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PHYSIOLOGICAL CHARACTERISTICS OF LIBERO AND CENTRAL VOLLEYBALL PLAYERS

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Abstract. The aim of this study is to determine the intensity of effort in competition of the libero and central players by measuring heart rate and blood lactate. A sample of 30 players from 10 teams was used. Heart rate was measured by telemetry during the matches. Blood samples were obtained when there were substitutions for the players and about 300 samples were taken. Significant differences were observed in mean and maximal heart rate values between the central players and the libero ($p<0.01$). Mean and maximal heart rate values tended to decrease in the last sets in all the positions analysed. Higher levels have been observed in the libero when the set is lost than when it is won. ($p<0.01$). With regard to blood lactate, significant differences were found in mean values between the two central players and the libero ($p<0.01$). It was observed that 40.9% of all the blood lactate concentrations, regardless of the position, corresponded to values higher than 4 $mmol \cdot l^{-1}$, and 2.8% were above 8 $mmol \cdot l^{-1}$. These values are far higher than those found in earlier studies.

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Key words: Volleyball - Physical effort - Heart rate - Blood lactate – Libero - Central players

Introduction

The introduction of the figure of the libero has brought important modifications to the structure of the game, as well as a greater specialisation of the players, both in those who play in the new position, the libero; and in those whose functions have been altered, the central players.

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These changes have caused a certain amount of confusion in the world of volleyball, basically because of a lack of knowledge of their consequences for the players' performance. In this sense, both heart rate and blood lactate concentration are suitable parameters for evaluating the intensity of effort which the players have to endure under the new rules.

Heart rate is frequently used as a reasonably reliable indicator of exercise intensity in sports involving intermittent effort [4,6,32]. Some authors state that it does not immediately reflect variations in exercise with these characteristics, as in spite of the wide fluctuations which occur between the phases of effort and phases of rest, it remains relatively constant when the periods of activity are of a short duration [34]. However, later studies in sports with similar characteristics have shown significant variations in heart rate when intervals of activity were compared with intervals of rest [12,17].

What has been observed is that, among different subjects, large differences can be appreciated in heart rates recorded during the match, due among other factors, to the time that they are on court, to their different physical aptitudes and to the position in which they play [28]. In the case of volleyball, the variable nature of the sport causes considerable fluctuations in heart rate. Values during the game can vary from 130 to 190 bpm (beats per minute)[37]. Even so, the evidence available in our sport on the behaviour of heart rate during competition is very limited. In studies carried out during the game different mean heart rates have been obtained, 127 bpm [40], 144 bpm [15], 139 bpm [19]. With regard to maximal heart rate, values have been found of 183±2.4 bpm [31], 185±9.0 bpm [23], 181 bpm [5], y 192±5.7 bpm [40].

In addition, evaluation of the physiological load by monitoring the levels of lactic acid concentration in the blood, permit us to establish the participation of the different metabolic systems in the production of the energy necessary for the type of effort required. Blood lactate also offers us the possibility of establishing the relationship between lactate and intensity. A relationship which is determined by the performance capacity of the athlete in terms of aerobic and anaerobic energy [30].

With regard to blood lactate concentration, numerous studies have been carried out in volleyball with the aim of determining the aerobic and anaerobic energy used during the game. In general, in the majority of these studies carried out before the introduction of the new rules, low concentrations of lactate were observed (2.61 $mmol \cdot l^{-1}$ [25]; 3.05 $mmol \cdot l^{-1}$ [40]; 2 $mmol \cdot l^{-1}$ [41]; 1.0 $mmol \cdot l^{-1}$ [13]; 2.48 $mmol \cdot l^{-1}$ [11], which led the different authors to state that volleyball is an aerobic sport because of the long length of the matches, with an anaerobic alactic component,

due to the short duration and high intensity of the active phases, in which the lactic anaerobic system hardly intervenes [10,15,25,40].

