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Research Article

Relationship of Body Composition Variables with Selected Physiological Parameters of Young Sports Person of Different Games -

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ABSTRACT

Background: Cellular level body components and their impact on functional performances are still unclear in sports. The present study was aimed to investigate the sports specific alterations in body composition and physiological parameters and their relationships.

Methods: Three forty-five (*n* = 345) junior elite athletes (mean age, 16.5 ± 1.91yrs) from different sports disciplines (football, *n* = 97; hockey, *n* =110; table tennis, *n* = 75, and badminton, *n* = 63) were evaluated at the end of their preparatory phase. Ninety-three (*n* = 93) age-matched (mean age, 16.3 ± 1.60 yrs) sedentary boys also served as a control group. Whole body Bio-Electrical Impedance Analysis (BIA) was performed using a multi-frequency analyzer ((Maltron Bioscan 920-2, Maltron International, Rayleigh, Essex, UK). Fat-Free Mass (FFM) and Total-Body Water (TBW) were calculated using Asian based prediction equations from the manufacturer's software. Maximal isometric hand grip & back strength, trunk flexibility and 20-meter multistage shuttle run test (bleep test; for VO_2 max) were conducted followed by standard procedure.

Results: One-way ANOVA showed significant differences ($p < 0.01$) in anthropometric indicators and body composition parameters [Body Cell Mass % (BCM %), ratio of Extra Cellular Mass and Body Cell Mass (ECM: BCM), Cell Quality (CQ), Total Body Potassium (TBK), Total Mineral Mass, Total-Body Water % (TBW %), Intra Cellular Water (ICW %)] with respect to specific sport. Field hockey players possessed significantly ($p < 0.01$) highest levels of active body tissue development and the most efficient cardiovascular systems. On the other hand, badminton players showed a larger body size, while soccer players exhibited higher values of body cell mass along with superior hydration status relative to body weight. Table tennis players demonstrated different physical and physiological characteristics as compared to their other counterparts. Age, Body Mass Index (BMI) and FFM were adjusted for multiple regression analysis and revealed that BCM% & ICW% were the key parameters having a significant positive relation ($p < 0.01$) with physiological parameters.

Conclusion: The present study demonstrated that differences in body composition parameters could be the potential indicators for evaluation of qualitative and quantitative alterations in the imposed training load of the athletes from different sports. ICW may have potential role of increasing body strength and aerobic capacity. The measurement of body composition could be a reference standard for an athletic population.

Keywords: Bio-electrical impedance; Body cell mass; Intra cellular water; Physiological performances; Young athletes

INTRODUCTION

Assessment of body composition not only determines athletes' motor fitness but also plays a key role in training. At the cellular level, physiological modeling of body composition associated with functions can be separated into different compartments. BCM is the metabolically active compartment of Fat-Free Mass (FFM) which reflects the body's cellular components involved in oxygen consumption, carbon dioxide production and resting metabolism [1]. On the other hand, the Extra Cellular Mass (ECM) includes non-metabolically active connective tissues such as collagen, elastin, skin, tendons, and bones along with interstitial water. Similarly, Total-Body Water (TBW) is distributed mainly into 2 compartments, Intra Cellular Water (ICW) and Extra Cellular Water (ECW). According to Bandyopadhyay, et al. [2], a high proportion of FFM relates to a high volume of TBW and its ICW component. On the other hand, ECW is composed of water in support and transport tissues which may not be related to muscle strength [2].

Changes in the metabolic activity of BCM and its diversified development have been used as information of athlete's adaptation to different types of physical activity and their training level [3]. Recent studies have verified the impact of sports activity and level of training on Body Cell Mass (BCM) such as, Randakova, et al. [4] (young cross-country skiers *vs* normal controls); Melchiorri, et al. [5] (two different soccer teams); Maly, et al. [6] (between two elite women's volleyball teams); Clarion, et al. [7] (between athletes and healthy subjects); Burdukiewicz, et al. [8] (junior football players of different position); Andreoli, et al. [9] (male recreational long-distance runners); Torres-Luque, et al. [10] (junior football players of different position); Mala, et al. [11] (five different sports games).

Very limited studies showed the comparison of body water spaces among different sports/sport events. Mala, et al. [11] compared body water spaces among elite female athletes of five different sports (viz., volleyball, softball, basketball, soccer, and handball). They found the change of ECW between female softball and soccer players despite of similar body height and weight (the difference between groups was 1.5%). Earlier, Bandyopadhyay, et al. [3] reported that greater the fat mass the greater the extra-cellular compartment.

The smaller deficit in BCM as a proportion of FFM in individual athletes may also be the result of different adaptations to the different types of training for different sports (for instance, strength training frequency) or the difference in the physiological demands on the players from the sport itself (i.e., during match–play). Again, more active its metabolism, more water is required to perform the chemical reactions associated with vigorous activities of muscle [12]. More specifically, small changes in the ICW compartment interfere more with performance, as reported by Silva, et al. [13] on Portuguese national level basketball, handball & volleyball players.

