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Anthropometric and physiological characteristics in young Indian elite swimmers: a comparative study

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Abstract. The aim of this study was to assess the role of gender on anthropometric and physiological characteristics of young swimmers. Twenty three young swimmers (15 boys: 15.28 ± 2.657 years old; and 8 girls 15.88 ± 2.181 years old) were evaluated. Various anthropometrics and physiological variables were selected. *Results.* The females were found to have a higher amount of fat mass (24.43 ± 4.542) while the males had a higher amount of muscle mass (22.39 ± 4.060) and fat free mass (83.72 ± 4.817) than females. The hand grip strength, trunk flexibility and relative back strength were also observed to be more in males and there exists significant relationship among these parameters as well as with glycogen, mineral, calcium content and muscle mass. No significant correlation was found between trunk flexibility and other parameters. There was a non-significant gender effect on BMI, right hand grip strength, trunk flexibility, body fluid content (total body water, extra cellular water and intra cellular water), body cell mass, total body calcium content, glycogen and mineral content. The BMI also had no differences with respect to gender. Although fat mass was found to be comparable, but fat free mass was found to be lower in male and female swimmers of the present study than their respective international counterparts. Intra cellular water is found to have negative correlation with almost all the parameters. The BMI also had no differences with respect to gender. *Conclusion*. Overall, there exists significant correlation in terms of the parameters between both the sexes. This kind of research helps athletes to precise information and feedback about their physical condition and effect of performance in order to adjust or continue their level of training.
Key words: *swimming, BMI, fat free mass, fat mass, BIA, correlation.*

Introduction

One of the most loved activities throughout the world; people of all ages indulge in the swimming, as it is ideally one of the best ways to exercise all the muscles of the body without any additional pressure. Regular swimming builds muscle strength, endurance and also enhances the cardio-vascular fitness of the person. In India, swimming is widely popular in all the three aspects - as a general activity, sporting event as well as occupational reasons. Despite the high requirements at such young ages, information about fluid intake and hydration during the strenuous training sessions of swimmer is scarce (1). Moreover, different methods have been used to assess the state of dehydration of the swimmers, which makes comparisons challenging. In this context, the bioelectrical impedance vector analysis (BIVA) emerges as a non-invasive and safe technique for assessing hydration and body composition changes (2).

The morphological differences between the swimmers and non-swimmers concern physical characteristics generally involved in swimming. Sprague (3) studied the relationship of certain physical measurement with swimming speed in male swimmers. Matheson (4) studied the relationship between swimming and selected physiological and anthropometric development and skill variables in 10-20 years old female competitive swimmers. In some studies, biological age was assessed by level of sexual maturation and the skeletal age while others were not taken into account gender or competitive levels. Furthermore, researchers have measured aerobic and anaerobic conditioning, anthropometric components, swimming techniques and body composition (5). Based on the findings of previous studies anthropometric measures, general and specific physical conditioning, swimming technique, competitive level and maturational aspects should be analyzed in young swimmers performance.

Regarding the gender gap, pubescent and adult/elite male and female swimmers differ in measures of anthropometrics, physiology, kinematics and energetics. In young swimmers' gender differences were reported in body fat (6). Even so, it seems that there are insignificant differences in the anthropometrics, growth and maturation processes between both genders at this early age (7).

Body mass (BM), height (H) and several body circumferences and areas presented insignificant differences between boys and girls (6). Nevertheless, young swimmers' energetic profile (e.g. aerobic capacity) assessment should be straightforward and non-invasive. Hence, the estimation of some of those parameters is necessity (8). Regarding aerobic capacity, Greco and Denadai (9) also found insignificant differences between genders. However, in these studies, it was not stated whether they were comparing boys and girls of the same sports level.

In this sense, it is of major interest to dispose of hypothetical differences between boys and girls that compete at the same level, instead of pooling into the same gender group subjects at different sports levels.

This study was aimed: (i) to evaluate and compare the gender effect on various anthropometric and physiologic profiles in swimming; (ii) to find out the correlation coefficient among these different anthropometric and physiological variables in both the groups; and (iii) to compare the values obtained from the present study with their international counterparts.