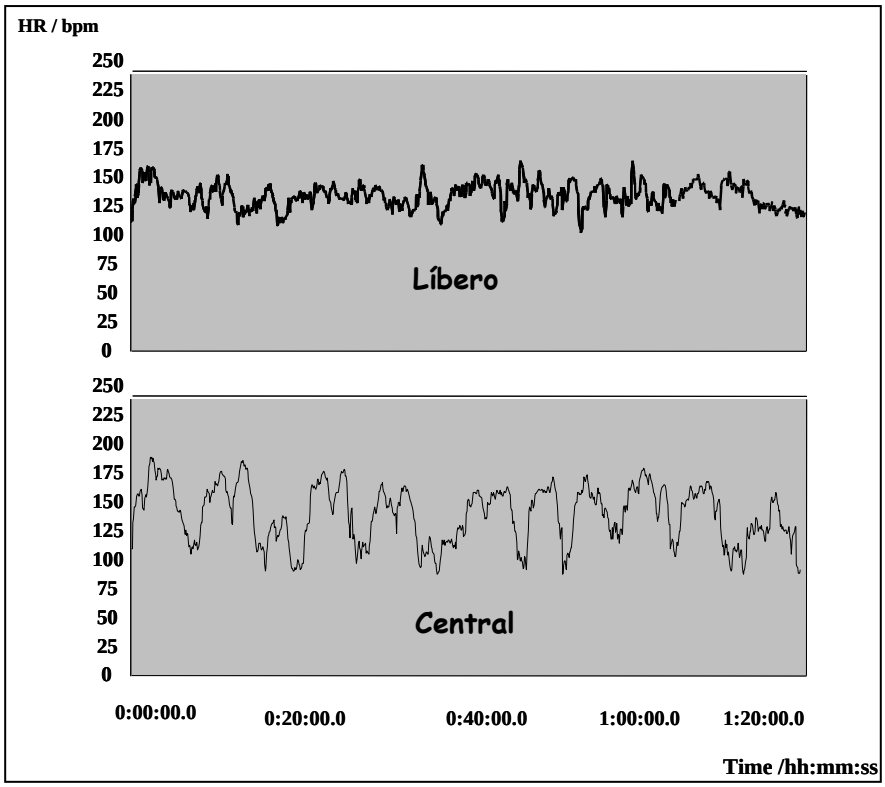

Fig. 1
Characteristics of heart rate curves in the libero and central players

However, some of the latest modifications to the rules have affected the structure and development of the game, as well as the performance of some of the players to such an extent that new studies are needed to be able to evaluate these changes.

The aim of this study is to determine the levels of lactic acid concentration in the blood, as well as the new variations of heart rate in the libero and both central players, with the purpose of discovering what type of effort is required of them under the new rules, and if these values are different from those found previously.

Material and Methods

Sample: The sample was drawn from the population of volleyball players (male) at the national level. It comprised 30 players from 10 teams: 10 liberos, 10 principal central players and 10 secondary central players.
Table 1 analyses the characteristics of the sample which participated in the study

Table 1
Characteristics of the subjects in each of the samples

Position	N	Experience years	Age	Height	Weight
Libero	10	13.40	27.15	1.80	76.50
Principal central	10	9	24.25	1.88	84.33
Secondary central	10	7.44	21.60	1.90	84.67
Total	30	10.07	24.43	1.86	81.64

Design: The design used in this research is descriptive. Measures were recorded during the matches for each sample (liberos, principal central and secondary central players).

The independent variables used in this study were:
The position: which has differentiated the sample into three groups as a result of the position the players occupy: libero, principal central player and secondary central player.
The periods of the game: which allowed us to differentiate in the players studied the different phases which can occur in competition, specifically considering the following periods:

On court: periods during which the players in the sample were on court and participating in the game before their substitution.

Off court: periods during which the players in the sample remained on the bench, due to the substitution between the libero and the central player, while the game continued.
The result of the set: A variable recorded as won or lost.
The order of the set: This variable was used to differentiate the sets with regard to their order in the match.

The independent variables measured were:

Blood lactate concentration: Capillary blood samples (20-25 microlitres) the amount recommended by Fell *et al.* [20], were taken to analyse blood lactate concentration ($mmol \cdot l^{-1}$). Samples were obtained by pricking the finger with a Boehringer Autoclix.