Bioelectrical Impedance Analysis (BIA), in contrast, is a rapid, safe and non-invasive alternative technique for the assessment of TBW and its respective compartments beside FFM, BCM and total body mineral in athletes. It has been recognized that above 50-100 kHz current frequency the TBW (and below 5 kHz for the ECW) can be accurately and precisely estimated by bioelectrical impedance analysis [14].

For sustained vigorous offensive and defensive maneuvers along with rapid and powerful movements, physical abilities are important for winning among Football, Hockey, Table tennis and Badminton players. In the Indian context, previously Dey, et al. [15] also have compared body cell mass characteristics in particular young athletes of different sports and found a clear positive influence of regular high-intensity training on the relatively greater increase in BCM. Due to the ever-increasing physical requirements and differing demands of specific sports, it is advisable to verify the association of body composition with both general and specific physical abilities.

Thus, evaluating and comparing the lean body composition, hydration status and functional performances of these different athletes would provide a new insight. The goal of this study was three-fold: i) To evaluate & compare the features of lean body composition, hydration status and functional characteristics among the players of different sport disciplines of two age group, ii) To find the impact of sports specific physical activity on the above profiles and iii) To find out whether specific lean body tissue characteristics and body water space/s is/are associated with increased the performance (if any).

MATERIALS AND METHODS

Three forty-five (*n* = 345) male players (mean age, 16.5 ± 1.91 yrs) from four different sports disciplines viz. football (*n* = 97), hockey (*n* = 110), table tennis (*n* = 75) and badminton (*n* = 63) and sedentary boys (*n* = 93; mean age; 16.3 ± 1.60 yrs) were participated as control group in this cross-sectional study. All the players belonged to various schemes of Sports Authority of India (SAI), eastern region and they were approached as their routine lab test at Human Performance Laboratory, SAI. The players of the present study were at least of a state-level performer with a minimum of 3-4 yrs of formal training history with no history of any hereditary and cardio-respiratory diseases. All the subjects belonged to almost the same socio-economic status, having similar dietary habits and were having training in the same kind of environmental/climatic condition. Hence, they were considered homogeneous.

Before commencement of the test, all the subjects were clinically examined by the specialized physicians of Sports Medicine following a standard procedure [16]. The subjects who were found to be medically fit, healthy and with no history of any hereditary and cardio respiratory diseases, were finally selected for the present study.

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all the procedures involving human subjects were approved by the Ethical Committee of Sports Authority of India, Kolkata. Prior to initial testing, a complete explanation of the purposes, procedures and potential risks and benefits of these tests were explained to all the subjects and a signed consent was obtained from them.

Training regimen

The formulation and implementation of systematic training program was made by the qualified coaches with the guidance of the scientists from Sport Science Department, SAI, Kolkata. The training programme applied on the present subject consisted of aerobic and anaerobic training, scrimmaging, and different resistance training along with flexibility exercises, which were common to all the four games except their game/event specific training. By and large, all the players underwent training on an average duration of 4-5 hours a day in both the morning and evening session. One hour training session both in the morning and afternoon was fixed for all the players to improve the physical fitness component. Rest of the period in both the session i.e. the morning and afternoon session were fixed for skill/technical and tactical training. The total training period was about 30 hours a week and Sunday was the off day. The warming up & cooling down session was also included in the training programme which was fixed after & before starting of the main practice. Players also undergone through the mental training sessions beside of their physical and skill/technical training programme.

The physical activity of sedentary boys (i.e., control group) was not more than three times per week (for a total period of approximately 3- 4 hours/week). They were all recruited from local public schools. Physical activities performed as evaluated based on questionnaire method were generally consisted of common recreational games, running, jogging etc. Their inclusion-exclusion criteria were same as mentioned above for the athletes.

The subjects were evaluated for various anthropometric, body composition and physiological variables at the Human Performance Laboratory of Sports Authority of India, Kolkata.

Measurement procedure

All the participants were scheduled to report at morning (09:00AM) on a particular day. All the recordings were performed in a same session (i.e., end of the Preparatory Phase, April-May) of the same year as a part of their lab routine test. The mean age was calculated from the date of birth recorded from the original birth certificate, produced by the subjects at the time of testing. Physical characteristics including height (to the nearest 0.1 cm) and weight (to the nearest 0.1 kg) were measured by digital stadiometer (Seca 242, Itin Scale Co., Inc., USA) and body composition analyzer (Tanita BF-350, Tanita Corporation of America Inc., USA) respectively.

Multi-Frequency Bioelectrical Impedance Analysis (MF-BIA): Total body electrical impedance to an alternate current (0.2 mA) with four different frequencies (5, 50, 100 and 200 KHz) was measured using a multi-frequency analyzer (Maltron Bioscan 920- 2, Maltron International, Rayleigh, Essex, UK) following the standard testing procedure [3].

Prior to the measurement, subjects were given instructions according to the following guidelines of Heyward & Stolarczyk [17]: i) No intake of alcohol 48 hours before the test; ii) No heavy exercise 12 h before the test; iii) No large meals & intake of caffeinated products 4 h before the test; iv) No intake of diuretics for 7 days before the test andv) Consumption of liquids limited to 1% of body weight, or, two 8-oz. glasses of water, 2h before the test.