Material and Method

The present study was carried out on 23 swimmers of which male (n=15) & female (n=8). All the swimmers belong to various schemes (viz., Centre of Excellence, Sports Training Centre & Special Area Games) of Sports Authority of India (SAI), eastern region. The swimmers of the present study were at least of state level performer with minimum of 3-4 yrs formal training history. All the subjects were evaluated for various anthropometric and physiological variables at Human Performance Laboratory of Sports Authority of India, Kolkata. The players were belonged to almost same socio-economic status with similar dietary habits and got trained in same kind of environmental/ climatic condition. Hence, they were considered as homogeneous. Before the commencement of test all the subjects were clinically examined by the physicians of SAI, Kolkata, who are specialized in Sports Medicine following standard procedure. Prior to initial testing a complete explanation of the purposes, procedures and potential risks and benefits of the tests were explained to all the subjects and a signed consent was obtained from them. 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 procedures involving human subjects were approved by the University's Institutional Human Ethical Board.

Training Program. The formulation and implementation of systematic training program was made by the qualified coaches with the guidance of the scientific expert from Sport Science Department, SAI, Kolkata. The training regimen for both male and female swimmers of the present study was held on an average 4 to 5 hours every day except Sunday which comes about 30 hours in a week including swimming specific skill tests. There were two sessions in a day i. e. morning session and evening session and both of which comprised of physical training for one hour and skill training for about two hours. The physical training schedule includes different strength and endurance training program along with flexibility exercises. Strength and Endurance training was also applied according to their sports specific requirement. Warm up & cool down session after & before starting of the main practice were also included in the programme. Besides the technical and tactical training the players were also provided psychological or mental training session.

Physical and physiological measurements. The physical characteristics of the subjects including height (cm) & weight (kg) were measured by anthropometric rod and digital weighing machine respectively followed by standard procedure (10). The decimal age of all the subjects were calculated from their date of birth recorded from original birth certificate, produced by them at the time of testing. Body Mass Index (BMI) was calculated from body height and weight. Back strength and hand grip strength (both right and left hand) (kg) were measured by back and grip dynamometer (Senoh, Japan) following the standard procedure (11). The hip and back flexion as well as extension of the hamstring muscles of the leg was evaluated by modified Sit-and-Reach Test using a 'Flexometer' (Lafayette Instrumental co, USA) following the standard procedure (11).

Bioelectrical Impedance Analysis (BIA). Body composition including fat mass (FM), fat free mass (FFM), total body water (TBW), extra cellular water (ECW), intra cellular water (ICW), ratio between extra and intra cellular water (ECW: ICW), body cell mass (BCM), muscle mass (MM), total body potassium (TBK), total body calcium (TBCa), glycogen and mineral were measured using Bioelectrical Impedance Analysis (BIA)(MaltronBioscan 920- 2, Made in UK).

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. Measurements were taken followed by the standard testing manual of Maltron International.
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 to limit the possible errors. Surface electrodes were placed on the right side of the body on the dorsal surface of the hands and feet. In case of hand, electrodes were placed proximal to the metacarpal-phalangeal and medially between the distal prominences of the radius and ulna. In case of feet, electrodes were placed proximal to the metatarsal-phalangeal joints, respectively, and also medially between the medial and lateral malleoli at the ankle. Before testing, the analyzer was calibrated according to the manufacturer's instructions. Before taking the measurement, the players were instructed according to the following guidelines: 1) no heavy exercise 12 h before the test; 2) no large meals 4 h before the test; and 3) consumption of liquids limited to 1% of body weight, or, two 8-oz. glasses of water, 2 h before the test (12). All the tests were conducted at a room temperature varying from 23 to 25 degree centigrade with relative humidity varying between 50-60%.
Statistical Analysis. Data were analyzed using the Statistical Program for the Social Sciences (SPSS) version 16.0 for Windows (SPSS Inc., Chicago, Il, USA). Differences between groups for all variables according to their gender were calculated using a one-way analysis of variance (ANOVA) and matrix of correlation coefficient. All values were expressed as means ± standard deviation (SD). A confidence level at $p < 0.05$ was considered as significant.

