**Medicina Sportiva (2015), vol. XI, no 2, 2533-2540**
Journal of the Romanian Sports Medicine Society



# Assessment of body cell mass in Indian junior elite players (male) of different sports using bioelectrical impedance analysis method

Swapan Kr Dey, Abhishek Bandyopadhyay, Sujata Jana, Subhra Chatterjee (Nee Karmakar)
*Sports Authority of India, Netaji Subhas Eastern Centre, Salt Lake City, Kolkata, India*

**Abstract**. The aim of this study was to assess and evaluate Body Cell Mass (BCM) of Indian junior male players of different sports discipline using Bio-electrical Impedance Analysis (BIA). *Material and Method*. 79 male subjects (age range =14-20 years) were participated in the present study from various sports discipline, football (N=15), gymnastics (N=15), hockey (N=16), table tennis (N=15) and age-matched sedentary control group (N=18). Whole body bioelectrical impedance analysis was performed using a multi-frequency analyzer (Maltron Bioscan 920-2, Maltron International, Rayleigh, Essex, UK). Physical characteristics, fat and fat free mass, protein, muscle and glycogen mass along with body cell mass (BCM) were evaluated. *Results.* Significant ($p<0.01$) differences were observed in height, weight and BMI except mean age of the subjects of different sports discipline and control group when compared among the groups. Body composition parameters except adiposity were found to be higher in hockey players as compared to their other counterparts. On the other hand, gymnasts were found to be smaller in size & have lower values in all the selected parameters. Significant differences ($p<0.05$ and $p<0.01$) were also observed in all the parameters when gymnasts were compared with the table tennis players. BCM in respect to body weight (relative BCM %) was found to be lower in table tennis players and higher in case of hockey players respectively. BCM was found to be highly correlated ($P<0.01$) with fat free mass and body weight in all the groups. *Conclusion.* BCM is related to the ability to extract and utilise oxygen by the working muscles and also to the improvement of muscular efficiency during activity. The present findings will be useful for the trainer to formulate the systematic and scientific training program to enhance sport performance as well as for future comparison.
**Key words**: *body cell mass, bioelectrical impedance analysis, football, hockey, gymnastics, table tennis*.

## Introduction

Body composition has a significant effect on athletic performance as exercise has the potential to alter body composition (1). For the assessment of body composition, recently a new approach has been regarded most meaningful is to measure the body cell mass (BCM) apart from simply assessing fat free mass and fat mass (2). BCM is defined as the total mass of "oxygen-consuming, carbon-dioxide producing, potassium-enriched, glucose oxidizing and metabolically active, work performing" cells of the body. BCM comprises protein-rich intracellular tissues responsible for nearly all of the metabolic process in the body and also for strength (3). In a normal healthy individual, muscle tissue consists approximately 60% of the body cell mass. The volume and function of the muscle portions of BCM further can be enhanced by physical activity and systematic exercise. Therefore, the evaluation of body cell mass in athletes is a stronger predictor of athletic performance and strength (2).

The "gold standard" method for the assessment of the BCM is by the means of naturally occurring isotope $^{40}K$ and NaBr dilution. Precise estimates of BCM can also be obtained by the measurement of the difference between extracellular water (ECW) and total body water (TBW) using multiple isotopes or the total-body potassium ($^{42}K$) approach. However, all these methods are found to be expensive, time consuming and not generally applicable in the field studies. Bioelectrical Impedance Analysis (BIA), in contrast, is relatively simple, quick (takes only a few minutes), and non-invasive technique by which BCM can be simply measured after injecting a standard current at a known frequency. BIA uses prediction equations usually include the impedance index ($height^2$/resistance) which is dependent on the capacitance effect of cell membranes and tissue interfaces (4). Football, hockey, table tennis and gymnastics are of four different sports among which football and hockey

although have its own distinctive skills, tactics and movement patterns, but they have almost similar physiological demands such as high aerobic power, high lactate tolerance and increased anaerobic capacity (5). On the other hand, gymnastics is a type of strength-power sport, demanding high levels of both flexibility and anaerobic capacities for successful performance (6). While Mitchell et al (7) classified sports activities based on the static component, dynamic component and energy system involved, where table tennis falls into the low-moderate group of sports, together with baseball, softball, volleyball and tennis (doubles) etc. Therefore, the amount of aerobic and anaerobic components varies among these sports. Thus, evaluating and comparing the body cell mass of these different athletes would provide new insight into the field of body composition.