Maximal isometric grip strength: After body composition, maximal isometric hand grip strength was determined by using a digital handgrip dynamometer (Takei A5401, Takei Scientific Instruments Co., Ltd., Niigata City, Japan) with visual feedback. The detailed testing procedures have been followed as described by Waldo [18].

Maximal isometric back strength: Maximal Back Strength (BS) was measured using a back muscle dynamometer (Takei A5402, Takei Scientific Instruments Co., Ltd., Niigata City, Japan). The detailed testing procedures have been followed as described by Bosco and Gustafson [19]. And finally, the absolute back strength was converted to the relative back strength by dividing body weight.

Trunk flexibility Test: Trunk flexibility was assessed by the sit & reach protocol with the help of sit and reach box followed by Wells and Dillon [20].

20 Meter Shuttle Test (Bleep Test): The 20 m shuttle run test protocol required the subject to run alternately back and forth across a 20-m distance as described by Leger, et al. [21]. This test was conducted in an open synthetic Astroturf. Throughout all the testing procedure room temperature was varying from 23 to 25-degree centigrade with relative humidity varying between 50-60%.

STATISTICAL ANALYSIS

Mean, Standard Deviations (±SD) for all the selected variables were calculated. The assumption of normality was verified using the Shapiro-Wilk W-test. One way ANOVA followed by Bonferroni's post-hoc test for the multiple comparisons among the selected variables was also performed. Results of regression analysis were plotted along the 'line of equality' (i.e. the line at a 45° angle) to visually examine the concordance in the scatter plots. To eliminate the effect of age, BMI and FFM over body composition parameters & physiological variables, standard partial regression coefficient (β) adjusting for age, BMI and FFM were calculated. Data were analyzed using the Statistical Package for Social Science (version 21.0, SPSS, Inc., Chicago, IL).

RESULTS

Table 1 demonstrates the comparison of mean and Standard Deviation (SD) and level of significance of physical characteristics of the players of different sports discipline. The table reveals that height and body weight was more in badminton players as compared to other sports discipline whereas both table tennis players and control group exhibited smaller in these components. These differences were statistically significant at the level of $p < 0.01$. On the other hand, no such significant differences were observed in the case of body weight and BMI when compared among these groups. BF% has shown to differ significantly ($p < 0.01$) when one-way Analysis of Variance (ANOVA) was applied among the groups. Bonferroni's post-hoc test was revealed that football and hockey players were found to be significantly ($p < 0.01$) leaner as (less BF%) compared to the racket sports players and control group.

Table 2 represented the comparison of mean, SD and level of significance of lean body composition, body water spaces and mineral status of these subjects. It was evident from the table that all the body composition parameters significantly differed among the groups except BCMI was found to be statistically insignificant. The fat-free mass, glycogen mass, and total mineral contents were significantly higher ($p < 0.01$) in badminton players as compared to other sports disciplines and the lowest values were obtained in the control group. Relative BCM (BCM%) has shown significantly ($p < 0.01$) higher mean value in hockey players and lower value in table tennis players and in the control group. Cell Quality (CQ) or BCM/FFM% was found to be almost similar among the sports disciplines, however, a significantly ($p < 0.01$) highest value was found in sedentary boys. Football players exhibited highest BCMI value whereas table tennis players and control group showed the lowest mean values in these parameters. TBK was significantly higher ($p < 0.01$) in badminton players and lower in table tennis players. Hockey players showed higher mean values (significant at $p < 0.01$) in total body water& intracellular spaces, relative to body weight over control group and

Table 1: Comparison of mean, standard deviation and level of significance of physical characteristics among different sports disciplines.

Variables	Football (n = 97)	Hockey (n = 110)	Table Tennis (n = 75)	Badminton (n = 63)	Control (n = 93)	F	p (4, 433)	Bonferroni's Post-hoc Test
Age (yrs)	17.0 ± 1.87	16.2 ± 1.87	16.8 ± 2.50	17.3 ± 2.97	16.3 ± 1.60	3.98	0.00350**	BDT *vs* HK*, CTRL*
Height (cm)	166.5 ± 5.21	169.1 ± 4.57	165.0 ± 5.51	170.1 ± 5.64	164.7 ± 7.00	15.06	0.00001**	HK *vs* FB*, TT**, CTRL**; BDT *vs* FB**, TT**, CTRL**
Weight (kg)	57.2 ± 5.35	57.9 ± 6.25	56.9 ± 10.41	60.0 ± 8.99	58.0 ± 13.74	1.17	0.32336^{ns}	ns
BMI (kg.m^{-2})	20.6 ± 1.51	20.3 ± 1.85	20.8 ± 3.23	20.9 ± 2.83	21.2 ± 4.33	1.38	0.23993^{ns}	ns
BF (%)	12.9 ± 4.06	13.1 ± 4.01	15.7 ± 5.36	15.7 ± 4.88	17.9 ± 5.62	18.59	0.00001**	FB *vs* TT**, BDT**, CTRL**; HK *vs* TT**, BDT**, CTRL**; CTRL *vs* TT*, BDT*

Significant differences between groups: $^{**}p < 0.01$, $^{*}p < 0.05$, ns: not significant. FB = Football; HK = Hockey; TT = Table tennis; BDT = Badminton; CTRL = Control

Table 2: Comparison of mean, standard deviation and level of significance of body composition parameters among different sports disciplines.