Results

Table 1 represented the mean, standard deviation and level of significance of various anthropometric and physiological profiles of both male and female swimmers. Male swimmers were found to be significantly ($p<0.01$) taller than their female counterparts although no such significant differences were obtained in age and body weight between both the groups. Fat mass and fat free mass were found to be significantly ($p<0.01$) higher and lower in females in comparison to the males respectively. Males are found to possess a significantly higher amount of muscle mass ($p<0.05$) and relative back strength (RBS) ($p<0.01$) than their female counterparts. Similar results were found in case of grip strengths of both hands. Both the hand grip strengths (HGS) were found to be higher in males in comparison to the females, however significant difference ($p<0.05$) was obtained in case of left hand grip strength only.
Table 2 represented the mean, standard deviation and level of significance of body fluids and other important body composition profiles of both male and female swimmers. Although the total body water, calcium, glycogen and mineral content were slightly higher in males in comparison to the females, still no significant differences were observed in them between both the groups. The total body potassium content ($p<0.05$) was found to be significantly higher in males than females.
Table 3 shows the correlation matrix of the parameters of the male swimmers (n=15).

Table 1. Comparison of various anthropometric and physiological profiles of elite Indian male and female swimmers

PARAMETERS	BOYS (n=15)	GIRLS (n=8)	SIGNIFICANCE
Age (yr)	15.28 ± 2.657	15.88 ± 2.181	0.29(NS)
Height (cm)	166.03 ± 4.791	160.36 ± 3.589	8.56**
Weight (kg)	55.45 ± 7.164	55.81 ± 5.780	0.01 (NS)
BMI (kg/m^2)	20.07 ± 1.957	21.67 ± 1.879	3.58 (NS)
Fat mass (%)	16.26 ± 4.836	24.43 ± 4.542	15.50**
Fat free mass (%)	83.72 ± 4.817	75.57 ± 4.569	15.45**
Body cell mass (kg)	25.22 ± 3.729	23.36 ± 2.094	1.68(NS)
Muscle mass (kg)	22.39 ± 4.060	18.31 ± 1.929	7.10*
Right Hand grip strength (kg)	33.40 ± 7.817	28.00 ± 3.817	3.33(NS)
Left Hand grip strength (kg)	34.13 ± 7.836	26.00 ± 2.976	7.85*
Rel. back strength (per kg body wt)	1.82 ± 0.334	1.25 ± 0.160	20.44**
Trunk flexibility (cm)	19.83 ± 3.194	17.37 ± 5.610	1.82(NS)

Values are (mean ± SD),= p<0.05, **=p<0.01 NS = Not significant*

Table 2. Comparison of body fluid levels of elite Indian male and female swimmers

PARAMETERS	**BOYS** (n=15)	**GIRLS** (n=8)	**SIGNIFICANCE** (F Value)
Total body water (l)	33.30 ± 4.745	31.18 ± 4.064	1.14(NS)
Extra cellular water (l)	36.45 ± 4.612	36.08 ± 8.238	0.01(NS)
Intra cellular water (l)	63.53 ± 4.599	63.83 ± 8.170	0.01(NS)
ECW/ICW	0.581 ± 0.116	0.588 ± 0.212	0.01(NS)
Total body potassium (mg)	119.65 ± 18.43	103.31 ± 9.484	5.43*
Total body calcium (mg)	845.26 ± 193.125	805.87 ± 91.007	0.29(NS)
Glycogen (mg)	422.33 ± 65.328	383.5 ± 50.341	2.13(NS)
Mineral (kg)	3.45 ± 0.640	3.20 ± 0.614	0.61(NS)

Values are (mean ± SD),= p<0.05, **= p<0.01, NS = Not significant*

Table 3. Pearson's Correlation matrix of the different anthropometric and physiological parameters of male swimmers

