Journal of Exercise Physiologyonline

February 2015
Volume 18 Number 1

JEPonline

Official Research Journal of the American Society of Exercise Physiologists

ISSN 1097-9751

Hemoglobin Concentration and Resilience of Professional Soccer Players Residing at Sea Level and Moderate Altitude Regions

Marco Cossio-Bolanos[1,2], Rossana Gómez-Campos[2,3,4], Cynthia Lee Andruske[2,5], Pedro R Olivares[3], Thiago Santi-Maria[6], Evandro Lazari[6], Cristian Luarte Rocha[7], y Miguel de Arruda[6]

[1]Department of Physical Activity Sciences, Catholic University of Maule, Chile, [2]Red Iberoamericana de Investigación en Desarrollo Biológico Humano, [3]Universidad Autonoma de Chile, Chile, [4]Grupo de estudios interdisciplinar en ciencias de la salud y deporte, [5]Universidad de Talca, Programa de idiomas, [6]Faculdade de Educacao Fisica, Universidade Estadual de Campinas, Sao Paulo, Brazil, [7]Facultad de Ciencias de la Actividad Física – Universidad San Sebastian, Concepción, Chile

ABSTRACT

Cossio-Bolaños MA, Gómez-Campos, R, Andruske CL, Olivares PR, Santi-Maria T, Lazari E, Luarte-Rocha C, Arruda M. Hemoglobin Concentration and Resilience of Professional Soccer Players Residing at Sea Level and Moderate Altitude Regions. **JEPonline** 2015;18(1):76-84. This study compared the hemoglobin (Hb) concentration and resilience of professional soccer players residing at sea level and moderate altitude regions. Subjects included 42 players (22 of the region at sea level and 20 of the region moderate altitude) with an age range of 20-35 yrs. We evaluated the weight, height, %fat, fat mass, fat-free mass, VO_2 max, and Hb concentration. The results showed no differences between the two groups of professional soccer players in age, experience, body weight, height, %fat, fat mass, and fat-free mass. Differences ($P<0.001$) emerged in the concentration of Hb ($g \cdot dl^{-1}$) and VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$). The group of professional soccer players living, training, and playing in Arequipa at a moderate altitude (2320 m above sea level) showed higher levels of Hb (16.2 ± 0.7 $g \cdot dl^{-1}$) and VO_2 max (54.1 ± 5.9 $ml \cdot kg^{-1} \cdot min^{-1}$) compared to players residing in regions at sea level (14.4 ± 0.7 $g \cdot dl^{-1}$) and (49.0 ± 5.9 $ml \cdot kg^{-1} \cdot min^{-1}$).

Keywords: Hemoglobin, VO_2 max, Soccer, Altitude

INTRODUCTION

Soccer is one of the most popular sports in the world. It is played by men, women, children, and adults with different levels of experience (16). Soccer is predominantly an aerobic sport of which the aerobic component is of great importance for the world performance of the elite soccer player (1).

Estimates indicate that aerobic metabolism contributes 90% of the energy used to play soccer (2). Athletic experience, body composition, strength, balance, aerobic power, and anaerobic power are important in evaluating elite soccer players (27). Additionally, hematological parameters may be crucial for predicting optimum physical performance (25) since hemoglobin and red blood cells play a fundamental role in transporting oxygen. In this regard, it has been widely demonstrated that resistance training produces adaptations at the blood level characterized by an increase in blood volume that is explained by an expansion in the volume of plasma and an increase in the number of red blood cells (24). One of the techniques used to increase these parameters is altitude training. However, other prohibited methods like blood transfusions and administration of erythropoietin (EPO) are also used (19).

As a result, in South America, professional and amateur soccer are practiced in various cities and important capitals located in high altitude zones. These cities include: (a) Bogotá (2600 m) in Colombia; (b) Quito (2850 m) in Ecuador; (c) Arequipa (2320 m); (d) Cusco (3300 m) and Huancayo (3280 m) in Peru; and (e) La Paz (3600 m) and Sucre (2904 m) in Bolivia. In these moderate and high altitude geographic regions, professional soccer clubs often hire native and non-native soccer players who have trained and played in diverse geographic regions. However, there are players (non-native) who for the first time train and play under hypoxic conditions. In fact, for this group of soccer players, it is necessary to program a period of acclimatization with the objective of overcoming the low partial oxygen pressure. In general, little time is available to develop the necessary preparation time for these athletes to adapt to different altitudes. Hence, frequently, it is impossible for them to reach an adequate level of performance similar to that of the native soccer players and/or those having experienced the acclimatization process in cities with moderate or high altitudes, respectively.