Parameters	Football (n = 97)	Hockey (n =110)	Table tennis (n = 75)	Badminton (n = 63)	Control (n = 93)	F	p (4, 433)	Bonferroni's Post-hoc Test
FFM (kg)	49.7 ± 5.91	50.3 ± 6.55	47.2 ± 7.77	51.2 ± 8.33	46.6 ± 9.98	5.47	0.00026**	BDT *vs* TT*, CTRL *vs* HK**, BDT**
ECM : BCM	0.85 ± 0.07	0.85 ± 0.07	0.85 ± 0.15	0.83 ± 0.12	0.81 ± 0.10	3.41	0.00923**	CTRL *vs* FB*, HK*
ECM (%)	40.0 ± 3.75	40.1 ± 3.24	38.2 ± 5.31	38.5 ± 4.87	36.3 ± 5.26	11.88	0.00001**	CTRL *vs* FB**, HK**, BDT*; HK *vs* TT*
BCM (%)	46.8 ± 1.96	47.0 ± 1.96	45.4 ± 3.57	46.7 ± 2.48	44.8 ± 2.93	13.32	0.00001**	TT *vs* FB**, HK**, BDT*; CTRL *vs* FB**, HK**, BDT**
CQ	54.1 ± 2.01	54.0 ± 2.01	54.5 ± 4.11	55.0 ± 4.14	55.5 ± 2.94	3.97	0.00356**	CTRL *vs* FB*, HK**
BCMI	9.7 ± 0.74	9.5 ± 0.87	9.4 ± 1.28	9.6 ± 1.16	9.4 ± 1.46	0.96	0.42924^{ns}	ns
Glycogen mass (gm)	451 ± 53.79	459 ± 55.33	426 ± 74.66	471 ± 70.94	423 ± 90.66	7.41	0.00001**	TT *vs* HK*, BDT**; CTRL *vs* HK**, BDT**
TBW (%)	62.3 ± 4.01	62.4 ± 3.93	59.9 ± 5.68	61.6 ± 4.22	58.6 ± 4.00	13.51	0.00001**	TT *vs* FB**, HK**; CTRL *vs* FB**, HK**, BDT**
ECW (%)	24.4 ± 4.29	24.1 ± 3.62	23.1 ± 4.72	23.8 ± 3.64	21.4 ± 3.67	8.24	0.00001**	CTRL *vs* FB**, HK**, BDT**
ICW (%)	37.9 ± 1.87	38.3 ± 2.44	36.8 ± 2.87	37.8 ± 2.29	37.2 ± 2.49	5.82	0.00014**	FB *vs* TT*; HK *vs* TT**, CTRL*
TBK (gm)	127.9 ± 12.77	129.7 ± 14.24	122.4 ± 20.35	133.4 ± 19.11	123.1 ± 24.67	4.77	0.00089**	BDT *vs* TT**, CTRL**
Total Mineral Mass (kg)	3.6 ± 0.58	3.7 ± 0.63	3.4 ± 0.78	3.8 ± 0.67	3.3 ± 0.85	8.14	0.00001**	TT *vs* HK**, BDT**; CTRL *vs* HK**, BDT**

Significant differences between groups: $^{**}p < 0.01$, $^{*}p < 0.05$, ns: not significant. FB = Football; HK = Hockey; TT = Table tennis; BDT = Badminton; CTRL = Control. FFM: Fat Free Mass; ECM: Extra Cellular Mass; BCM: Body Cell Mass; CQ-Cell Quality; BCMI: Body Cell Mass Index; TBW: Total Body Water; ECW: Extra Cellular Water; ICW: Intra Cellular Water; TBK: Total Body Potassium

Table 3: Comparison of mean, standard deviation and level of significance of static strength, flexibility and aerobic capacity among different sports disciplines.

Variables	Football (*n* = 97)	Hockey (*n* = 110)	Table tennis (*n* = 75)	Badminton (*n* = 63)	Control (*n* = 93)	F	*p* (4, 433)	Bonferroni's Post-hoc Test
Grip$^{(R)}$ Strength (kg)	37.3 ± 5.04	40.0 ± 4.76	33.8 ± 6.90	40.8 ± 7.44	35.3 ± 3.98	23.22	0.00001**	FB *vs* HK**, TT**, BDT**; TT *vs* HK**, BDT**; CTRL *vs* HK**, BDT**
Grip$^{(L)}$ Strength (kg)	36.8 ± 4.94	39.8 ± 5.41	31.4 ± 7.00	35.8 ± 6.65	34.0 ± 4.07	29.04	0.00001**	HK *vs* FB**, TT**, BDT**, CTRL**; TT *vs* FB**, BDT**, CTRL*; FB *vs* CTRL**
Back Strength (kg)	105.8 ± 13.89	110.0 ± 16.67	95.9 ± 20.17	109.6 ± 24.55	86.0 ± 22.07	25.86	0.00001**	TT *vs* FB**, HK**, BDT**; CTRL *vs* FB**, HK**, TT*, BDT**
Relative Back Strength	1.9 ± 0.25	1.9 ± 0.25	1.7 ± 0.27	1.8 ± 0.30	1.5 ± 0.13	46.26	0.00001**	TT *vs* FB**, HK**, BDT*; CTRL *vs* FB**, HK**, TT**, BDT**
Trunk Flexibility (cm)	16.2 ± 5.01	13.7 ± 4.51	9.7 ± 6.71	11.2 ± 6.76	8.7 ± 7.18	24.62	0.00001**	FB *vs* HK*, TT**, BDT**, CTRL**; HK *vs* TT**, CTRL**
VO_2max (ml.kg^{-1}.min^{-1})	56.7 ± 4.64	59.8 ± 4.98	46.2 ± 4.97	53.4 ± 4.12	43.4 ± 5.87	183.82	0.00001**	FB *vs* HK*, TT**, BDT**, CTRL**; HK *vs* TT**, BDT**, CTRL**, TT *vs* BDT**, CTRL**; BDT *vs* CTRL**

