & mineral content in trained athletes of different sports using bioelectrical impedance analysis. Balt J Health Phys Act. 2018; 10(2): 43-54. doi: 10.29359/BJHPA.10.2.05

Abstract

Background: The aim of the present study was to evaluate & compare the body fluid level and the total mineral content in trained male and female players of four different sport disciplines. Materials and Methods: 46 archers (M=18 & F=28), 57 track & field athletes (M=26 & F=31), 81 footballers (M=24 & F=57) and 43 gymnasts (M=21 & F=22) were evaluated using a multi-frequency bioelectrical impedance analyser. Results: Track & field athletes were found to be bigger in size while gymnasts were smaller. Total body water (%) was found to be higher in all the male players than in their female counterparts. Total mineral mass, total body Ca2+ and K+ were also found to differed significantly (p<0.05 & p<0.01) between male & female players of different sports disciplines, except for gymnastics. However, overall significant difference (p<0.05 & p<0.01) was observed only in archers vs gymnasts, archers vs footballers in both male & female players when Scheffe's post hoc test was applied. Conclusions: The present study revealed the influence of specific training load and gender on total body water and mineral content in athletes playing different sports. These findings could be implemented in sports to formulate a systematic training program and also for future comparisons.

Keywords

bioelectrical impedance analysis, body water spaces, dehydration, mineral content, trained athletes

Baltic Journal of Health and Physical Activity 2018; 10(2): 43-54
Journal of Gdansk University of Physical Education and Sport
e-ISSN 2080-9999

ORIGINAL

doi: 10.29359/BJHPA.10.2.05

Assessment of body water spaces & mineral content in trained athletes of different sports using bioelectrical impedance analysis

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Abhishek Bandyopadhyay[BCDE], Subhra Chatterjee (*nee* Karmakar)[DEF], Sujata Jana[B], Swapan K. Dey[ACD]

Human Performance Laboratory, Sports Authority of India, Netaji Subhas Eastern Center, Salt Lake City, Kolkata, India

abstract

Background: The aim of the present study was to evaluate & compare the body fluid level, total mineral content in trained male and female players of four different sport disciplines

Material and methods: 46 archers (M = 18 & F = 28), 57 track & field athletes (M = 26 & F = 31), 81 footballers (M = 24 & F = 57) and 43 gymnasts (M = 21 & F = 22) were evaluated using a multi-frequency bioelectrical impedance analyzer

Results: Track & field athletes were found to be bigger in size while gymnasts were smaller. Total body water (%) was found to be higher in all the male players over their female counterparts. Total mineral mass, total body Ca^{2+} and K^{+} were also found to differ significantly ($p < 0.05$ & $p < 0.01$) between male & female players of different sports disciplines except in gymnastics. However, overall significant difference ($p < 0.05$ & $p < 0.01$) was observed between archers and gymnasts, as well as archers and footballers in both male & female players when Scheffe's Post hoc test was applied.

Conclusions: The study revealed the influence of specific training load and gender on total body water and mineral content on athletes playing different sports. These findings could be implemented in sports to formulate the systematic training program and also for future comparison.

Key words: bioelectrical impedance analysis, body water spaces, dehydration, mineral content, trained athletes.

article details

Article statistics: **Word count:** 3,676; **Tables:** 6; **Figures:** 0; **References:** 33

Received: January 2017; **Accepted:** May 2018; **Published:** June 2018

Full-text PDF: http://www.balticsportscience.com

Indexation: Celdes, Clarivate Analytics Emerging Sources Citation Index (ESCI), CNKI Scholar (China National Knowledge Infrastructure), CNPIEC, De Gruyter - IBR (International Bibliography of Reviews of Scholarly Literature in the Humanities and Social Sciences), De Gruyter - IBZ (International Bibliography of Periodical Literature in the Humanities and Social Sciences), DOAJ, EBSCO - Central & Eastern European Academic Source, EBSCO - SPORTDiscus, EBSCO Discovery Service, Google Scholar, Index Copernicus, J-Gate, Naviga (Softweco, Primo Central (ExLibris), ProQuest - Family Health, ProQuest - Health & Medical Complete, ProQuest - Illustrata: Health Sciences, ProQuest - Nursing & Allied Health Source, Summon (Serials Solutions/ProQuest, TDOne (TDNet), Ulrich's Periodicals Directory/ulrichsweb, WorldCat (OCLC)

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interests: Author has declared that no competing interest exists.

Corresponding author: Dr. S. K. Dey, Senior Scientific Officer, Sports Authority of India, Human Performance Laboratory, Netaji Subhas Center, Salt Lake City, Kolkata-700106, India; e-mail: drsk_dey@rediffmail.com

INTRODUCTION

Athletes' body composition is an important criterion in determining the optimal body profile that is required for optimal health and performance in many sports disciplines, and exercise has the potential to change the body composition of children and youth [1]. Measurement of total body water (TBW) is often performed to assess the body composition, nutritional status and the level of dehydration. It is also the gold standard for determining the hydration status [2].