	Ht	.Wt	BMI	FFM	FM	TBW	ECW	ICW	ECW/ICW	BCM	MM	TBK	TBCa	Gly	Min	RHGS	LHGS	RBS
Age	.602*	.862**	.795**	.540*	-.534*	.923**	.661**	-.660**	.678**	.917**	.931**	.909**	.951**	.932**	.927**	.925**	.877**	.809**
Ht		.720**	.407	.299	-0.291	.719**	.342	-..341	.344	.746**	.719**	.738**	.721**	.712**	.690**	.416	.600*	0.397
Wt			.926**	.236	-.227	.951**	.398	-.397	.412	.981**	.953**	.976**	.912**	.926**	.841**	.841**	.928**	.689**
BMI				.131	-.123	.858**	0.324	-.324	.341	.884**	.858**	.882**	.800**	.825**	.719**	.867**	.881**	.676**
FFM					-1.000**	.519*	.944**	-.944**	.938**	.396	.496	.414	.480	.585*	.680**	.329	.311	.446
FM						-.511	-.941**	.942**	-.935**	-.388	-.488	-.405	-.474	-.577*	-.674**	-.325	-.306	-.445
TBW							.650**	-.649**	.661**	.985**	.990**	.987**	.945**	.995**	.944**	.839**	.906**	.741**
ECW								-1.000**	.999**	.525*	.618*	.544*	.568*	.700**	.761**	.465	.456	.507
ICW									-.999**	-.525*	-.618*	-.544*	-.568*	-.699**	-.760**	-.465	-.456	-.507
ECW/ICW										.538*	.631*	.557*	.584*	.709**	.767**	.484	.468	.512
BCM											.983**	.994**	.959**	.971**	.908**	.859**	.915**	.730**
MM												.993**	.954**	.987**	.928**	.865**	.929**	.722**
TBK													.949**	.973**	.897**	.858**	.925**	.707**
TBCa														.947**	.926**	.883**	.885**	.753**
Gly															.968**	.831**	.897**	.745**
Min																.780**	.828**	.767**
RHGS																	.919**	.776**
LHGS																		.750**

**Correlation is significant at the 0.05 level (2 tailed); **Correlation is significant at the 0.01 level (2 tailed)*

Age shows significant positive relationship with parameters like BMI, body weight, TBW, ECW/ICW, BCM,MM, TBK, TBCa, glycogen, mineral, HGS right, HGS left and RBS at p<0.01 and with height and FFM at p<0.05.There exists a significant negative relation between FM and ICW with age at p<0.05 and p<0.01 respectively. Height shows a positive and significant correlation with weight, BMI, TBW, BCM, MM, TBK, TBCa, glycogen and mineral at p<0.01 and with HGS left at p<0.05. Body Weight shows significant positive correlation with BMI, TBW, BCM, MM, TBK, TBCa ,Glycogen, Mineral, HGS Right, HGS Left and RBSat p<0.01. BMI is found to have highly significant (p<0.01) correlation with TBW, BCM, MM, TBK, TBCa, Glycogen, Mineral, HGS Right, HGS Left and RBS.FFM shows significant positive correlation at p<0.01 with ECW, ECW/ICW, Mineral and at p<0.05 with TBW and Glycogen. Highly significant (p<0.01) negative correlation is found between ICW and FFM. FM shows positive and significant correlation at p<0.01 with ICW only. It shows negative correlation with ECW,ECW/ICW and Mineral at p<0.01and with Glycogen at p<0.05.TBW shows significant positive correlation with ECW, ECW/ICW, BCM, MM, TBK, TBCa, Glycogen, Mineral, HGS Right, HGS Left and RBS at p<0.01 and negative correlation with ICW at p<0.01.ECW shows significant positive correlation at p<0.01 with ECW/ICW, Glycogen and Mineral and with BCM,MM, TBK and TBCa at p<0.05.Negative correlation is found between ECW and ICW at p<0.01.ICW shows significant negative correlation (p<0.01) with ECW/ICW, BCM, MM, TBK, TBCa, Glycogen and Mineral. ECW/ICW shows significant positive correlation at p<0.01with Glycogen and Mineral and with BCM, MM, TBK and TBCa at p<0.05.BCM is found to have positive correlation with MM, TBK, TBCa, Glycogen, Mineral, HGS Right, HGS Left, RBS at p<0.01.MM is found to have positive correlation with TBK, TBCa, Glycogen, Mineral, HGS Right, HGS Left, RBS at p<0.01.TBK shows positive correlation with TBCa, Glycogen, Mineral, HGS Right, HGS Left, RBS at p<0.01.TBCa shows positive correlation with Glycogen, Mineral, HGS Right, HGS Left, RBS at p<0.01.Glycogen shows positive correlation with Mineral, HGS Right, HGS Left and RBS at p<0.01.Mineral shows positive correlation with HGS Right, HGS Left and RBS at p<0.01.HGS Right shows positive correlation at p<0.01 with HGS Left and RBS.HGS right shows positive correlation at p<0.01 with RBS.