From this perspective, very little attention has been dedicated to describing and comparing hemoglobin concentrations and VO_2 max values of professional soccer players at sea level and other altitudes. These parameters may be a relevant characteristic of these groups and in predicting the physical performance of soccer players, especially for the players who for the first time live, train, and compete in cities at an altitude. Thus, the purpose of this study was to compare the concentration of hemoglobin and resilience of professional soccer players residing in regions at sea level and moderate altitudes.

MATERIAL AND METHODS

Subjects

Forty-two first division soccer players from two clubs in Peru belonging to the National Professional Soccer League participated in this study. The subjects (22 from sea level and 22 from moderate altitude) ranged in age from 20 to 35 yrs old. Convenience non-probabilistic sampling was used to select the professional players.

In general, until 2007, Peruvian soccer (1ª professional division) had 14 professional clubs of which 04 clubs belonged to cities with altitude: two clubs in Arequipa (2320 msnm), one club in Huaraz (3100 msnm) and in Cusco (3400 msnm). The other clubs were located in cities at sea level (<200 m above sea level).

Data collection occurred during January of 2006 and January of 2007 at the start of the pre-season for the two professional clubs from the city of Arequipa (2320 msnm). These assessments were conducted as part of the routine medical, biochemical, physical, technical, tactical, and psychological examinations that both clubs organize every year at the beginning of the preparatory training (pre-season). In general, in Peruvian soccer, the preparatory period lasts for 2 to 3 wks, and every year in Peru, the playing season begins in February and ends in November. For this study, players were separated into two groups: (a) those never having played at an altitude (residents at sea level); and (b) those having played the previous season and others in Arequipa at (2320 msnm) (natives and residents of moderate altitudes). Soccer players with injuries and cold symptoms were excluded as were the porters. The medical departments and the technical commissions of both teams examined and evaluated the players within the first 24 hrs after arriving at the moderate altitude (2320 msnm).

Evaluation of the participating soccer players' hemoglobin concentrations occurred while they fasted (first day). During the morning (8:00-9:00 hrs) of the second day in a closed laboratory with the room temperature maintained between 20ºC and 24ºC, the subjects' anthropometric assessment took place. Between 9:00 and 10:00 am on a soccer field with natural grass, the subjects' resilience Course-Navette) was measured. Through the respective medical departments of both soccer clubs (Arequipa), each player was informed of the benefits and risks of the evaluation. In all cases, the subjects signed an informed consent before the research began. The ethics' committee from the University Institute of Sport form the Universidad Nacional de San Agustín de Arequipa (Peru) approved the assessment protocol.

To determine the hemoglobin concentration, blood samples were drawn from the cubital vein of players having fasted. The 10 ml blood samples were paced in sterile plastic receptacles with anticoagulant (EDTA K3) covering the sides as suggested by Kuipers et al. (10). In all of the cases, the same experienced evaluator was in charge of the collection process. Data analysis was conducted by the automated hemoglobin analyzer XT-2000 (Sysmex Corporation, Kobe, Japón). The intra-rater of error showed values of less than 1%.

The Test Course Navette evaluation began with players running a distance of 20 meters (m) there and back, touching the line at the 20 m mark. The subjects' initial speed was 8.5 $km \cdot h^{-1}$ progressively increasing (0.5 $km \cdot h^{-1}$ each minute) according to the sound generated by the computer. Each stage consisted of various races. The subjects were instructed to follow the rhythm of the signal during the maximum time possible. When the subject could no longer maintain the rhythm, the last stage was used to predict the subject's oxygen consumption using the equation by Leger et al. (11) where $Y = 31.025 + 3.238 X - 3.248E + 0.1536EX$, where: $Y = VO_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$), X = maximum race velocity at that stage ($km \cdot h^{-1}$), E = age (yrs).