The usefulness of bioelectrical impendance analysis (BIA) in athletes depends on whether the desired use is for groups of athletes or for individuals. BIA, by contrast, is relatively simple, quick, and non-invasive technique which gives reliable measurements of body composition with minimal intra and inter-observer variability [3]. BIA has been a widely adopted method for body composition assessment, not only for scientific purposes but also in clinics and leisure centres [4]. A wide frequency band from 1 kHz to 1 MHz is used in BIA to identify the frequencies that reflect various conditions of electrolytes at the cellular level. BIA is universally used as follows: 5 kHz to estimate the extracellular fluid, 50 kHz to determine the distinction of skeletal muscle characteristics, and 200 kHz to identify the total amount of intracellular and extracellular fluid [5].

The maintenance of fluid balance is a major concern for athletes competing in all types of events and disciplines. In adults, 2% to 3% dehydration causes decreased reflex activity, maximum oxygen consumption, physical work capacity, muscle strength, and muscle endurance and impairs temperature regulation. At 4% to 6% dehydration, further deterioration occurs in maximum oxygen consumption, physical work capacity, muscle strength, and endurance time; temperature regulation is severely impaired [2]. Variability in mineral mass due to involvement in different sports has also been well reported in earlier studies [6, 7, 8]. Slaughter et al. [9] claim that FFM represents a greater proportion of mineral content than only by the body weight and also represents the effect of different physical activity and sports.

Several studies have been conducted on the assessment of body water & mineral content using bio-electrical impedance method in elite athletes. Lukaski et al. [10] conducted a study of BIA with densitometry in a group of male and female college athletes who practised basketball, football, swimming, wrestling, track & field and volleyball. All these athletes underwent measurements of BIA and body density both in an uncontrolled state with no restrictions on exercise, hydration, and time of last feeding, and 2 h after a light meal with no preceding exercise. Battistini et al. [11] examined the relationship between physical activity training and body water without using an intervention protocol. Instead, they studied differences in body composition between young elite and non-competitive athletes. Several investigations were carried out [12, 13] on body composition by BIA including anthropometric or hydrometric analysis. However, most of these studies were conducted on individuals who were not physically active or on students of physical education universities only or athletes with no training control. In addition, as per literature, few studies have been conducted on athletes, particularly female athletes only, on the assessment of body composition [14, 15]. Furthermore, no such study has yet been conducted on Indian athletes, particularly of various sports and games and their gender effect. Therefore, the aims of the present study were as follows: i) to assess the body fluid level & the total mineral content of both male & female players of different sports, and ii) to compare the above variables according to their specific sport disciplines viz. archery, football, athletics and gymnastics.

MATERIAL AND METHODS

The present study was carried out on 46 archers (male = 18 & female = 28), 57 track & field athletes (male = 26 & female = 31), 81 footballers (male = 24 & female = 57) and 43 gymnasts (male = 21 & female = 22). All the players belong to various schemes (i.e., Centre of Excellence, Sports Training Centre & Special Area Games) of Sports Authority of India (SAI), eastern region. The players of the present study were at least state level performer with minimum of 5–6 years of formal training history. All the players were evaluated for various anthropometric and physiological variables at the Human Performance Laboratory, Sports Authority of India, Kolkata. They had almost the same socio-economic status and similar dietary habits and were trained in similar environmental/climatic conditions. Hence, the subjects were considered as homogeneous. Prior to the tests, all the players were clinically examined following standard procedure by physicians of SAI, Kolkata, who specialize in sports medicine [16]. Prior to initial testing, a complete explanation of the purposes, procedures and potential risks and benefits of the tests were explained to all the players, and a signed consent was obtained from them. The experiment was conducted after following the revised ethical guidelines for biomedical research on human participants (2006) of the Indian Council of Medical Research (ICMR). The players who were found medically fit, healthy and with no history of any hereditary and cardio respiratory diseases, were finally selected for the present study.

TRAINING REGIMEN

The formulation and implementation of a systematic training program was made by qualified coaches with the guidance of a scientific expert from the Sport Science Department, SAI, Kolkata. The training regimen was almost common to all the four sports of the present study, except the skill training, and was apply, on average, 4 to 5 hours every day except Sunday, which gives about 30 hours a week. There were two sessions a day, i.e. the morning session and the evening session, both of which comprised physical training for one hour and skill training for about two hours. The physical training schedule included different strength and endurance training program along with flexibility exercises. Strength and endurance training was also applied according to their sports specific requirements. The training load/volume of training was analysed and set as per age and gender for each sport separately. Warm up & cool down sessions before & after the main practice were also included in the programme. Beside the technical and tactical training, the players were also provided a psychological or mental training session.

MEASUREMENT PROCEDURE

The subjects' physical characteristics, including height (cm) & weight (kg), were measured by anthropometric rod and digital scales respectively, following a standard procedure [17]. The decimal age of all the subjects was calculated from their date of birth recorded from the original birth certificate, produced at the time of testing.