Table 4 shows the correlation matrix of the parameters in female swimmers (n=8).

Table 4. Pearson's Correlation matrix of the different anthropometric and physiological parameters of female swimmers

	Ht	Wt	BMI	FFM	FM	TBW	ECW	ICW	ECW/ICW	BCM	MM	TBK	TBCa	Gly	Min	RHGS	LHGS	RBS
Age	.59	.528	.357	.734*	-.734*	.679	.887**	-.891**	.883**	.341	.649	.342	.668	.759*	.664	.096	-.033	-.315
Ht		.637	.260	.191	-.191	.463	.605	-.600	.573	.357	.569	.37	.551	.577	.635	.412	.27	.100
Wt			.909**	.256	-.255	.859**	.443	-.426	.401	.927**	.965**	.933**	.937**	.889**	.694	.750*	.61	-.163
BMI				.258	-.258	.836**	.257	-.239	.222	.969**	.914**	.969**	.878**	.821*	.556	.725*	.646	-.239
FFM					-1.000**	.593	.843**	-.842**	.865**	.182	.466	.191	.406	.670	.583	-.065	.064	.061
FM						-.591	-.844**	.843**	-.866**	-.18	-.466	-.19	-.404	-.669	-.586	.063	-.067	-.062
TBW							.561	-.548	.548	.857**	.909**	.866**	.955**	.946**	.561	.389	.344	-.198
ECW								-1.000**	.998**	.194	.58	.205	.49	.736*	.822*	.158	.134	.056
ICW									-.998**	-.177	-.566	-.187	-.478	-.723*	-.812*	-.14	-.114	-.048
ECW/ICW										.160	.545	.171	.462	.714*	.788*	.104	.086	.056
BCM											.904**	.999**	.905**	.801*	0.472	.704	.603	-0.27
MM												.907**	.945**	.961**	.778*	.706	.607	-.204
TBK													.911**	.810*	.478	.694	.606	-0.23
TBCa														.920**	.584	.507	.409	-.268
Gly															.798*	.531	.487	-.104
Min																.664	.633	.104
RHGS																	.855**	-.091
LHGS																		.298

**Correlation is significant at the 0.05 level (2 tailed)*
***Correlation is significant at the 0.01 level (2 tailed)*

Age has got significant positive correlation with parameters like ECW, ECW/ICW at $p<0.01$ and with FFM and Glycogen at $p<0.05$.Age has a significant negative correlation with FM($p<0.05$) and ICW ($p<0.01$).Weight has significant positive correlation with BMI, TBW, BCM, MM, TBK, TBCa, Glycogen ($p<0.01$) and with HGS Right at $p<0.05$.BMI has positive correlation with TBW,ECW/ICW, BCM, MM, TBK, TBCa ($p<0.01$) and with Glycogen and HGS Right ($p<0.05$);negative correlation exists with ICW ($p<0.05$).FFM has got positive correlation with ECW,ECW/ICW and negative correlation with FM,ICW and HGS Right at $p< 0.01$.FM has got positive correlation with ICW and negative correlation with ECW and ECW/ICW at $p<0.01$.TBW is found to show positive correlation with BCM, MM, TBK, TBCa and Glycogen at $p<0.01$.ECW is found to show positive relation at $p<0.01$ with ECW/ICW and Mineral and shows negative correlation at $p<0.01$ with ICW only. ICW shows only significant negative correlation with ECW/ICW, Glycogen and Mineral at $p<0.01$.ECW/ICW shows positive correlation with Glycogen and Mineral at $p<0.01$.BCM shows positive significant correlation with parameters like MM, TBK, TBCa and Glycogen ($p<0.01$).MM shows positive correlation with TBK, TBCa, Glycogen and Mineral at $p<0.01$.TBK is found to have positive correlation with TBCa and Glycogen at $p<0.01$.TBCa has positive correlation with Glycogen at $p<0.01$. Glycogen has positive correlation with Mineral ($p<0.01$)and HGS Right has positive correlation with HGS Left at $p<0.01$.