Before beginning the test, all players performed warm up exercises for a period of 10 to 15 min wearing soccer shoes for playing on natural grass. Throughout the test, the subjects were encouraged and motivated to use their maximum potential. Height was measured in a laboratory setting with a standiometer (Holtain) that had an accuracy of 0.1 cm. Body mass was measured with a calibrated Tanita scale with an accuracy of 0.1 kg. After urination, the subjects were measured with the least possible number of clothes on and in the same state of nutrition and hydration. Skin folds were measured in 4 anatomic regions of the body using a Harpenden (British Indicator Ltd, Luton, United Kingdom) adiopometer. The high pressure was obtained according to the manufacturer's specifications and maintained at 10 g·cm^{-2}. Measurements were taken on the triceps, subscapular, supraliac, and abdomen (mm). The anthropometric variables were identified and measured according to Wilmore (30) where an average of two measurements were taken to represent the skin fold thickness (coefficient of intra-rater reliability CR = 98.5%). Percentage of body fat was determined by using the equation proposed by Cossio-Bolaños et al. (6): %G = (TR+SE+SI+AB) / (6.0478*0.507). Values for fat-free body mass and body fat were obtained by estimating the measures of body fat and body mass.

Statistical Analysis

Normal data distribution was verified by the Shapiro Wilks' test. Test results were represented as means and standard deviation (Means ± SD) calculated by conventional procedures. All calculations were performed with Microsoft Excel and the statistical software package SPSS 9 (Chicago, IL). To determine the differences between both groups of soccer players, the Student's *t*-test was performed with independent variables with a probability of P<0.001.

RESULTS

The median values and standard deviation for age (yrs), professional experience (yrs), body weight (kg), height (cm), percentage of fat (% g), body fat, and fat-free body mass (kg) are shown in Table 1. No significant differences were found between the two groups of soccer players in the seven values evaluated except for a slight advantage related to years of professional experience exhibited by the soccer players living at a moderate altitude compared to the players living at sea level. Figures 1 and 2 illustrate the significant differences between both groups of soccer players related to hemoglobin concentration (g·dl^{-1}) and VO_2 max (ml·kg^{-1}·min^{-1}). Professional soccer players living, training, and playing during past seasons in Arequipa at a Moderate altitude (2320 m above sea level) showed higher levels of hemoglobin (16.2 ± 0.7 g·dl^{-1}) and VO_2 max (54.1 ± 5.9 ml·kg^{-1}·min^{-1}) compared to the players residing in regions at sea level (14.4 ± 0.7 g·dl^{-1}) and (49.0 ± 5.9 ml·kg^{-1}·min^{-1}), respectively.

Table 1. Body Composition and Anthropometric of Professional Soccer Players (M ± SD).

	Residents at Sea Level (n=22)	**Residents at Moderate Altitude (n=20)**
Age (yrs)	26.0 ± 4.1	27.1 ± 3.8
Professional Experience (yrs)	7.3 ± 4.0	9.0 ± 3.0
Weight (kg)	74.9 ± 5.6	74.7 ± 6.2
Height (cm)	1.8 ± 0.1	1.8 ± 0.1
Body Mass (%)	13.3 ± 2.9	13.0 ± 2.2
Body Fat (kg)	10.0 ± 2.5	9.9 ± 1.9
Fat-Free Body Mass (kg)	64.9 ± 4.4	64.7 ± 5.3

No significant difference (P>0.001)

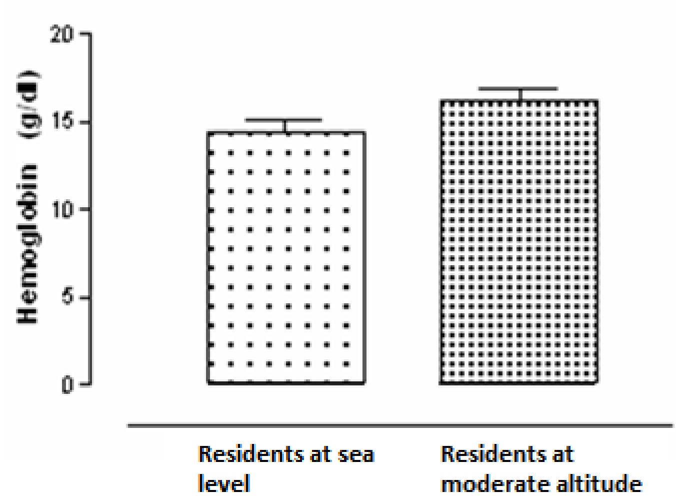

Figure 1. Hemoglobin Concentration ($g \cdot dl^{-1}$) of Professional Soccer Players.