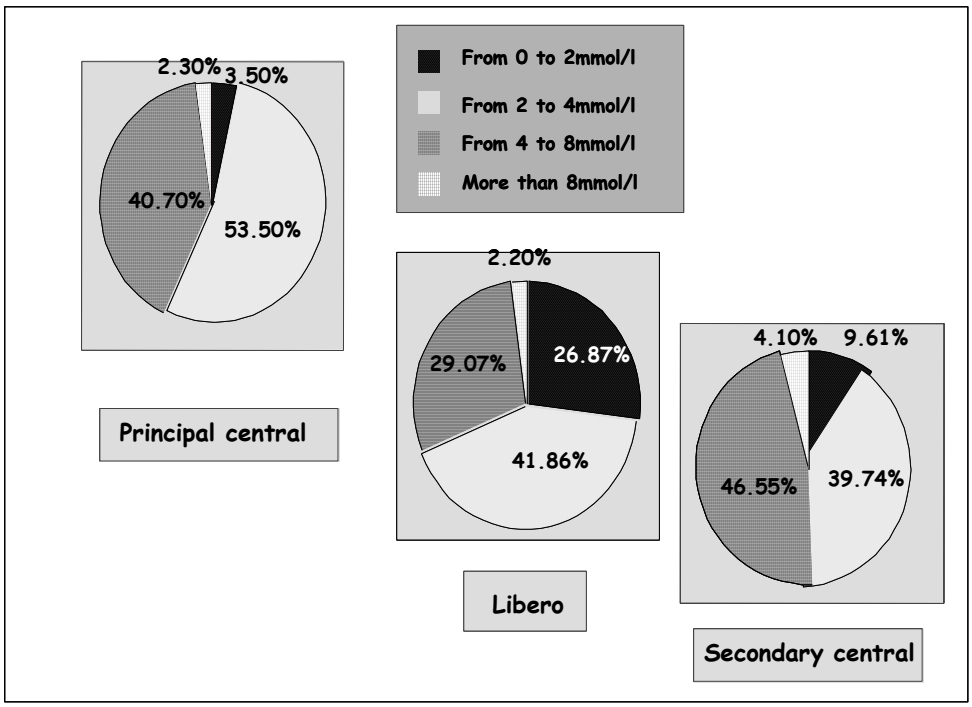

Fig. 2
Percentages of the different blood lactate concentrations ($mmol \cdot l^{-1}$) in each position

Heart rate was recorded by telemetry throughout the match at 5-second intervals. The mean and maximal heart rate values for each subject in the different phases of the game were used as summary measures.

Materials: The extraction of capillary blood and its delivery to the analyser was done with a YSI model 1501 pipette. The samples were analysed immediately in a YSI Incorporated 1500 Lactate analyser (Sport from the Yellow Springs Instrument Co. Inc. Yellow Springs). Several studies have demonstrated the validity and precision of this analyser [7,33].

Heart rate was monitored with Polar Vantage NV-TM pulsometers, the reliability and validity of which have been confirmed by numerous studies over the

15 years they have been in existence [26]. The Polar Advantage-TM interface unit permitted the introduction of the data into a Dell Optiplex Gs+ computer to obtain the evolution of heart rate throughout the whole match using Polar Precision Performance software.

Procedure: The data were collected during a tournament, in which 10 teams participated. Five matches were played and 10 liberos, and 20 central players: 10 principal and 10 secondary, were studied.

Blood samples were taken from the players playing in the position of principal central player and secondary central player every time that they left the court after substitution by the libero. In the case of the libero they were taken alternately in each substitution. An average of 2 to 3 samples were taken each set and from 8 to 11 in the whole match from every player. Approximately 220 to 300 blood samples were taken for lactate analysis during the whole study.

Heart rate was monitored throughout the whole match at 5-second intervals.

A *statistically descriptive analysis* has been used in this study, using means, standard deviations, maxima and minima. *Inferential statistical* have also been applied using ANOVA and Student's t-test.

Results

Table 2
Mean values (±SD) for heart rate (HR) in the different periods of the match, with regard to result, and order of the set in the different positions

Position	HR on court	HR off court	HR Won	HR lost	HR first set	HR second set	HR third set	HR fourth set
Libero	137± 16.42	131± 15.93	133± 17.71	139± 18.92	137± 17.39	139± 17.87	135± 15.14	136± 15.40
Principal central	148± 16.16	124± 13.21	150± 15.74	147± 16.56	148± 16.32	156± 12.54	149± 13.78	142± 18.22
Secondary central	149± 12.23	118± 18.42	147± 12.65	151± 11.30	151± 11.75	152± 13.54	144± 11.68	149± 11.31

The results obtained, shown in table 2, present the mean values for heart rate in the different positions in the periods of the game analysed, in relation to the order

of the set and its result. The highest values correspond, in all positions, to the period spent on court, with significant differences ($p<0.01$) in mean heart rate between on and off court measurements, in all the positions analysed. The highest values found in the on court periods correspond to both central players (principal central, 148 bpm and secondary central 149 bpm); with significant differences ($p<0.01$) between these players and the libero (137 bpm). With regard to heart rate in relation to the order of the set, a decrease in shown in the last sets compared with the first ones in all positions, but to a significant extent ($p<0.01$) in relation to the principal central player. With regard to heart rate and the result of the set, higher values are observed in the libero when the set is lost (139 bpm) than when it is won (133 bpm) ($p<0.01$).