As per literature, very scanty research has been conducted in professional athletes worldwide. However, in recent years few studies (2, 8-9) have been conducted to verify the impact of different sports in body cell mass (BCM). In spite of the availability of the literature related to the assessment of the impact of different sports in body cell mass (BCM), standard data on such parameters are scanty in Indian context. To fulfill the lacunae of literature, the present study was undertaken i) to assess and evaluate BCM and related parameters of Indian junior elite male players and ii) to compare BCM and related parameters among the players of different sports disciplines.

## Material and method

The present study was carried out on 61 male junior elite athletes of football (N=15; mean age= 15.2±0.86 years), gymnastics (N=15; mean age= 15.3±2.92 years), hockey (N=16; mean age= 15.4±0.78 years) and table tennis (N=15; mean age= 15.6±2.27 years). An adequate number of age- matched male control group (N=18; mean age= 15.4±0.55 years) with no particular athletic background from the same place was also included in the study. All the players were belonging to various schemes of Sports Authority of India (SAI), eastern region. The players of the present study were at least of state level performer with minimum of 3-4 yrs formal training history. All the subjects including the control group 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 (10). 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.

*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 was almost common to all the four games of the present study except the skill training and was used to apply on an average 4 to 5 hours every day except Sunday and which comes about 30 hours in a week. 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 and cool down sessions after and 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.

On the other hand, control group's activity levels were not closely monitored. However, these subjects did not exercise more than three times per week, for a total of approximately 3 hours in a week. Physical activities consisted of running, jogging, recreational games, etc.

*Measurement procedure*. The physical characteristics of the subjects including height (cm) and weight (kg) were measured by anthropometric rod and digital weighing machine respectively followed by standard procedure (11). 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.

*Bioelectrical Impedance Analysis (BIA).*Body composition including body cell mass (BCM), body mass index (BMI), fat free mass (FFM), fat mass, total fat percent, total muscle mass (TMM), protein mass, glycogen mass and relative BCM were measured using Bioelectrical Impedance Analysis (BIA) with a multi-frequency analyzer (Maltron Bioscan 920-2, Made in UK). Total body electrical impedance to an alternate current (0.8 mA) with four different frequencies (5, 50, 100 and 200 KHz) was measured. Measurements were taken followed by the standard testing manual of Maltron International (12). 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 Heyward & Stolarczyk (13) by 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. FFM and BCM were calculated using the formula developed by Bhat et al (14), De Lorenzo et al (4) respectively. 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*. Differences among groups for all variables according to their specific sport disciplines were calculated using a 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 and control group. The data were analyzed 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 (SD). A confidence level at 5% ($p<0.05$) was considered as significant. Correlation coefficient between BCM and other parameters were also represented graphically to make comparison among male athletes of different sport disciplines and male control group.

## Results

Table I represents the physical characteristics of the subjects according to their specific groups. Table tennis players were found to be bigger in size whereas gymnasts exhibit smaller in size as compared to all the sport disciplines and control group. On the other hand height was dominated by the hockey players (167.6 cm, ±4.43) and found to be tallest in respect to their other counterparts. Significant difference ($p<0.01$) in height, weight and BMI was observed when compared among the groups. No such significant difference was observed in age.