Bioelectrical impedance analysis (BIA)

Body composition including the body mass index (BMI), fat free mass (FFM), fat mass, total muscle mass (TMM), body mineral content including total body calcium (TbCa), total body potassium (TbK) and body water spaces including total body water (TBW), extracellular water (ECW), intracellular water (ICW) were measured using BIA with a multi-frequency analyser (Maltron Bioscan 920-2, Made in UK). Total body electrical impedance with an alternating current (0.2 mA) with four different frequencies (5, 50, 100 and 200 KHz) was measured. Measurements were taken following a standard testing manual of Maltron International [18]. The subject was in a supine position taking rest for 5 minutes on a non-conducting surface, with the arms slightly abducted from the trunk and the legs slightly separated. Before placing the surface electrodes, the sites were cleaned using isopropyl alcohol ensuring adherence and limiting any possible errors. Surface electrodes were placed on the right side of the body on the dorsal surface of the hands and feet proximal to the metacarpal-phalangeal and metatarsal-phalangeal joints, respectively, and also medially between the distal prominences of the radius and ulna and between the medial and lateral malleoli at the ankle. Before testing, the analyser was calibrated according to the manufacturer's instructions. Before taking the measurement, the players were instructed, according to Heyward & Stolarczyk [19], by the following guidelines: 1) no heavy exercise 12h before the test; 2) no large meals 4h before the test; and 3) consumption of liquids limited to 1% of body weight, or, two 8-oz. glasses of water, 2h before the test. All the tests were conducted at a room temperature varying from 23 to 25°C with relative humidity varying between 50−60%.

Statistical anaysis

Differences among groups for all variables according to their specific sport disciplines and gender were calculated using one-way analysis of variance (ANOVA). If significant main effects or interactions occurred, Scheffe's post-hoc multiple comparison test was used to detect the differences among the selected parameters of the four sport disciplines. The data were analysed using the Statistical Program for the Social Sciences (SPSS) version 21.0 for Windows (SPSS Inc., Chicago, Il, USA). All values are expressed as means ± standard deviation (M ±SD). A confidence level at 5% ($p < 0.05$) was considered as significant.

Results

Physical characteristics, mineral & body water content of the subjects according to their gender & specific sport disciplines are listed in Table 1. Mean age was found to differ significantly ($p < 0.01$) only in the case of football players, as female footballers were older in age (20.3 yrs, ±4.01) than their male counterparts (15.2 yrs, ±0.89). Height & weight was also found to be significantly different ($p < 0.01$ & $p < 0.05$) between male & female players in each sport discipline, except gymnastics, though male gymnasts were taller and heavier as compared to their female counterparts. No such significant gender difference was observed in the BMI of any of the four sports disciplines. FFM, TBK, TBCa, TBW, ECW, Fat mass (except athletes and football players), TMM (except football players and gymnasts) and ICW (except gymnasts) were found to be significantly different ($p <0.05$ & $p < 0.01$) when comparing male & female players in all four sport disciplines. On the other hand, no such

Baltic Journal of Health and Physical Activity 2018; 10(2): 43-54
Journal of Gdansk University of Physical Education and Sport
e-ISSN 2080-9999

significant difference was observed in ECW/ICW when comparing male and female players in all four sports disciplines.

In the case of male players, the values of all the parameters were found to be significantly ($p < 0.01$ & $p < 0.05$) higher in athletes and lower in gymnasts. On the other hand, female archers showed a significantly ($p < 0.01$ & $p < 0.05$) higher value in all the parameters, whereas less in gymnastics as compared to other sports discipline. All the variables were found to differ significantly ($p < 0.01$ & $p < 0.05$) when comparing male & female players of four sport disciplines separately.

Table 1. Comparison of physical characteristics, mineral & body water content of the players (male & female) of four different sports

Variables	Archery			Athletics			Football			Gymnastics			Level of significance (ψ)
	Male (n = 18)	Female (n = 28)	Level of significance (φ)	Male (n = 26)	Female (n = 31)	Level of significance (φ)	Male (n = 24)	Female (n = 57)	Level of significance (φ)	Male (n = 21)	Female (n = 22)	Level of significance (φ)	
Age (yrs)	19.7 ±4.26	21.3 ±5.76	NS	18.7 ±3.22	19.2 ±4.31	NS	15.2 ±0.89	20.3 ±4.01	**	15.8 ±3.52	14.2 ±2.88	NS	(M **) (F**)
Height(cm)	168.2 ±5.39	161.0 ±6.02	**	174.5 ±5.40	157.9 ±5.91	**	166.4 ±5.80	157.4 ±5.34	**	154.1 ±11.82	148.1 ±9.32	NS	(M **) (F**)
Weight(Kg)	65.7 ±13.05	57.1 ±9.11	*	66.5 ±12.16	51.3 ±9.18	**	54.6 ±6.08	50.5 ±5.96	**	44.5 ±12.25	42.6 ±8.15	NS	(M **) (F**)
BMI (kg.m-2)	23.0 ±3.82	21.9 ±2.57	NS	22.0 ±3.70	20.5 ±3.10	NS	19.6 ±1.59	20.4 ±1.87	NS	18.3 ±2.66	19.2 ±2.30	NS	(M **) (F**)
FFM (kg)	55.8 ±8.25	43.2 ±5.66	**	58.1 ±6.66	40.3 ±5.57	**	45.1 ±5.28	39.9 ±4.51	**	39.4 ±11.36	33.0 ±5.32	*	(M **) (F**)
Fat Mass (kg)	9.9 ±6.28	13.9 ±4.53	*	9.0 ±6.73	11.0 ±5.25	NS	9.1 ±3.68	10.5 ±3.05	NS	5.1 ±1.50	9.5 ±3.83	**	(M *) (F**)
TMM (kg)	3.95 ±0,846	3.46 ±0 539	*	4.21 ±0.668	3.28 ±0.623	**	3.26 ±0.456	3.42 ±0.639	NS	2.8 ±0.838	2.51 ±0.479	NS	(M **) (F**)
TBK (g)	143.9 ±20.62	102.5 ±14.99	**	148.5 ±17.32	95.1 ±11.23	**	119.3 ±12.28	91.4 ±7.88	**	100.8 ±29.36	81.3 ±14.53	**	(M **) (F**)
TBCa (g)	1110 ±183.9	830 ±107.5	**	1136 ±122.0	777 ±97.3	**	884 ±95.8	765 ±77.0	**	760 ±280.2	622 ±140.1	*	(M **) (F**)
TBW (l)	40.6 ±5.71	31.2 ±4.54	**	41.9 ±4.71	29.0 ±3.86	**	32.5 ±3.78	28.1 ±2.71	**	28.6 ±8.37	24.3 ±3.92	*	(M **) (F**)
ECW (l)	16.4 ±2 91	13.1 ±2.90	**	16.9 ±2.28	12.0 ±3.26	**	11.3 ±2.59	12.6 ±2.36	*	11.2 ±4.12	8.5 ±2.30	*	(M **) (F**)
ICW (l)	24.2 ±3.16	18.2 ±3.79	**	25.0 ±3.06	17.0 ±2.22	**	21.2 ±2.00	15.6 ±1.59	**	17.4 ±4.39	15.8 ±3.23	NS	(M **) (F**)
ECW / ICW	0.68 ±0.083	0.75 ±0.209	NS	0.68 ±0.079	0.72 ±0.210	NS	0.53 ±0.113	0.82 ±0.166	**	0.62 ±0.100	0.56 ±0.202	NS	(M **) (F**)