Significant differences between groups: $^{**}p < 0.01$, $^{*}p < 0.05$, ns: not significant. FB = Football; HK = Hockey; TT = Table tennis; BDT = Badminton; CTRL = Control

Table 4: Partial regression coefficient (β) of lean body tissues, body water spaces, and physiological characteristics by adjusting age BMI & FFM.

	Grip$^{(R)}$ Strength (kg)	Grip$^{(L)}$ Strength (kg)	Back Strength (kg)	Relative Back Strength	Trunk Flexibility (cm)	VO_2max (ml.kg^{-1}.min^{-1})
ECM (%)	-0.143*	-0.106^{ns}	-0.174**	0.060^{ns}	0.010^{ns}	0.013^{ns}
BCM (%)	0.061^{ns}	0.092*	0.084*	0.262**	0.161**	0.282**
CQ (%)†	0.121*	0.116*	0.144**	0.109^{ns}	0.085^{ns}	0.152**
TBW (%)	-0.030^{ns}	0.027^{ns}	0.070^{ns}	0.278**	0.101*	0.247**
ECW (%)	-0.149**	-0.096^{ns}	-0.046^{ns}	0.166**	0.013^{ns}	0.118*
ICW (%)	0.134**	0.168**	0.180**	0.282**	0.165**	0.286**

Significant differences between groups: $^{**}p < 0.01$, $^{*}p < 0.05$, ns = not significant
†Standard partial regression coefficient (β) values after controlling only age and BMI.

table tennis players. However, extracellular space relative to body weight was highest in soccer players.

Table 3 demonstrated the comparison of mean, SD, and level of significant of various physiological parameters of different sports groups including the control. The table reveals that all the parameters were statistically significant when compared among the groups. Hockey players showed significantly ($p < 0.01$) highest values in both hand grip strength, back strength, relative back strength, trunk flexibility and maximal aerobic capacity as compared among the groups and significantly ($p < 0.01$) lowest values were observed in sedentary counterparts. A significantly higher ($p < 0.01$) trunk flexibility was exhibited by the football players over their other counterparts. Bonferroni's test was also confirmed that the significant differences were obtained due to the difference in hockey & football *vs* other sports discipline and control group.

Table 4 demonstrated the standard partial regression coefficients (β) among the selected body composition parameters and physiological profiles while adjusting age, BMI & FFM. Relative ECM was found to be significantly and negatively correlated only with Grip$^{(R)}$ Strength ($p < 0.05$) and Back strength ($p < 0.01$) whereas no such significant relation was found with other physiological parameters. In the case of CQ, positive relationships ($p < 0.01, 0.05$) were observed with the physiological parameters except for relative back strength & trunk flexibility. All the physiological parameters were found to be positively correlated ($p < 0.01$) with relative ICW. On the other hand, relative ECW was negatively and significantly related ($p < 0.01$) with almost all the parameters expect VO_2max. However, in the case of TBW (%), a significant relation was exhibited with relative back strength, trunk flexibility and VO_2max.

Figure 1 (a)-(d) depicts the scatter plot of BMI (on the x-axis) in relation with BCMI (on the y-axis) of four different sports disciplines. A slight variability in BCMI value as per BMI for all the sports disciplines was observed in contrast to the control group.

Distribution of points for the measured functional characteristics along the line of identity (i.e., at 45˚) with body composition variables is shown in figure 2 (a)-(g).