**Table** I. Mean, standard deviation and level of significance of General Physical Characteristics of all subjects

| Variables | Football (N=15) | Gymnastics (N=15) | Hockey (N=16) | Table Tennis (N=15) | Control (N=18) | Level of Significance |
|---|---|---|---|---|---|---|
| Decimal Age (yrs) | 15.2 ±0.86 | 15.3 ±2.92 | 15.4 ±0.78 | 15.6 ±2.27 | 15.4 ±0.55 | NS |
| Height(cm) | 164.3 ±3.76 | 153.3 ±9.97 | 167.6 ±4.43 | 165.5 ±5.68 | 163.4 ±2.73 | ** |
| Weight(kg) | 51.4 ±2.80 | 43.0 ±10.01 | 56.1 ±4.58 | 59.1 ±10.47 | 51.6 ±6.23 | ** |
| BMI ($kg.m^{-2}$) | 19.1 ±1.24 | 18.0 ±2.25 | 20.3 ±1.66 | 21.4 ±3.03 | 19.3 ±2.51 | ** |

*Values are (mean ± sd); **P< 0.01,* P< 0.05, NS= Not Significant.*

Table II represents all the body composition parameters of the subjects according to the specific groups. Again table tennis players' exhibited high adiposity as compared to rest of the groups whereas gymnasts possess comparatively lowest body fat. The table further reveals that hockey players found to have higher values in the body composition parameters (fat free mass, body cell mass, glycogen mass) comparatively to all the sport disciplines and control group. Gymnasts followed by the control group showed lowest values in case of all theses parameters. BCM in respect to body weight (Relative BCM%) was found to be lower in table tennis players and higher in case of hockey players respectively. A statistically significant difference ($p<0.01$) was observed in case of all the parameters when compared among the groups. Scheffe's F test for multiple comparisons of the selected parameters among the groups was represented by Table III.

**Table** II. Mean, standard deviation and level of significance of Body composition of all subjects

| Variables | Football (N=15) | Gymnastics (N=15) | Hockey (N=16) | Table Tennis (N=15) | Control (N=18) | Level of Significance |
|---|---|---|---|---|---|---|
| Fat Mass (kg) | 8.6 ±2.41 | 4.8 ±1.21 | 7.3 ±2.25 | 11.1 ±6.99 | 9.2 ±3.81 | ** |
| Body Fat (%) | 16.8 ±4.56 | 11.6 ±3.06 | 12.8 ±4.01 | 18.1 ±8.61 | 17.6 ±6.13 | ** |
| Fat Free Mass (kg) | 42.7 ±3.24 | 38.1 ±9.51 | 49.9 ±4.65 | 48.0 ±7.39 | 42.4 ±5.23 | ** |
| Body Cell Mass (kg) | 23.8 ±1.44 | 20.4 ±5.17 | 27.0 ±2.02 | 26.4 ±3.94 | 23.5 ±2.49 | ** |
| Protein Mass (kg) | 8.8 ±0.79 | 7.7 ±1.98 | 10.6 ±1.14 | 9.8 ±2.31 | 8.7 ±1.52 | ** |
| Muscle Mass (kg) | 21.1 ±1.37 | 18.2 ±4.87 | 24.2 ±2.04 | 23.5 ±3.77 | 20.8 ±2.40 | ** |
| Glycogen Mass (gm) | 388.0 ±29.52 | 346.3 ±86.42 | 452.8 ±42.16 | 436.1 ±67.12 | 384.7 ±47.55 | ** |
| Relative BCM (%) | 46.4 ±1.19 | 47.3 ±1.71 | 48.1 ±1.91 | 44.9 ±2.48 | 45.8 ±1.70 | ** |

*Values are (mean ± sd); **P< 0.01,* P< 0.05, NS= Not Significant.*

**Table** III. Scheffe's F test for multiple comparisons of physical characteristics and body composition

| Variables | FB vs GYM | FB vs HK | FB vs TT | FB vs CTRL | GYM vs HK | GYM vs TT | GYM vs CTRL | HK vs TT | HK vs CTRL | TT vs CTRL |
|---|---|---|---|---|---|---|---|---|---|---|
| Height (cm) | ** | NS | NS | NS | ** | ** | ** | NS | NS | NS |
| Weight (Kg) | NS | NS | NS | NS | ** | ** | ** | NS | NS | NS |
| Body Mass Index ($kg.m^{-2}$) | NS | NS | NS | NS | NS | ** | NS | NS | NS | NS |
| Fat Mass (Kg) | NS | NS | NS | NS | NS | ** | * | NS | NS | NS |
| Body Fat (%) | NS | NS | NS | NS | NS | * | NS | NS | NS | NS |
| Fat Free Mass (kg) | NS | NS | NS | NS | ** | ** | NS | NS | * | NS |
| Body Cell Mass (kg) | NS | NS | NS | NS | ** | ** | NS | NS | NS | NS |
| Protein Mass (kg) | NS | NS | NS | NS | ** | * | NS | NS | * | NS |
| Muscle Mass (kg) | NS | NS | NS | NS | ** | ** | NS | NS | * | NS |
| Glycogen Mass (gm) | NS | NS | NS | NS | ** | ** | NS | NS | * | NS |
| Relative BCM (%) | NS | NS | NS | NS | NS | * | NS | ** | * | NS |