*Values are (mean ±SD); **P < 0.01,* P < 0.05, NS = not significant.*

φ comparisons between male and female players of each sport by one way ANOVA

ψ comparisons among different sports of male players (M) and female players (F) separately by one way ANOVA

BMI – body mass index; FFM – fat free mass; TMM – total mineral mass; TBK – total body potassium; TBCa – total body calcium; TBW – total body water; ECW – extracellular water; ICW – intracellular water

Tables 2 and 3 present Scheffe's F test for multiple comparisons of the selected parameters of both male and female players of four different sport disciplines, respectively. Almost all the parameters were found to differ significantly ($p < 0.01$ & $p < 0.05$) between archers vs gymnast & footballers; athletes vs footballers & gymnasts in male and gymnasts vs archers, athletes & footballers in female when Scheffe's post hoc test was applied. However, no such significant difference was observed in any of the parameters between archers vs athletes in men and athletes vs footballers in women players. Height, weight, TBK, ICW & ECW / ICW was found to differ significantly ($p < 0.01$ & $p < 0.05$) between gymnasts & footballers in men. On the other hand, only body weight, fat mass, TBK, TBCa, TBW & ICW was found to differ significantly ($p < 0.01$) between female archers & footballers when the post hoc test was applied.

Table 2. Scheffe's F test for multiple comparisons of physical characteristics, mineral & body water content of the male players of four different games

Variables	ARCH vs ATH	ARCH vs FB	ARCH vs GYM	ATH vs FB	ATH vs GYM	GYM vs FB
Age (yrs)	NS	**	**	**	*	NS
Height(cm)	NS	NS	**	**	**	**
Weight(Kg)	NS	*	**	**	**	*
BMI (kg.m-2)	NS	**	**	NS	**	NS
FFM (kg)	NS	**	**	**	**	NS
Fat Mass (kg)	NS	NS	*	NS	NS	NS
TMM (kg)	NS	*	**	**	**	NS
TBK (g)	NS	**	**	**	**	*
TBCa (g)	NS	**	**	**	**	NS
TBW (l)	NS	**	**	**	**	NS
ECW (l)	NS	**	**	**	**	NS
ICW (l)	NS	NS	**	**	**	**
ECW / ICW	NS	**	NS	**	NS	*

***P < 0.01,* P < 0.05, NS = not significant. ARCH – archery; ATH – athletics; FB – football; GYM – gymnastics.*

Table 3. Scheffe's F test for multiple comparisons of physical characteristics, mineral & body water content of the female players of four different games

Variables	ARCH vs ATH	ARCH vs FB	ARCH vs GYM	ATH vs FB	ATH vs GYM	GYM vs FB
Age (yrs)	NS	NS	**	NS	**	**
Height(cm)	NS	NS	**	NS	**	**
Weight(Kg)	*	**	**	NS	**	**
BMI (kg.m-2)	NS	NS	**	NS	NS	NS
FFM (kg)	NS	NS	**	NS	**	**
Fat Mass (kg)	NS	**	**	NS	NS	NS
TMM (kg)	NS	NS	**	NS	**	**
TBK (g)	NS	**	**	NS	**	**
TBCa (g)	NS	*	**	NS	**	**
TBW (l)	NS	**	**	NS	**	**
ECW (l)	NS	NS	**	NS	**	**
ICW (l)	NS	**	*	NS	NS	NS
ECW / ICW	NS	NS	**	NS	*	**