DISCUSSION

Differences in relative BCM reflect the varied level of physical performance in athletes [8]. The alterations in the current BCM content were followed among different sports groups as per previous studies [3-6]. Notably, a higher relative BCM (%) in present hockey, football and badminton players may be the causative influence of high-intensity aerobic training in comparison to table tennis players and sedentary boys. This fact was further justified by significant relationship BCM% with VO_2max (Figure 2a). Furthermore,

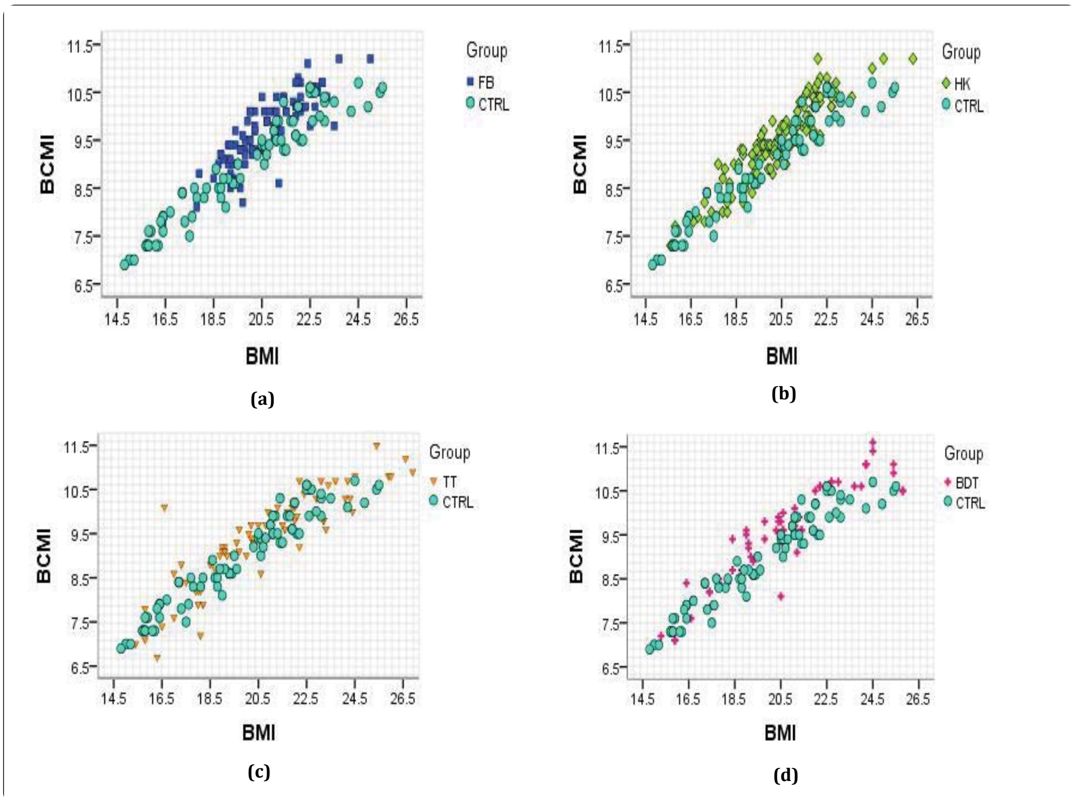

Figure 1: Scatter plot of the body mass index (BMI, kg/m2) and the body cell mass index (BCMI, kg/m2) of (a) Football; (b) Hockey; (c) Table tennis; (d) Badminton players in respect to the control group. FB = Football; HK = Hockey; TT = Table Tennis; BDT = Badminton; CTRL = Control..

standardized regression coefficient revealed strong dependency on 'quality' of muscle mass i.e., BCM/relative BCM with physiological variables. On the other side, table tennis, a low-moderate group of sports [22] represent much lower BCM% than others sports disciplines. Since sedentary boys did not engage themselves in such athletic training, they possess the lowest BCM% eventually much lower FFM. The fact was further justified by the strong negative relationship of BCM% with BF% as a result of current finding (Figure 2b).

In case of ECM/BCM ratio, the lower the number, the higher the amount of active mass used for physical or sports activities [23]. In athletes, its values range from 0.70-1.00 depending on the type of sport [24]. In current setup, the degree of training load predictably is lower than Polish male junior football players (mean age; 16.2 ± 0.70 yrs; Burdukiewicz, et al. [8]) who featured a much decreased relative extracellular mass than the current study. However, present values were well comparable to the Slovak women's national team (0.84 ± 0.08, Mala, et al. [25]; 0.86 ± 0.09, Maly, et al. [6]), and young Czech boys of 6 to 14 years (0.87 ± 0.12 [26]) respectively. From the perspective of individual's, the lowest recorded value of current ECM/BCM ratio was 0.80, but values of 0.90-0.99 was also found in our table tennis players, which represents individuals engaged in recreational sport. Increased values in current sedentary group (1.07-1.16) may relate to ontogenesis and indicate lowest actual predispositions of physical activity (muscular activity). With this context, previously, a similar finding was also reported in untrained subjects [26]. A significant difference in current ECM/BCM index was registered among sedentary boys, football & hockey players. This difference could be the causative factor as the level (quality) difference of these players from the perspective of physical preparedness and play success than the other existing groups. ECM/BCM for evaluation of physical exercise prevalence was further confirmed by the significant dependency with VO_2max (Figure 2c) which is also in agreement with the findings of Bunc, et al. [27].

BCM as per FFM or Cell Quality (CQ) indicates a high quality of LBM in players when the mean value of four sports disciplines (CQ = 54.4%) crossed the limit of the recommended value i.e., 50% of BCM proportion in LBM [24]. The mean values of the present study were well comparable with the result reported on Slovak U17 (CQ = 53.4%), U19 (CQ = 51.8 %) and senior national (CQ = 54.5%) women volleyball players respectively as reported by Mala, et al. [25]. Although, the CQ difference was not statistically significant among different disciplines, however, still it is unclear as better predispositions were seen in current sedentary boys than highly active football and hockey players. It has been reported that chemical maturity of FFM is not attained until late adolescence or young adulthood, i.e., 18 to 20 years of age in boys [28]. As a majority, current subjects were in their adolescent stage; having similar observations in ECM/BCM ratio, CQ and BCMI represents reserves in their training load.