*vs=versus; Values are (mean ± sd); **P< 0.01,* P< 0.05, NS= Not Significant. FB= Football; GYM= Gymnastics; HK= Hockey; TT= Table Tennis; CTRL=Control*

Significant differences ($p<0.05$ and $<0.01$) in case of all the parameters were observed when gymnasts were compared with the table tennis players. Similarly, significant difference ($p<0.01$) in case of gymnasts vs hockey players were also observed in all the parameters except BMI, fat mass, fat percentage & relative BCM. Only height was found to be differed significantly ($P<0.01$) when football players were compared with their gymnastics counterparts. None of the parameter showed any significant difference when football players were compared to any of the groups. On the other hand, only height, weight & fat mass in control vs gymnasts and fat free mass, protein mass, glycogen mass & relative BCM in case of control vs hockey was significantly differed ($p<0.05$ and $p<0.01$). No such parameters showed any significant difference in both control vs gymnasts & hockey players respectively. Also, none of the parameters differed significantly when table tennis players were compared to hockey & control group.

Figure 1 and 2 represents the relationship between body cell mass with body weight and fat free mass respectively. The figures revealed that body cell mass was found to be significantly ($P<0.01$) correlated with the above parameters in case of all the four different sports and also their control counterparts.

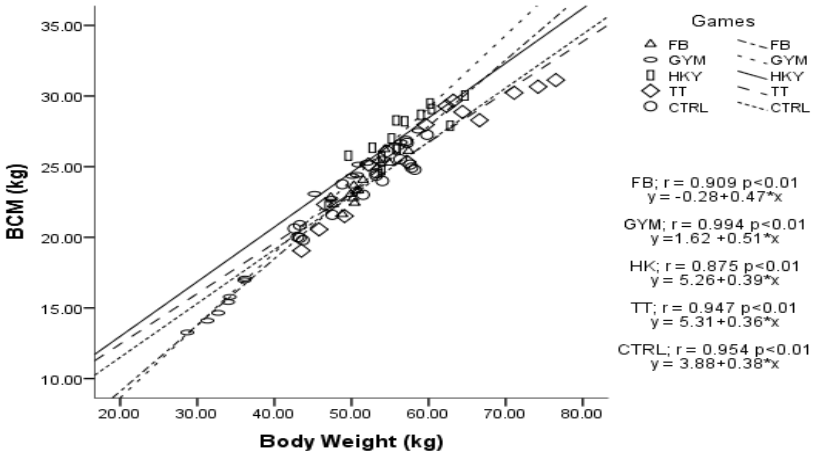


**Figure**1. Relationship between Body Weight and Body Cell Mass

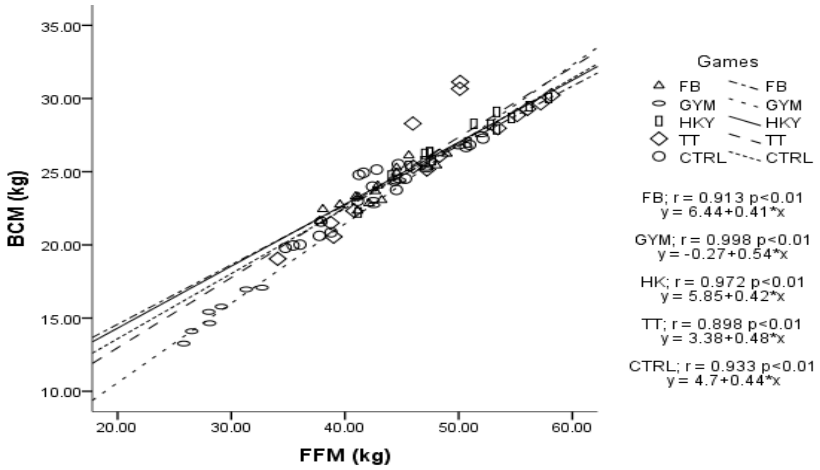


**Figure** 2. Relationship between Fat Free Mass and Body Cell Mass

## Discussion

The optimal body composition varies among different sport events. Changes in body composition have been used as information regarding the athlete's adaptation to different types of training (2). It was previously reported that, in precision sports, such as golf, bowling and shooting, the results are less dependent upon body composition as in sports as athletics, soccer, gymnastics, figure skating etc. (15).

Players of different sports involved in different types of body size, shape & activity. Distinctive anthropometric characteristics come about by natural selection of successful athletes and by an adaptation to the training demands within the present generation. The "final" body shape and composition in a given sport results from a phenomenon called "sport morphological optimization" (16). It is well established that suitable physique has an importance to achieve success in particular sports. The measurement of height and weight has some importance in selecting sports talents (17). In the present study, gymnasts were found to be the smallest in size and lightest in body weight among the players of other sports and the control group. In some activities, especially aesthetic sports like gymnastics and those in which high power to body mass is important, an increase in body weight can negatively influence performance (18). Gymnasts represent lower growth velocity and a marked stunting of leg-length growth failing to reach the full familial height (19). This is probably due to an early occlusion of the