***P < 0.01,* P < 0.05, NS = not significant; ARCH – archery; ATH – athletics; FB – football; GYM – gymnastics.*

Body water & mineral content in respect to body weight and fat free mass (FFM) of the players (both male & female) of four different sports disciplines are presented in Table 4. The table revealed that all the parameters (TMM, TBW, ECW, ICW) showed a higher value when they were represented with respect to FFM instead of body weight. TMM and TBW, both as per body weight and FFM differed significantly in female players and insignificantly in male players among four sports disciplines (archery, football, athletics and gymnastics). Whereas, ECW and ICW when represented with respect to body weight and FFM differed significantly in male as well as female players of all the four sports disciplines (except ICW/body weight among male players). Gender difference was found to be significant in the case of footballers, archers, athletes and gymnasts when all the parameters (TMM, TBW, ECW and ICW) are expressed in terms of body weight (except TMM/body weight in archery, athletics and gymnastics; ECW/body weight in archery). On the other hand, when the same parameters were represented in terms of FFM, the gender difference was found to be insignificant in the case of TBW/FFM and ECW/FFM in archery, athletics and gymnastics and ICW/FFM in archery and athletics.

Table 6. Comparison of physical characteristics, mineral & body water content of the players (male & female) of four different sports

Variables	Archery			Athletics			Football			Gymnastics			Level of significance (ψ)
	Male (n = 18)	Female (n = 28)	Level of significance (φ)	Male (n = 26)	Female (n = 31)	Level of significance (φ)	Male (n = 24)	Female (n = 57)	Level of significance (φ)	Male (n = 21)	Female (n = 22)	Level of significance (φ)	
TMM / weight	5.77 ±0.865	5.96 ±0.916	NS	6.19 ±0.813	6.45 ±1.000	NS	5.77 ±0.696	6.67 ±1.012	**	6.28 ±0.595	5.76 ±0.944	NS	(M NS) (F **)
TMM / FFM	7.03 ±0.886	8.04 ±0.893	**	7.24 ±0.620	8.1 ±0.781	**	7.22 ±0.441	8.51 ±0.878	**	7.12 ±0.620	7.6 ±0.661	*	(M NS) (F **)
TBW / weight	62.6 ±5.88	54.9 ±3.44	**	63.6 ±5.18	57.0 ±3.57	**	59.7 ±4.25	55.9 ±2.65	**	63.9 ±3.20	57.6 ±2.89	**	(M NS) (F **)
TBW / FFM	72.9 ±3.41	72.2 ±3.08	NS	72.1 ±2.38	72.0 ±2.70	NS	72.2 ±1.70	70.6 ±3.02	*	72.6 ±2.39	73.7 ±2.28	NS	(M NS) (F **)
ECW / weight	25.3 ±3.31	23.0 ±4.31	NS	25.7 ±3.09	23.4 ±4.71	*	20.7 ±4.11	24.8 ±3.79	**	24.5 ±3.44	20.3 ±4.77	**	(M**) (F **)
ECW / FFM	29.4 ±2.96	30.2 ±4.96	NS	29.1 ±2.41	29.4 ±5.02	NS	24.9 ±3.20	31.2 ±3.78	**	27.8 ±3.37	25.7 ±4.70	NS	(M **) (F **)
ICW / weight	37.4 ±3.78	31.9 ±5.17	**	37.9 ±3.23	33.6 ±4.77	**	38.9 ±1.60	31.0 ±3.44	**	39.4 ±1.66	37.4 ±3.89	*	(M NS) (F **)
ICW / FFM	43.5 ±2.64	42.0 ±7.20	NS	43.1 ±2.55	42.6 ±6.75	NS	47.3 ±3.65	39.4 ±5.93	**	44.8 ±2.25	48.0 ±6.53	*	(M **) (F **)

*Values are (mean ±SD); **P < 0.01,* P < 0.05, NS = not significant.*

φ comparisons between male and female players of each sport by one way ANOVA

ψ comparisons among different sports of male players (M) and female players (F) separately by one way ANOVA

BMI – body mass index; FFM – fat free mass; TMM – total mineral mass; TBK – total body potassium; TBCa – total body calcium; TBW – total body water; ECW – extracellular water; ICW – intracellular water

Tables 5 and 6 present Scheffe's Post-hoc test for multiple comparisons of the selected parameters of both male and female players of four different sport disciplines. TBW and ECW, when expressed in terms of body weight, and ECW and ICW, when expressed in terms of FFM, were found to be significantly different between athletes vs footballers, gymnasts vs footballers and archers vs footballers in male players, whereas in the case of female players, all the parameters (TMM, TBW, ECW and ICW), when represented in terms of body weight and FFM, differed significantly between archers vs gymnasts (except TMM/body weight, TMM/FFM, TBW/FFM and ECW/ body weight), athletes vs gymnasts (except TMM/ body weight, TMM/FFM, TBW/body weight, TBW/ FFM, ECW/ body weight) and gymnasts vs footballers (except TBW/ body weight).