Body Cell Mass Index (BCMI) has been proved to be a more sensitive parameter than BMI revealing characteristics of muscle mass [29]. BCMI range of 9.0 to 11.0 kg/m^2, within shortest BMI range (i.e., 20.0 and 22.5 kg/m^2), in current soccer and hockey players may be one of the causative factor of improved lean mass quality and muscular development in them (Figure 1a, 1b). On the other side, similar mean BCMI within a wider BMI range (i.e., 19.0 and 24.5 kg/m^2) represents lower energy demand and lean mass quality in current table tennis and badminton players (Figure 1c, 1d).

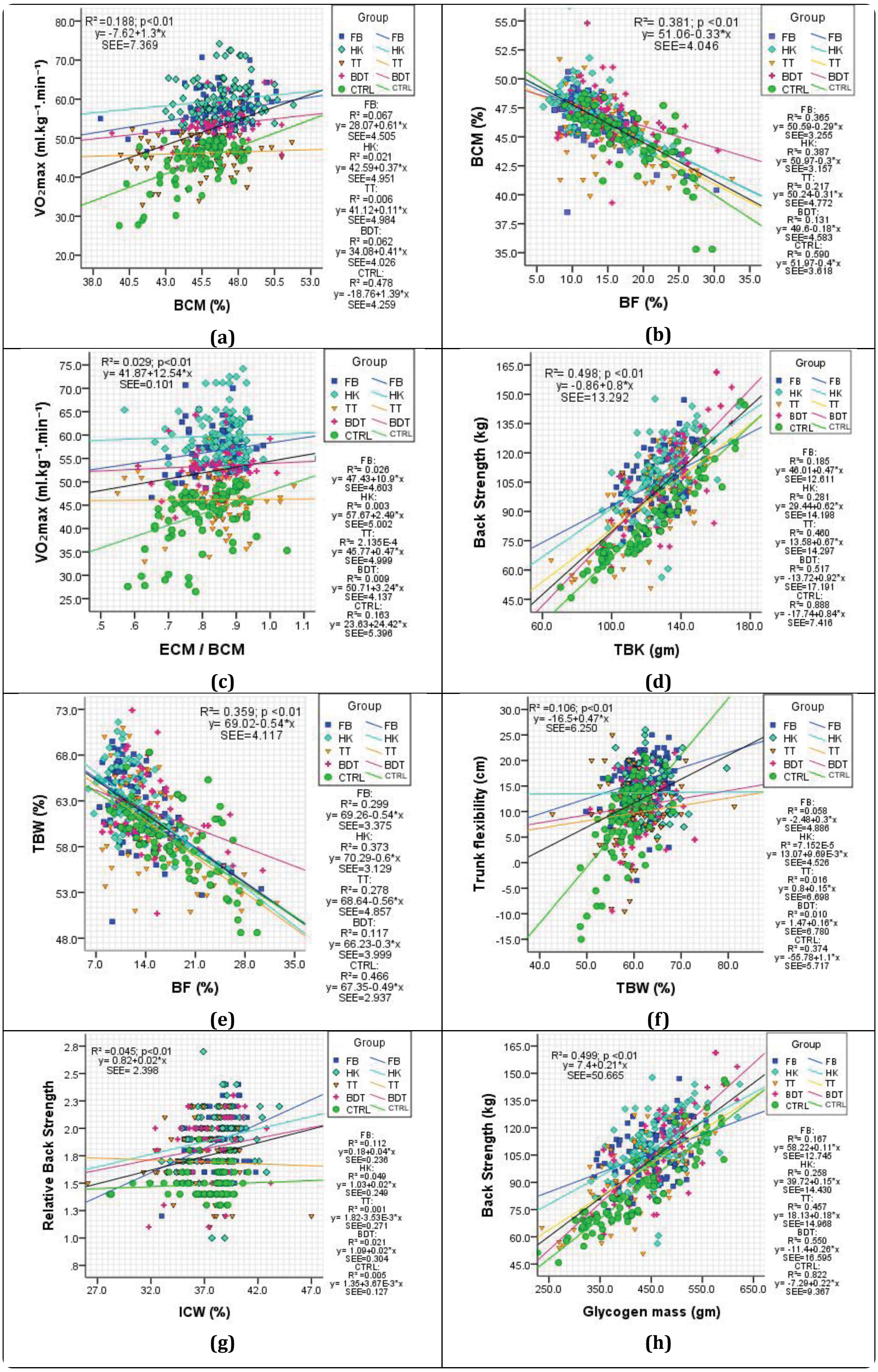

Figure 2: (a) Relationship between- VO2max (ml.kg-1.min-1)and BCM (%); (b) Relationship between- BCM (%) and BF (%); (c) Relationship between- VO2max (ml.kg-1.min-1)and ECM:BCM; (d) Relationship between- Back Strength (kg) and TBK (gm); (e) Relationship between- TBW (%) and BF (%); (f) Relationship between- Trunk flexibility (cm) and TBW (%); (g) Relationship between- Relative Back Strength (kg) and ICW (%); (h) Relationship between- Back Strength (kg) and Glycogen mass (gm). —— Characteristics of the regression line according to five different groups are given in the plot. FB= Football; HK = Hockey; TT = Table Tennis; BDT = Badminton; CTRL = Control.