cartilage growth as a consequence of the mechanical effect of the ground impact (20). Smallness is actually beneficial regarding their performance i.e., rotational movement, arm hang and support elements etc. (21). On the other hand, height provides distinct advantages for specific playing positions in hockey (22) and football (23). In the present study, hockey players were found to be the tallest among the players of different sports as well as the control groups. Tall players have an advantage in certain playing positions such as in goalkeeping, central defence and central attack in both hockey and football. On the other hand, though height was found to be more in table tennis players of the present study as compare to gymnastic, football and control groups but it is not the prime pre- requisite for table tennis players. A professional table tennis player requires high level physical capacity, technical skills and tactical competence (24).

The percentage of body fat plays an important role for the assessment of physical fitness of the players (25). Increase in body fat can reduce the aerobic and anaerobic fitness (26). Present study showed a decrease in body fat percent in the young players of football, hockey and gymnastics as compare to the table tennis and control group. Aerobic training increases the fat utilization during exercise, which may be the cause of the reduced fat level after training. On the other hand, table tennis has been classified as low-moderate group of sports on the basis of the static component, dynamic component and energy system involved (7). As a result, the fat mass and body fat percentage, table tennis players showed a higher value among the groups including the control group.

Physiological modeling of body composition at the cellular level can be separated into different compartments associated with functions: energy store in fat mass (FM), energy expenditure and metabolism by body cell mass (BCM). 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 (27). The normal range of BCM is set at 40% of the ideal healthy body weight (28). BCM is a strong predictor of athletic performance as well as muscular efficiency. High level of FFM and BCM are related to increases in muscular efficiency, and the lower BCM signifies decreases in muscular efficiency (2). Since the present study includes players of varying heights and weights belonging to different sports we can hypothesize that weight adjusted measurement of BCM (Relative BCM) could be a single best predictor of athletic performance rather than simply assessing BCM. A highly significant correlation ($p<0.01$) between BCM and body weight was also found in the present study (fig. 1).

High level of relative BCM in gymnastics which is a non endurance sports signifies the type of strength-power sport demanding high levels of both anaerobic, explosiveness and flexibility for successful performance and where leanness is associated (29). In a study of Andreoli et al. (2), endurance sports where aerobic demand is high, and showed a greater BCM content. Again, according to MacDougall and Sale (30), high intensity intermittent training results in improvements of the ability to extract and utilize oxygen by the working muscles.