Table 5. Scheffe's F test for multiple comparisons of the Mineral & body water content with respect to the body composition of the male players of four different sports

Variables	ARCH vs ATH	ARCH vs FB	ARCH vs GYM	ATH vs FB	ATH vs GYM	GYM vs FB
TBW / weight	NS	NS	NS	*	NS	*
ECW / weight	NS	**	NS	**	NS	**
ECW / FFM	NS	**	NS	**	NS	*
ICW / FFM	NS	**	NS	**	NS	*

***P < 0.01,* P < 0.05, NS = not significant; ARCH – archery; ATH – athletics; FB – football; GYM – gymnastics.*

Table 6. Scheffe's F test for multiple comparisons of the Mineral & body water content with respect to the body composition of the male players of four different sports

Variables	ARCH vs ATH	ARCH vs FB	ARCH vs GYM	ATH vs FB	ATH vs GYM	GYM vs FB
TMM / weight	NS	NS	NS	NS	NS	*
TMM / FFM	NS	NS	NS	NS	NS	**
TBW / weight	NS	NS	*	NS	NS	NS
TBW / FFM	NS	NS	NS	NS	NS	**
ECW / weight	NS	NS	NS	NS	NS	**
ECW / FFM	NS	NS	**	NS	*	**
ICW / weight	NS	NS	**	NS	*	**
ICW / FFM	NS	NS	*	NS	*	**

***P < 0.01,* P < 0.05, NS = not significant; ARCH – archery; ATH – athletics; FB – football; GYM – gymnastics.*

DISCUSSION

In many sports, the body composition of an individual athlete plays an important role. Changes in body composition have been used as information regarding the athlete's adaptation to different types of training [20]. The optimal body composition varies from sports to sports; performance in precision sports such as golf, bowling, shooting, etc. is less dependent upon body composition, whereas in athletics, soccer, gymnastics, figure skating, etc. performance is highly dependent on body composition [21].

The present study provides data about mineral content of male and female players of four different sports disciplines. It shows that the variability of total mineral mass is associated with maturation and gender, which also have been well documented in earlier study [22]. To overcome the effect of gender & age, mineral mass with respect to fat free mass (FFM) has been introduced in the present study. In accordance the findings of Slaughter et al. [9], the effect of different physical activity and sports was well represented by mineral mass as per FFM than only as per body weight.

Male athletes in the present study showed a little higher level of mineral mass than their archer counterparts both with respect to body weight & FFM, although they were younger (18.7 yrs vs. 19.7 yrs). One of the probable reasons might be that sports like soccer, athletics, etc. in which intermittent and high-intensity activities are associated, such as sprinting, jumping, accelerating, decelerating, as well as transverse and torsional loads brought about by fast changes in body displacement direction creates high peak strains on the skeleton, which leads to stimulating bone mineral acquisition [23]. The physiological mechanisms involved in the response of bone cells to mechanical stress are still unclear. A possible explanation may be that osteocytes acting as mechanoreceptors respond to and release a chemical factor capable of promoting osteoblast proliferation at the local bone site. Stress applied to a skeletal segment affects the geometry of the bone, the micro architecture, and the composition of the matrix [24]. However, the data obtained in the case of female athletes of the present study does not support the above findings.

As observed in the present study, low mineral mass in the case of male and female gymnasts in comparison to their footballer, archer and athletes counterparts was probably due to their smaller size. In gymnastics, smallness with the centre of gravity near the axis of rotation is actually beneficial regarding the performance, i.e., rotational movement, arm hang and support elements, balance, etc. [25]. It has been reported that gymnasts are the smallest and the lightest of all athletes since they represent lower growth velocity and a marked stunting of leg-length growth failing to reach the full familial height [26]. Therefore, it is logical that the smaller the body size, the lower would be the mineral content. According to Slaughter et al. [9], an increase in mineral mass occurs later in the maturation spectrum (between the pubescent and post-pubescent stage) in the lean group when compared to the average and obese groups, intimating a delayed skeletal growth or maturation. Low bone mineral content is also likely to occur in lean sports, such as gymnastics [27]. However, these facts could not be justified since there was a very slight difference (0.10%) between male gymnasts & footballers when total mineral mass was expressed over FFM (TMM / FFM) in the present study.

The present study also provides distribution of body water spaces in both male and female athletes of different sport disciplines which have been found to be influenced by gender, body composition and age. In the present study, female players contained a less amount (~50%) of water than their male counterparts (~59%), and the percentage of total body water was also negatively associated with age. The possible explanation of the above facts might be due to the gender difference in body fluid spaces occurring from the teenage years onwards due to their differing fat levels, and as in the elderly, muscle mass is replaced with fat [28]. Since women contain greater amount of fat mass than men, their water reserve is lower as compared to men. Association of gender & age with the body fluid level has been well demonstrated by Ritz et al. [28] and Aloia et al. [29], respectively, in previous studies which corroborate with the findings of the present study.

The relative proportion of ICW and ECW fraction appears to be as important marker of aging as well as gender difference. Slightly greater volumes of ECW in older individuals & female players were observed, whereas ICW was found to decrease with age & was also found to be higher in men in the present study. The explanation of these facts could be that, as in the elderly, muscle mass is replaced with fat. Therefore, older individuals have more fat content, and also women have higher fat mass as compared to men. The relationship between fatness and ECW is that little water is contained in fat mass (5–10%) as extra-cellular water. It is logical that the greater the fat mass, the greater the extra-cellular compartment. This fact has also been shown in obese as compared to lean people [30]. At a similar BMI, women are made of more fat than men, hence they should have a greater proportion of extra-cellular water. Associations of age & gender with both ECW & ICW have been demonstrated by Ellis [31] & Tuuri et al. [32] respectively in earlier studies, which corroborate with the findings of our study.