Table 5 represented the comparison of anthropometric and physiological profiles of the male and female swimmers of the present study with their national and international counterparts. The mean age of the male swimmers of the present study was found to be less in comparison to their national counterparts of the previous study. Differences were also noticed in case of height. The male swimmers of previous study are found to be taller than their present study counterparts. There is no remarkable difference observed in the BMI in either of the genders or in comparison to the previous studies. The fat free mass and fat mass content (kg) were found to be lesser in both the males and females of present study in comparison to their male and female international counterparts respectively. The mean values of hand grip strengths of both male and female swimmers of the present study are found to be considerably lower than their male and female International counterparts respectively.

Table 5. Comparison of the physiological and anthropometric profile of the present and previous study

Parameters	**Boys**		**Reference**	**Girls**		**Reference**
	Present study	***National/International studies***		***Present study***	***National/International studies***	
Age	15.28 ± 2.657	20.10±1.0	Dey et.al, (14)	15.88 ± 2.181	15±1.0.0	Bond et al (15)
Height	166.03 ± 4.791	171.47±4.19	Dey et.al (14)	160.36 ± 3.589	161±0.0	Bond et al (15)
Weight	55.45 ± 7.164	58.9±0.0	Bond et al (15)	55.81 ± 5.780	51.2±0.0	Bond et al (15)
BMI	20.07 ± 1.957	20.64±2.52	Boostani et al (20)	21.67 ± 1.879	20.8±2.9	Kostoulas et al (21)
FFM(kg)	46.5 ±7.18	77.3±1.7	Lukaski et al. (2)	42.23±5.55	47.0±1.1	Lukaski et al. (2)
FM(kg)	8.94±2.77	11.1±0.7	Lukaski et al. (2)	13.57±2.66	15.5±1.1	Lukaski et al. (2)
HGS	33.765±7.826	41.62±4.95	Bansode et al (25)	27.0±3.396	28.91±3.15	Bansode et al (25)

Discussion and Conclusion

Anthropometric and physiological measurements may possibly be used to detect potentially successful athletes for a specific discipline. Grimston & Hey (13) developed a theoretical model to identify anthropometric variables relevant to identify anthropometric variables relevant to success in swimming. Previously, Matheson (4) studied the relationship between swimming and selected physiological and anthropometric development and skill variables in 10-20 years old female competitive swimmers. The mean age of the swimmers was found to be around (15.28±2.657 years) in males and (15.88 ± 2.181 years) females. The mean height of the male and female swimmers in the present study was found to be 166.03±4.791cms and 160.36±3.589cms respectively. In the previous studies conducted by Dey et al (14) the mean height of the male counterparts have been considerably higher, while the females had more or less similar mean height (15). Height is found to have strong positive correlations with parameters like body weight, fat mass, body water content, mineral content, relative back strength and hand grip strengths. Moura et. al (16) found that the propulsive force of the arm was correlated with body height ($r = 0.34$; $p = 0.013$). Although the maturation processes during pre-puberty and puberty are independent, indicators of sexual and somatic maturation are positively correlated, suggesting that an individual with advanced/delayed sexual maturation will have an advanced/delayed increase in body height (17). The mean weights of the male and female subjects of the present study are 55.45 ± 7.164 kgs and 55.81 ± 5.780 kgs respectively. In a previous study conducted by Bond et al (15), the mean weight of the male swimmers were slightly higher whereas, on the other hand, females were found to have lesser body weight than their present study counterparts. The height for age and weight for age depends upon a number of factors for example genetic, nutritional and environmental factors. However, the majority of authors report that swimming training does not disturb the puberty period (18) and does not inhibit physical development (19), including height increase, which, to a large degree, is dependent on the genetic traits inherited from their parents. These factors have a combined impact of growth and development pattern of an individual. Though the training regimen is generally considered to be same for everyone, differences occur due to these above mentioned factors.