Sports in which intermittent and high-intensity activities viz., sprinting, jumping, accelerating, decelerating are associated, creates high peak strains on the skeleton eventually leads to stimulate bone mineral acquisition [30]. In accordance with this fact, higher mineral content was observed in both the present hockey and badminton players. A significant relationship between maximal isometric strength and mineral content (Figure 2d) further justified this fact which was in agreement with the findings of Tsuji, et al. [31].

A significantly low hydration level was observed in current table tennis players indicating lower physical capacities among the groups. Earlier, the physiological demand for table tennis has been reported to be low [22], which corroborates with the similarity in level of adiposity with current sedentary boys. This fact was further justified by negative association of TBW% with BF% (Figure 2e). However, significantly higher body water spaces in hockey and badminton players might be the resultant of their superior functional capacities as body water spaces strongly correlated with physiological capacities (Table 4; Figure 2f).

It is well established that an increased TBW is predominantly due to an increase in ICW compartment as it occupies a greater amount of fluid than ECW [2]. Furthermore, our result (Figure 2g) is also in agreement with the findings of Silva, et al. [32], as they pointed out that the association between ICW with maximal hand grip strength and upper-body power. Recently, an increased ICW pool reported to increase the strength and jumping performance even adjusted for gender, age, season length and sports discipline [13]. Standardized regression analysis (adjusted for age, BMI and FFM) of current data showed a significant positive correlation of ICW and relative ICW with physiological characteristics. One of the interesting finding of current study was that, in spite of having similarity in age, height, weight, and BMI in present table tennis and football players; a ~3% less ICW% content in table tennis players might be the potential factor causing ~13 % lower grip strength, ~14 % lower back strength, ~11% lower RBS and ~20 % lower aerobic capacity than the footballers.

For a better defense of decreased plasma volume, more fluid reported to be moved from the intracellular to the extracellular compartment during maximal exercise [33]. Although, the present study was aimed at euhydrated subjects, however, our results are also in agreement with this hypothesis as higher content of relative TBW and ICW was exhibited by hockey and soccer players. This fact was further justified by the strong and significant association of ICW spaces and maximal aerobic capacity (Table 4).

The exact physiological basis linking cell hydration with an anabolic drive is yet to be determined. As reported, the cellular hydration related to both an increase in protein synthesis and a decrease in proteolysis [34]. Furthermore, 'cell swelling theory' claims that cellular volume is a key signal for the metabolic orientation of cell metabolism resulting anabolism, whereas cellular shrinkage promotes catabolism [12]. Glycogen, on the other side, has an osmotic effect whereby it draws three grams of water into the cell for every gram of glycogen [35]. Therefore, the result of enhanced upper body strength in field hockey and badminton players among the groups is due to increased glycogen store that mediates a favorable muscle protein balance over time [35]. Our results were in agreement with this fact as there was strong association existed between maximal isometric strength and glycogen content (Figure 2h).

Study limitation

Although the present sample of young national level players with unique characteristics evaluated during well-defined periods, however, a small number of limitations exist. To more accurately assess the hydration status, performing urine specific gravity or osmolarity test was beyond our scope. Total energy expenditure was also not assessed to understand whether energy balance was maintained. Moreover, we did not analyze fluid volume and composition within 2 hours of each training session. The rate of glycogen synthesis seems to be delayed after 2 hours of exercise and this fact would be interesting to explore the role of cell volume in strength production [36]. Additionally, results do not account for position-specific variations that likely to be exists in football & hockey players.

Gold standard techniques to assess TBW (i.e., deuterium) and ECW (bromide) in athletes have been reported only in few studies [37,32]. Hence, the lack of literature using valid techniques for assessing TBW and its compartments may consider as limitation factor. BIA may be a useful method for estimating TBW variation if the fluid compartments have been reached equilibrium and electrolyte concentrations are unchanged while not in the case when hydration status, FFM and FM simultaneously vary [38].

CONCLUSION

Body cell mass, measured using the whole body multi-frequency bio-impedance method, represents an innovative, simple approach to assess body composition. The present study demonstrates that differences in BCM, relative BCM, ECM/BCM, BCM/FFM and BCMI could be the potential indicators for evaluation of qualitative and quantitative alterations in the imposed training load of the athletes from different sports. On the other hand, TBW alters due to different sports activities and increases with functional capacities. ICW was the only component associated significantly with functional variables despite different age categories and sports. Specifically, to establish the regulating effect of cellular hydration and interconnected fluid compartments on whole-body physiology and metabolism, further research is necessary. Measures of TBW and ICW should be performed to establish a reference standard for an athletic population.

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