However, the association between body hydration and the amount of physical activity is still unclear. The ratio of TBW with respect to body weight is, therefore, a poor indicator of hydration. It varies between 50% and 75% across ages. It has been reported that hydration is influenced by gender and body composition and cannot be used as an indicator of hydration. As for TBW, ECW and ICW was positively influenced by weight and negatively by fatness. According to literature, the relationship between hydration and cognitive or exercise performance, intracellular water should be the indicator of choice, as functional impairment should be more related to the cell volume than to the cell environment [28].

Mercier et al. [33] have reported that a lower proportion of fat mass and more muscle mass are preferred, while a high proportion of FFM relates to a high volume of TBW and its ICW component. The fact was found to corroborate with the present study as when the percentage of ICW was expressed as FFM (i.e., ICW/FFM), no such gender difference was found except in the case of footballers. Subsequent increases in ICW (39.4% of body weight in female footballers and 47.3% in male footballers) due to controlled physical activity in the form of sport training will correspond to an increase in active mass and musculature. The recorded value of FFM in women footballers was 79.0%, while in men footballers FFM amounted to 82.6% of body weight in the present study. Again, ICW as per body weight and ICW as per FFM were found to be lower in female footballers as compared to other sport disciplines although they were in advantage of the highest level of FFM in the group. On the other hand, ICW was supposed to be higher in female footballers over their archer counterparts, as they were younger. This is may be due to the fact that ICW spaces are higher in younger than older individuals, as discussed above. Since the present study reported the indicators of hydration, female footballers could have a lower body water reservoir. Women could also be considered at a greater risk of dehydration. This hydration disorder could be due to strenuous physical activity in their regular practise schedule. TBW losses in female football players are not well documented. However, Maughan and Leiper [34] reported that male football players could lose 1.0-2.5 litres of body water in matches held in temperate climates.

CONCLUSIONS

Thus, there is a definite influence of physical maturation and gender difference on normal bone mineral content, which also depends on the skeletal activity triggered by athletes' physical activity patterns and training loads. This is best represented by weight adjusted mineral mass content (i.e., TMM / FFM). The body fluid level is also influenced by gender, age and the body fatness level. The study shows a negative association of total body water and intra cellular water spaces with age, whereas extracellular water spaces were higher in older counterparts. Women contain higher ECW & lower ICW, while in men this is reversed. Thus, young and well trained athletes could have a higher body water level since they have less fat mass through proper conditioning & systemic training. However, sports where strenuous physical activity is held in temperate climate could be the reason for a low body water level in normal conditions. The results of the present study may be useful to maintain the desirable hydration & mineral level of an athlete and also to formulate a systematic training program to enhance sport performance.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to the SAI Eastern Centre, Kolkata, for providing facilities and expertise.

REFERENCES

[1] Kurkeu R. The comparison of body composition bioelectrical impedance analysis method of primary school students who do and don't exercise. Biomed Res. 2017;28(3):1107-1109.

[2] Turocy PS, DePalma BF, Horswill CA, et al. National Athletic Trainers' Association position statement: Safe weight loss and maintenance practices in sport and exercise. J Athl Train. 2011;46(3):322-336. https://doi.org/10.4085/1062-6050-46.3.322

[3] Dehghan M, Merchant AT. Is bioelectrical impedance accurate for use in large epidemiological studies? Nutr J. 2008;7:26. https://doi.org/10.1186/1475-2891-7-26

[4] Kyle UG, Bosaeus I, DeLorenzo AD, et al. Bioelectrical impedance analysis – part I: Review of principles and methods. Clin Nutr. 2004;23:1226-1243. https://doi.org/10.1016/j.clnu.2004.06.004

[5] Kim SB, Lee NR, Shin AM, Lee YH. Development and evaluation of multi-frequency bioelectrical impedance analysis analyzer for estimating acupoint composition. J Acupunct Meridian Stud. 2014; 7(1):33-43. https://doi.org/10.1016/j.jams.2013.01.021

[6] Heinonen A, Oja P, Kannus P, et al. Bone mineral density in female athletes representing sports with different loading characteristics of the skeleton. Bone. 1995;17(3):197-203. https://doi.org/10.1016/8756-3282(95)00151-3

[7] Andreoli A, Monteleone M, VanLoan M, Promenzio L, Tarantino U, De Lorenzo A. Effects of different sports on bone density and muscle mass in highly trained athletes. Med Sci Sport Exerc. 2001; 33(4):507–511. https://doi.org/10.1097/00005768-200104000-00001

[8] Marwaha RK, Puri S, Tandon N, et al. Effects of sports training & nutrition on bone mineral density in young Indian healthy females. Ind J Med Res. 2011;134:307-313.

[9] Slaughter MH, Christ CB, Stillman RJ, Boileau RA. Mineral and water content of the fat-free body: Effects of gender, maturation, level of fatness, and age. Obes Res. 1993;1:40-49. https://doi.org/10.1002/j.1550-8528.1993.tb00006.x

[10] Lukaski HC, Bolonchuk WW, Siders WA, Hall CB. Body composition assessment of athletes using bioelectrical impedance measurements. J Sport Med Phys Fitness. 1990;30:434-440.

[11] Battistini N, Virgili F and Bedogni G. Relative expansion of extracellular water in elite male athletes compared to recreational sportsmen. Ann Hum Biol. 1994;21:609-612. https://doi.org/10.1080/03014469400003612

[12] Houtkooper LB and Going SB. Body composition: how should it be measured? Does it affect sport performance? Sport Sci Exchange. 1994;7(5):112-118.