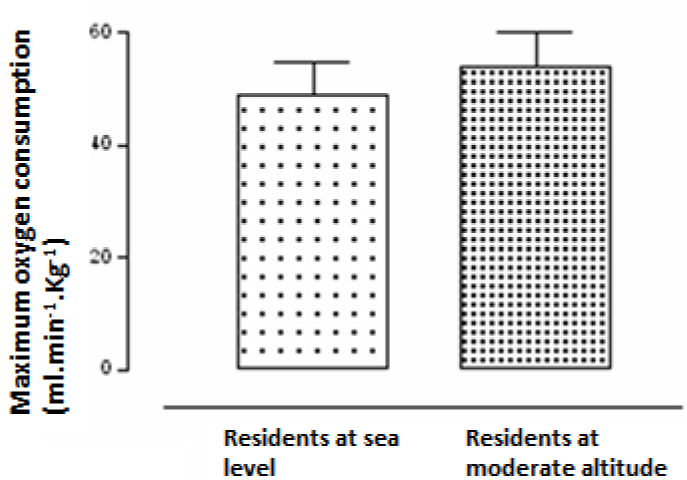

Figure 2. Maximum Oxygen ($ml \cdot kg^{-1} \cdot min^{-1}$) Consumption of Professional Soccer Players.

DISCUSSION

The purpose of this study was to describe the two groups of professional soccer players studied: (a) residents at sea level; and (b) residents at moderate altitude. The results demonstrated that no significant difference existed between the two groups with respect to age, professional experience, weight, height, %fat, body fat, and fat-free body mass. In agreement, various international studies show similar results related to age (20,27), professional experience (15,17), body mass, height (20,27), %fat (22,27), fat mass, and fat-free body mass (5). These results confirm that professional soccer players are relatively homogenous in terms of their morphological characteristics independent from the geographical region where they practice soccer. However, some factors do exist such as ethnic and racial characteristics that influence the average body size of a team or a national team.

The results of this study demonstrate that players residing in places of moderate altitude have greater concentrations of hemoglobin (16.2 ± 0.2 $g \cdot dl^{-1}$) compared to players not living at an altitude (14.4 ± 0.7 $g \cdot dl^{-1}$). The mean VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$) value of the players residing at a moderate altitude

(54.1 $ml \cdot kg^{-1} \cdot min^{-1}$) was also significantly greater than the players residing in the low regions (49 $ml \cdot kg^{-1} \cdot min^{-1}$). These findings show that players residing at an altitude are characterized by their increased ability to carry oxygen in the blood than the non-adapted subjects living in lower regions (26). A number of studies have demonstrated that the hemoglobin concentration is related to an improved physical performance of between 5 and 10% (29), particularly at moderate altitudes (hypoxia) (4). In fact, the assumption in this study is that the group of players residing in areas of moderate altitude showed increased levels of hemoglobin and VO_2 max values due to the adaptation process these athletes experienced during the past seasons. Therefore, the assumption is that in athletic competitions and soccer, for example, taking place in regions with altitude, players coming from low lying regions might be at a disadvantage since they may not have had enough time for their erythropoietin systems to adapt (26). As a result, prior to transitioning from low lying regions to moderate and high altitudes, soccer players, like those in this study, should go through a period of acclimatization to improve their hemoglobin and VO_2 max levels.

Some studies suggest a substantial overall increase in hemoglobin mass after 3 to 4 wks of training at altitudes of 2100 and 2500 m (12,23). Therefore, the results of this study suggest that soccer players residing at low lying regions should travel to the higher regions a few days prior to the start of the pre-season period (training). The reason for this is that erythropoiesis begins the first day an individual is at the higher altitude (14). In approximately 4 to 7 days, this translates into an increase in the hemoglobin concentration (9).

As a result, following athletes through hematological means is fundamental to identifying good health, and it may be critically important in predicting optimum physical performance (25). In fact, Taylor and Lombardo (28) maintain that apart from the assessment of the number of erythrocytes, mean corpuscle volume and platelet count, the hemoglobin is the only useful variable. Recently, it has been suggested that the assessment of the total mass of hemoglobin be used as a predictor of VO_2 max in athletes because it may be useful for identifying talents in endurance sports (7).