The results obtained from the present study has shown that some of the anthropometric and physiological parameters of the swimmers is found to vary significantly in terms of mean and SD between the groups. For e.g. fat mass is found to be higher in females than males in the present study. The previous studies conducted by Lukaski et al (2) also showed that the mean fat were higher in females than males. The mean BMI of the male and female swimmers in the present study was found to be around 20 which are corroborated with the findings of Boostani et al (20) and Kostoulas et al (21). Compared to other sports the BMI of the swimmers were found to be slightly higher. When a sport is performed in the water, however, fat provides more buoyancy than muscle mass. This allows swimmers who have a higher percentage of fat to float more readily in the water. Instead of using energy to stay horizontal, the athlete can focus on strokes and kicks to pull forward. Most female athletes carry between 8 and 15 percent fat, but swimmers usually have a bit more between 14 and 24 percent. Generally, fat content rises in females than males after the puberty. The larger proportion of fat mass in the female swimmers might allow for more buoyancy, which could be an advantage that allows females to kick at a higher rate and with a better buoyancy profile than male swimmers. While any body fat percentage below 30 is perfectly healthy for a woman, it's expected that competitive athletes be among the leanest and sleekest people around. Swimming has different demands than land-based sports, though. Female swimmers who have a little extra padding are actually at an advantage in competition (http://www.livestrong.com). Although the mean fat mass (kg) in both male and female swimmers of the present study were less than their male and female international counterparts respectively but the mean fat free mass (kg) was found to be higher in International subjects than their respective counterparts of the present study.

The muscle mass is higher in males than females in the present study. Studies (22) had proven that a large cross sectional area of the muscle was presented with increased muscle strength generating characteristics. And, due to skeletal and hormonal maturity during childhood and adolescence, increase in the muscle performance resulted due to muscle related changes in the muscle enzyme activity. According to the same study, pubertal development led to greater muscle mass and force production due to increased height and bone length. Bencke et al (23) stated that increases in power output have been correlated with increases in swimming speed in young swimmers. So it can be stated that greater emphasis should be placed on power training as part of the overall training program for competitive swimming. The observed gender differences in strength might be a result of the greater muscle mass in males than in females. Swimmers with a lot of muscle mass may have more strength, but it's wasted on the mechanics of staying high in the water. Multi-sport athletes, particularly triathletes, tend to err on the side of being lean because the majority of their competition is spent cycling and running - sports that benefit from a lower body fat level.

In previous studies performed by M. L. Zampagni et. al (24), it has been found that a relevant influence of hand grip strength on performance time exists, which was stronger in short races. Increasing age confirmed a disadvantageous factor on performance time, which was more evident in long than in short distances. In our present study, however, we found that both the hand grip strengths were found to be higher in males in comparison to the females which are corroborated with the findings of Bansode et al (25). Moreover, handgrip strength should also be employed for identifying potentially talented athletes. Mastudo et al (26) mentioned that it was demonstrated that handgrip strength was significantly correlated with swimming performance (R=.78) in national-level Portuguese swimmers in the four competitive swimming strokes. It is also found that hand grip strengths are highly and positively correlated with age, height, BMI, fat free mass, total body water, body cell mass, muscle mass, total body calcium, glycogen, mineral content and relative back strengths. These correlation values of hand grip strengths with the above parameters in the present study were found to be relatively higher in males than females. So, possibly this may be the reason of higher hand grip strengths in males.

In a similar way, relative back strength was also found to be higher in males than female swimmers. Back strength plays a vital role in the daily activities of man. It is an essential factor for including in almost all games and sports. Clarke (27) and Oppliger (28) stated that endurance is basic in measuring organic capacity believing that if one is able to run or swim more than the normal distance without undue fatigue he is in good physical conditions. Trunk flexibility was found to be absolutely insignificant with all the anthropometric and physiological parameters. Oppliger (28) stated that swimmers had greater shoulder abduction flexibility than non-swimmers, with female exhibiting greater ankle and trunk flexibility than males. Older and more proficient swimmers were stronger, with male swimmers superior to females in all strength measures except dominant grip. Age-group swimmers possess superior strength, body composition, and flexibility characteristics when compared to non-swimmers.