Therefore, a high BCM content in respect to body weight i.e., relative BCM (%) of hockey players in the present study predicts that they have undergone through high intensity aerobic training as compared to the other two endurance sports viz., football & table tennis. Field hockey and soccer have both been described as multiple sprint sports consisting of high-intensity sprints that require short bursts of near maximal effort. The motion activities for elite hockey and soccer players are considered to be similar (31). Similar physical characteristics were also observed in the present study which has been previously reported by Reilly & Borrie (32). BCM is the metabolically active compartment of FFM and a high BCM content may be found in case of leanness and less adiposity population. A highly significant correlation between FFM and BCM also has been found in the present study (fig. 2). Since, table tennis does not involve a great deal of aerobic activity shows a higher adiposity and thus leading to a low relative BCM.

The activity pattern of control group is mainly comprised of various recreational games and the frequency is much lower than that of other four sport disciplines of the present study. However, an unexpected result was found in the present study that a lower adiposity as well as higher relative BCM exists in the sedentary boys as compared to the table tennis players. This may be due to the training pattern/schedule of table tennis players which does not alter their body composition much. It has been evidenced that most coaches believe that table tennis training is highly specific (33) which based on technique only. For example, when doing multi-ball practice one might overlook the importance of cardio respiratory endurance as an important element of a complete training program. There is some fear in coaches' minds that additional strength might impair basic motor movement and fine coordination, i.e. the sense for a good stroke.

## Conclusion

From the above discussions it may be concluded that weight adjusted BCM is a strong predictor of athletic performance. BCM is related to the ability to extract and utilize oxygen by the working muscles and also to the improvement of muscular efficiency. The results of the present study may be useful for the trainer to formulate the systematic and scientific training program to enhance sport performance as well as for future comparison.

*Acknowledgement*. Sports Authority of India, Eastern centre is greatly acknowledged to provide all the facilities to complete the present study.

**References**

1. Segal KR (1996). Use of bioelectrical impedance analysis measurements as an evaluation for participating in sports. *Am. J. Clin. Nutr*. 57(suppl), 469S-471S.
2. Andreoli A, Melchiorri G, Brozzi M, Di Marco A, Volpe SL, Garofano P, Di Daniele N, De Lorenzo A (2003). Effect of different sports on body cell mass in highly trained athletes. *Acta. Diabetol*. 40, S122–S125.
3. Moore FD, Olesen KH, McMurray JD, Parker HV, Ball MR, Boyden CM (1963). *The body cell mass and its supporting environmen*t. WB Saunders, Philadelphia.
4. De Lorenzo A, Andreoli A, Matthie J, Withers P (1997). Predicting body cell mass with bioimpedance by using theoretical methods: a technological review. *J Appl Physiol*. 82, 1542–1558.
5. Bangsbo J (2000). Physiology of intermittent exercise. In: *Exercise and Sport Science*. WE Garrett and DT Kirkendall (eds). Philadelphia, Lippincott, Williams and Wilkins, pp. 53–65.
6. Arazi H, Faraji H, Mehrtash M (2013). Anthropometric and physiological profile of Iranian junior elite gymnasts. *Physic Educ Sports*. 11(1), 35 – 41.
7. Mittchel, JH, Haskell, WL, Raven, PB (1994).Classification of sports. *Med Sci Sports Exerc*. 26(10-supplement), 242-245.
8. Melchiorri G, Monteleone G, Andreoli A, Callà C, Sgroi M, De Lorenzo A (2007).Body cell mass measured by bioelectrical impedance spectroscopy in professional football (soccer) players. *J Sports Med Phys Fitness*. 47(4), 408-412.
9. Clarion A, Ribbe E, Rebeyrol J, Rousseaux-Blanchi M, Dechavanne C, Moreno M (2013). Bio-impedance body composition comparisons between athletes and healthy subjects. *J Phy*: Conference Series 4/2013 434(1): 253-256.
10. SAI (1992). Sports Authority of India National Sports Talent Contest Scheme, *Spotting and Nurturing of Sport Talent*. Appendix D, 110-116.
11. Weiner JS, Lourie JA (1969). *Practical Human Biology*. Academic press, London.
12. Maltron International (1999). *Maltron Bioscan 920-2 operating and service manual*, pp 8-30.
13. Heyward, VH, Stolarczyk LM (1996). *Applied body composition assessment* Champaign. Human Kinetics.
14. Bhat DS, Yajnik CS, Sayyad MG, Raut KN, Lubree HG, Rege SS, Chougule SD, Shetty PS, Yudkin JS, Kurpad AV (2005). Body fat measurement in Indian men: comparison of three methods based on a two-compartment model. *Int J Obes Relat Metab Disord*. 29, 842–848.