The values of hemoglobin concentration in the players from low lying regions are similar to those of the players in Ostojic and Ahmetovic's (16) research. These values are also relatively lower than the concentrations of the players in Eastwood and colleagues' study (7). However, the group of players residing in moderate altitude regions had relatively higher values of hemoglobin concentration when compared to athletes at similar altitudes. Although factors such as the volume of training, type of nutrition, and use of nutritional supplements may have influenced the current study, the findings clearly demonstrate that the time spent at a moderate attitude modified the levels of concentration of hemoglobin and the VO_2 max values. Another possible limitation to this study is the absence of the registration of the heart rate frequency. This would have allowed for a better interpretation of the results.

Therefore, in general, the results of the hemoglobin values in both groups of soccer players studied demonstrate a pattern and a normal distribution of hemoglobin concentration since both groups of soccer players showed higher values than those indicated by the OMS (19) for subjects at moderate altitudes (2500 msnm) ($<13\ g \cdot dl^{-1}$). In the present study, no anemia was observed in either group of soccer players. Yet, Mercer and Densmore (13) indicated that the prevalence of iron deficiency among athletes generally is still significant. The prevalence of iron deficiency among soccer players is approximately 15% (21).

With regard to VO_2 max values, both groups of players had low values compared to international research (25,27) that evaluated elite professional soccer players. These lower values are probably due to the period and stage of training when the variables were assessed. The soccer players in this study were measured before the pre-season training period began where it is normal to see lower values in comparison to other stages such as the pre-competitive and competitive, respectively. Various studies (3,18,27) have found that the average values of elite soccer payers vary between 55 and 68 $ml \cdot kg^{-1} \cdot min^{-1}$.

CONCLUSION

These results suggest that professional soccer players living and competing in moderate altitude regions have significantly higher hemoglobin concentration and VO_2 max values compared to soccer players who reside at low lying regions. These findings indicate that soccer players residing in lower regions should arrange to go the moderate altitude regions a few days before the pre-training period begins with the goal of anticipating the time necessary for acclimatizing since hypoxia increases the volume of red blood cells. The concentration of hemoglobin and the ability for the red blood cells to carry oxygen are increased. At the same time, these results should not be generalized conclusively because this is a cross sectional study that used a non-probabilistic sample (convenience). This fact could limit the generalizability of the results to other studies. As a result, we suggest conducting more research focusing on professional soccer players who train at altitudes greater than 2320 m. At the same time, it also appears necessary to implement intervention programs during the pre-season and competition stages in regions with altitude.

Address for correspondence: Marco Cossio Bolaños, Department of Physical Activity Sciences, Catholic University of Maule, Chile, Email: mcossio1972@hotmail.com

REFERENCES

1. Aziz AR, Chia M, Teh KC. The relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. ***J Sports Med Phys Fitness.*** 2000;40:195-200.

2. Bangsbo J. The physiology of soccer - with special reference to intense intermittent exercise. ***Acta Physiol Scand.*** 1994;151:S619.

3. Barbosa Coelho D, Figueiredo Morandi R, Anunciação de Melo MA, Silami-Garcia E. Cinética da creatina quinase em jogadores de futebol profissional em uma temporada competitiva. ***Rev Bras Cineantropom Desempenho Hum.*** 2011;13(3):189-194.

4. Calbet JA, Lundby C, Koskolou M, Boushel R. Importance of hemoglobin concentration to exercise: Acute manipulations. ***Respir Physiol Neurobiol.*** 2006;151:132-140.

5. Carling C, Orhant E. Variation in body composition in professional soccer players: Interseasonal and intraseasonal changes and the effects of exposure time and player position. ***J Strength Cond Res.*** 2010;24(5): 1332-1339.

6. Cossio-Bolaños MA, Arruda M, Lancho JL. Concordancia del porcentaje graso a través de métodos antropométricos en futbolistas profesionales. ***Kronos.*** 2011;X(II):48-54.

7. Eastwood A, Bourdon PC, Withers RT, Gore CJ. Longitudinal changes in hemoglobin mass and VO_2(max) in adolescents. ***Eur J Appl Physiol.*** 2009;105(5):715-721.

8. Hinrichs T, Franke J, Voss S, Bloch W, Schänzer W, Platen P. Total hemoglobin mass, iron status, and endurance capacity in elite field hockey players. ***J Strength Cond Res.*** 2010;24 (3):629-638.

9. Klausen T, Mohr T, Ghisler U, et al. Maximal oxygen uptake and erythropoietic responses after training. ***J Appl Physiol.*** 1991;62:376-379.