Hydration is one of the most important nutritional concerns for an athlete. Approximately 60 percent of body weight is water. Research has shown that losing as little as 2% of total body weight can negatively affect athletic performance. For example, if a 150-pound athlete loses 3 pounds during a workout or competition, their ability to perform at peak performance due to dehydration is reduced. Proper fluid replenishment is the key for preventing dehydration and reducing the risk of heat injury in athletes engaged in training and competition. In a study conducted by Matias et al (29), the ICW compartment is determined as the difference between the TBW and ECW compartments. It has been recently shown that reductions in the ICW compartment decrease strength and power in elite judo athletes and leg strength and jumping height over a season in basketball, handball and volleyball players. These findings further support the important role of an effective monitoring of the water distribution volumes (TBW, ECW, and ICW) in physical performance. However, our present study did not corroborate with the findings of the earlier study. The ECW were less in females than in males. Thus, it means the females are better adapted to the training regimen than the male swimmers. The TBW in males and females were found to have significant negative correlation with ICW and significant positive correlation with other parameters. ECW has significant negative correlation with ICW in both males and females. The ratio of ECW and ICW was found to be positively correlated with muscle mass, mineral, potassium, glycogen and mineral content of the body in the present study. The TBW was found to have highly significant positive correlations with parameters like body minerals, muscle mass, fat mass, body muscle strengths except intracellular water. ICW on the other hand was found to have negative correlation with all the parameters in both males and females. Similarly, in a previous study, performed by Tuuri et. al.,(30) a group of adult male competitive swimmers changes in body water and the relative proportion of ICW and ECW fractions appear to be important markers of aging. The results of this investigation suggest that in adult male competitive swimmers change in body water fractions are the most obvious marker of growing older. With increasing age, the volume of ICW appears to decline and the ICW-to-TBW ratio becomes smaller. Another study (31) confirmed that the ratio of TBW over weight decreased with increasing BMI and was lower in women than in men. The ratio of ICW over fat free mass was normally distributed, and decreased with BMI, more so in women than in men.

Proper hydration and electrolyte balance is important for cellular metabolism, blood flow and therefore physical and athletic performance. The maintenance of precise osmotic gradients of electrolytes is important. Such gradients affect and regulate the hydration of the body as well as blood pH, and are critical for nerve and muscle function. Electrolytes are molecules capable of conducting electrical impulses and include sodium**,** potassium**,** calcium**,** magnesium and chloride (32). Without sufficient levels of these key electrolytes, muscle weakness or severe muscle contractions may occur. The potassium content was found to be significantly higher in males than females in our study and also potassium content has got significant positive correlation with the total body calcium and glycogen in females and along with that mineral, hand grip strengths and relative back strengths in males of the present study. In a study conducted by Henkin, Sehl and Meyer (33), the sweat rate and electrolyte concentration in swimmers, runners and non-athletes were compared. [K+] was similar among group. Potassium is an important electrolyte in the body which helps to reduce muscle cramps in the swimmers.

Maintaining good hydration is particularly important to competitive and distance swimmers as the continuity of good hydration is important to kidney health. The body calcium content in males was significantly and positively correlated to the mineral, back strength and hand grip strengths in male subjects of present study whereas it was found to have significant positive correlation with only glycogen in females. The male swimmers in the present study insignificantly have a higher amount of calcium, glycogen and mineral content compared to the females. Mineral content in males have significant positive correlation with hand grip strengths and back strengths but it was absolutely insignificantly correlated with the said parameters in females. Apart from genetic factors, the proper increase of bone mass in the period of intensive development is affected by environmental factors linked with lifestyle, the most significant of which include physical activity (34) and eating habits, appropriate intakes of calcium and phosphorus with diet in particular .A study conducted by Derman and Cinemre (35) showed that a highly active nonimpact sport such as swimming may lead to increased bone mineral content only for male swimmers. However, dietary behaviours may be more important than swimming on bone metabolism among adolescents. Physical activity has been shown to have a positive effect on bone metabolism among adolescents. Swimming, as a non-weight-bearing sport, has been considered to be insignificant in the maintenance of bone mass. Due to availability of less number of literatures, investigators could not compare the above mentioned parameters with their national & international counterparts.

The study shows that there exists a significant correlation among the anthropometric and physiological parameters in both the genders. Body fat content is found more in females than males. Fat mass has got significant negative correlation with many parameters. This suggests that increase of fat mass decreases many parameter values like body fluids, muscle strengths, glycogen and mineral content of the body. Males on the other hand, contain a greater amount of muscle mass. The muscular strengths are also found to be greater in males than females. Thus, muscle mass has got significant positive correlation with the parameters like body calcium, glycogen, mineral content and muscle strengths. Intra cellular water is found to have negative correlation with almost all the parameters. Trunk flexibility was found to be absolutely insignificant with all the anthropometric and physiological parameters. So it has got no effect on swimming performance in either of the gender. The BMI also had no differences with respect to gender. This kind of research helps athletes to precise information and feedback about their physical condition and effect of performance in order to adjust or continue their level of training.

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