[13] Wit B, Piechaczek H, Błachnio D, Buśko K. Comparative assessment of selected body components from bioelectrical impedance or skinfold measurements. Biol Sport. 1998;15(4):205-210.

[14] Eckerson JM, Evetovich TK, Stout JR, et al. Validity of bioelectrical impedance equations for estimating fat-free weight in high school female gymnasts. Med Sci Sport Exerc. 1997;29(7):962-968. https://doi.org/10.1097/00005768-199707000-00017

[15] Szczepańska B, Malczewska J, Gajewski J. Tissue components of athletes representing different sports: comparison of measurements taken by caliper and Bioelectric Impedance Analyzer BIA. Pol J Hum Nutr Metab. 2001;1(Suppl 28):176-181.

[16] Debnath M, Roy M, Chatterjee (nee Karmakar) S, Dey SK. Body composition profile of elite Indian male and female archers: a comparative study. Int J Health Phys Edu Comp Sci Sport. 2016;23(1):19-25.

[17] Neogi A, Bandyopadhyay A, Chatterjee (nee Karmakar) S, Dey SK. Anthropometric and physiological characteristics in young Indian elite swimmers: a comparative study. Med Sport. 2016;XII(2):2762-2771.

[18] Bolanowski M, Nilsson BE. Assessment of human body composition using dual-energy x-ray absorptiometry and bioelectrical impedance analysis. Med Sci Monit. 2001;7(5):1029-1033.

[19] Dey SK, Bandyopadhyay A, Jana S, Chatterjee (nee Karmakar) S. Assessment of body cell mass in Indian junior elite players (male) of different sports using bioelectrical impedance analysis method. Med Sport. 2015;11(2):2533-2540.

[20] Andreoli A, Melchiorri G, Brozzi M, et al. Effect of different sports on body cell mass in highly trained athletes. Acta Diabetol. 2003;40:S122-S125. https://doi.org/10.1007/s00592-003-0043-9

[21] Maughan RJ, Burke LM. Sports Nutrition. Handbook of sports medicine and science. Malden, Mass.: Blackwell Publishing; 2002. https://doi.org/10.1002/9780470757185

[22] Lohman TG, Going SB. Body composition assessment for development of an international growth standard for preadolescent and adolescent children. Food Nutr Bull. 2006;27(4):S314-S325. https://doi.org/10.1177/15648265060274S512

[23] Fredericson M, Chew K, Ngo J, Cleek T, Kiratli J, Cobb K. Regional bone mineral density in male athletes: a comparison of soccer players, runners and controls. Br J Sport Med. 2007;41:664-668. https://doi.org/10.1136/bjsm.2006.030783

[24] Branca F. Physical activity, diet and skeletal health. Public Health Nutr. 1999;2:391-396. https://doi.org/10.1017/S1368980099000531

[25] Kyselovičová O, Labudová J, Zemková E, Čierna D, Jeleň M. Anthropometric and cardiovascular variables of elite athletes. Acta Facultatis Educationis Physicae Universitatis Comenianae. 2016; 56(2):143-158. https://doi.org/10.1515/afepuc-2016-0012

[26] Theintz GE, Howald H, Weiss U, Sizonenko PC. Evidence for a reduction of growth potential in adolescent female gymnasts. J Pediatr. 1993;122:306-312. https://doi.org/10.1016/S0022-3476(06)80139-3

[27] Beals KA, Manore MM. Disorders of the female athlete triad among collegiate athletes. Int J Sport Nutr Exerc Metab. 2002;12:281-293. https://doi.org/10.1123/ijsnem.12.3.281

[28] Ritz P, Vol S, Berrut G, Tack I, Arnaud MJ, Tichet J. Influence of gender and body composition on hydration and body water spaces. Clin Nutr. 2008;27:740-746. https://doi.org/10.1016/j.clnu.2008.07.010

[29] Aloia JF, Vaswani A, Flaster E, Ma R. Relationship of body water compartments to age, race, and fat-free mass. J Lab Clin Med. 1998;132:483-490. https://doi.org/10.1016/S0022-2143(98)90126-3

[30] Manna T, Goswami A, Chatterjee (nee Karmakar) S, Dhingra M and Dey SK. Comparison of various physical and body composition profiles between Indian elite male and female gymnasts. Baltic J Health Phys Act. 2017;9(2):39-49. https://doi.org/10.29359/BJHPA.09.2.04

[31] Ellis KJ. Human body composition: In vivo methods. Physiol Rev. 2000;80:649-680. https://doi.org/10.1152/physrev.2000.80.2.649

[32] Tuuri G, Keenan MJ, West KM, Delany JP, Loftin JM. Body water indices as markers of aging in male masters swimmers. J Sport Sci Med. 2005;4:406-414.

[33] Maughan RJ, Leiper JB. Fluid replacement requirements in soccer. J Sport Sci. 1994;12:29-34. https://doi.org/10.1080/02640414.1994.12059276

Cite this article as:

Bandyopadhyay A, Chatterjee (nee Karmakar) S, Jana S, Dey SK.
Assessment of body water spaces & mineral content in trained athletes of different sports using bioelectrical impendance analysis.
Balt J Health Phys Act. 2018;10(2):43-54.
doi: 10.29359/BJHPA.10.2.05