10. Kuipers H, Moran J, Dubravcic-Simunjak S, Mitchell DW, Shobe J, Sakai H, Ambartsumov R. Hemoglobin level in elite speed skaters from 2000 up to 2005, and its relationship with competitive results. ***Int J Sports Med.*** 2007; 28(1):16-20.

11. Leger LA, Mercier D, Gadoury C, Lambert J. The multi stage 20-m shuttle run test for aerobic fitness. ***J Sports Sci.*** 1988;6(2):93-101.

12. Levine BD, Stray-Gunderson J. ‘‘Living high-training low’’: Effect of moderate altitude acclimatization with low altitude low altitude training on performance. ***J Appl Physiol.*** 1997; 83:102-112.

13. Mercer KW, Densmore JJ. Hematologic disorders in the athlete. ***Clinics in Sports Medicine.*** 2005;24:599-621.

14. Milledge JS, Coates PM. Serum erythropoietin in humans at high altitude and its relation to plasma rennin. ***J Appl Physiol.*** 1985;59:360-364.

15. Mirkov DM, Nedeljkovic A, Kukolj M, Ugarkovic D, Jaric S. Evaluation of reliability of soccer specific field tests. ***J Strength Cond Res.*** 2008;22:1046-1050.

16. Ostojic SM, Ahmetovic Z. Indicators of iron status in elite soccer players during the sports season. ***Int. Lab. Hem.*** 2009;31:447-452.

17. Ostojic SJ. Seasonal alterations in body composition and sprint performance of elite soccer players. ***JEPonline.*** 2003;6(3):11-14.

18. Ostojic SM, Stojanovic M, Jukic I, Pasalic E, Jourkesh M. The effects of six weeks of training on physical fitness and performance in teenage and mature top-level soccer players. ***Biol Sport.*** 2009;26(4):379-387.

19. Organización Mundial de la Salud. Concentraciones de hemoglobina para diagnosticar la anemia y evaluar su gravedad. Ginebra, Organización Mundial de la Salud, (WHO/NMH/NHD/ MNM/11.1) (http://www.who.int/ vmnis/indicators/haemoglob in_es.pdf. Acceso 31/01/2012, 2011.

20. Poulmedis P. Isokinetics maximal torque power of Greek elite soccer players. ***J Orthop Sports Phys Ther.*** 1985; 6(5):293-295.

21. Resina A, Gatteschi K, Giamberardino MA, Imreh F, Rubenni MG, Vecchiet L. Hematological comparison of iron status in trained top-level soccer players and control subjects. ***Int J Sports Med****.* 1991;12:453-456.

22. Rienzi E, Mazza JC, Carter JEL, Reilly T. ***Futbolista sudamericano de elite: Morfología, análisis del juego y performance***. Rosario, Byosistem Servicio educativo, 1998.

23. Rusko HK, Tikkanen HO, Peltonen JE. Altitude and endurance training. ***J Sports Sci.*** 2004; 22:928-945.

24. Sawka MN, Convertino YA, Eichner ER, Schnieder SM, Young AJ. Blood volume: Importance and adaptations to exercise training, environmental stresses and trauma/sickness. ***Med Sci Sports Exerc.*** 2000;32:332-348.

25. Schumacher YO, Schmid A, Grathwohl D, Bultermann D, Berg A. Hematological indices and iron status in athletes of various sports and performances. ***Med Sci Sports Exerc.*** 2002; 34:869-875.

26. Schmidt W., Prommer N. Effects of various training modalities on blood volume. **Scand *J Med Sci Sports.*** 2008;18:57-69.

27. Sporis G, Jukic I, Ostojic SM, Milanovic D. Fitness profiling in soccer: Physical and physiologic characteristics of elite players. ***J Strength Cond Res.*** 2009;23(7):1947-1953.

28. Taylor WC, Lombardo JA. Pre-participation screening of college athletes: Value of the complete blood cell count. ***Phys Sports Med.*** 1990;18:106-118.

29. Wilber RL. Detection of DNA-recombinant human epoetin-alfa as a pharmacological ergogenic aid. ***Sports Med.*** 2002:32:125-142.

30. Wilmore JH. Sports Medicine. In: Lohman TG, Roche AF, Martorell R. (Eds). ***Anthropometric Standardization Reference Manual***. Champaign, IL: Human Kinetics, 1988, pp.155-159.