15. Maughan, RJ, Burke, LM (2002). *Sports Nutrition.* Handbook of Sports Medicine and Science, Malden, Mass: Blackwell Publishing.
16. Norton K, Olds T (2001). Morphological evolution of athletes over the 20th century: causes and consequences. *Sports Med*. 31: 763-783.
17. Beunen G, Malina BM (1988). Growth and physical performance relative to the timing of the adolescent spurt. *Exerc Sports Sci Rev*. 16: 503-546.
18. Wilmore, JH (1992). Body weight standards and athletic performance. In: *Eating, body weight and performance in athletes: disorders of modern society*. Brownell KD, Rodin J, Wilmore JH (eds). Philadelphia, Lea and Febiger, 315–329.
19. Malina RM, Bouchard C, Shoup F, Demirjian A, Lariviere, G (1976). Age at menarche, family size and birth order in athletes at the Montreal Olympic Games. *Med Sci Sports Exer***.** 11, 354-358.
20. Rêgo C, Guerra A, Fontoura M, Silva D, Lourenço S, Brás L, et al. (1997). Growth, pubertal development and gonadal function of adolescent female rhytmic gymnasts. *Horm Res*. 48 Suppl 2, 135.
21. Bale P, Goodway J (1990). Performance variables associated with the competitive gymnast. *Sports Med*, 10(3), 139-145.
22. Reilly T, Bangsbo J, Ranks A (2000). Anthropometric and physiological predisposition for elite soccer. *J Sports Sci*. 18, 669-683.
23. Manna I, Khanna GL, Dhara PC (2006). Effect of Training on Morphological, Physiological and Biochemical Variables of Young Indian Soccer Players. *J Exerc Sci Phys*. 2, 42-51.
24. Kondrič M, Furjan-Mandić G, Kondrič L, Gabaglio A (2010). Physiological demands and testing in table tennis. *Int J Table Tennis Sci*. 6, 165-170.
25. Sergej MO (2003). Seasonal alterations in body composition and sprint performance of elite soccer players. *J Exerc Physiol*. 6, 24-27.
26. Powers SK, Howley ET (1997). *Exercise Physiology*. Brown & Benchmark Publishers, Madison.
27. Ellis KJ (2000). Human body composition: in vivo methods. *Physiol Rev*. 80, 649 –668.
28. Williams SB, Bartsch G, Muurahainen N, Collins G, Raghavan, SS, Wheeler, D (2003). Protein intake is positively associated with body cell mass in weight-stable HIV-infected men. *J Nutr*. 133(4),1143–1146.
29. Sinning WE (1978). Anthropometric estimation of body density, fat and lean body weight in women gymnasts. *Med Sci Sports*. 10(4), 243–249.
30. MacDougall D, Sale D (1981). Continuous vs interval training: A review for the athlete and coach. *Can.J.Sports Sci*. 6, 93-97.
31. Spencer M, Lawrence S, Rechichi C, Bishop D, Dawson, B, Goodman, C (2004). Time-motion analysis of elite field hockey, with special reference to repeated-sprint activity. *J Sports Sci*. 22, 843-50.
32. Reilly T, Borrie A (1992). Physiology applied to field hockey. *Sports Med*. 14, 10-26.
33. Junhua Z, Qingtang L, Zongkai Y (2012). Development of a Moodle course for schoolchildren's table tennis learning based on Competence Motivation Theory: Its effectiveness in comparison to traditional training method. *Comput Educ*. 59(2), 294-303.

***Corresponding author***
Swapan Kr Dey
Sports Authority of India
Netaji Subhas Eastern Center, Kolkata, India
E-mail: *drsk_dey@rediffmail.com*

Received: March 18, 2015
Accepted: May 15, 2015