Table 3
Mean values (±SD) and percentages of the different blood lactate concentrations in each position

Position	Mean values (±SD)	% from 0 to 2 $mmol \cdot l^{-1}$	% from 2 to 4 $mmol \cdot l^{-1}$	% from 4 to 8 $mmol \cdot l^{-1}$	Equal to or more than 8 $mmol \cdot l^{-1}$
Libero	3.23±1.62	26.87%	41.86%	29.07%	2.20%
Principal central	3.92±1.37	3.50%	53.50%	40.70%	2.30%
Secondary central	4.32±2.05	9.61%	39.74%	46.55%	4.10%

Table 3 shows that the principal central player and the secondary central player present similar mean blood lactate values (3.92 and 4.32 $mmol \cdot l^{-1}$, respectively). However, there were significant differences (3.23 $mmol \cdot l^{-1}$) ($p<0.01$) between these and the libero. With regard to percentages, the libero is the player who presents the highest percentages in the lower values (from 0 to 2 $mmol \cdot l^{-1}$l). The highest percentages are observed in all the players in the range between 2 and 4 $mmol \cdot l^{-1}$); although in the central players the percentages which correspond to higher values (4 to 8 $mmol \cdot l^{-1}$.) are also considerable, almost equal to half the samples.

Fig. 3 shows that of the approximately 300 samples taken, 59.1% refer to values of less than 4 $mmol \cdot l^{-1}$ and 40.9% to values higher than 4 $mmol \cdot l^{-1}$.

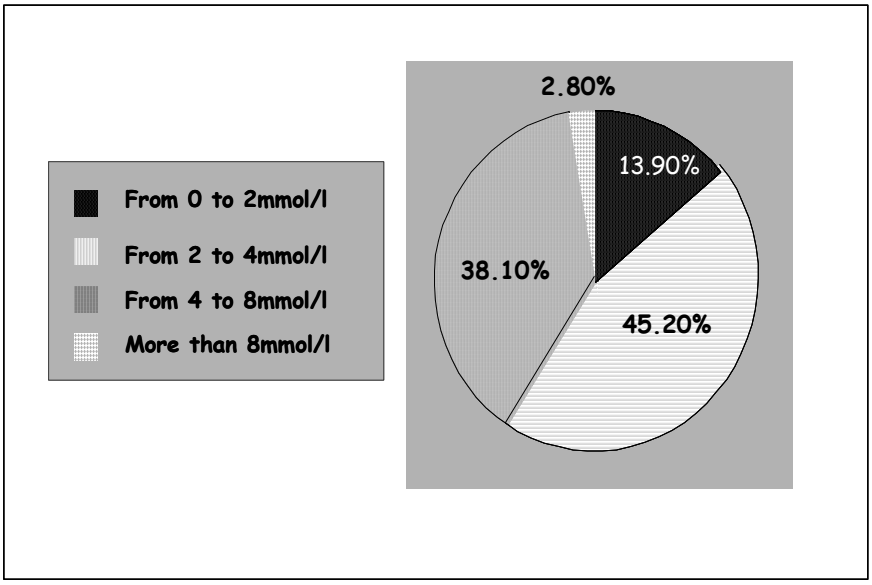

Fig. 3
Percentages of the values of blood lactate concentration ($mmol \cdot l^{-1}$) in all the samples taken from the players

Discussion

Heart rate: The variable nature of volleyball means that there are continuous variations in heart rate during the match [37]. However, the new rules have brought about a new specificity of the players and consequently the variations in heart rate are also caused by the position in which they play.

With the new rules there are continuous substitutions of players, so that during the match they spend time on the bench alternately with time on court, which has caused alterations in heart rate as a consequence of this alternation.

The fluctuations produced in heart rate are determined by the length of time that these phases last and by the position occupied by the players [4,28,39], which determines their actions in the game. Thus, significant differences have not been shown between the two central players, but there have been some between these players and the libero. This is due to the action of the libero in the game, which not being of high intensity [21], does not cause a high mean heart rate during the work phase. Moreover, the time spent off court is very short (29 s) [22], so that heart rate decreases less. These fluctuations are much greater in the central players, in the

first place because their activity during the work phase is very intense [21], which causes higher heart rate values, the rest phases however, are long (2 min) [22] which allow heart rate to slow considerably.

In the same way, these fluctuations permit determination of the increase in heart rate from beginning to end of the activity phase making it possible to identify the load [35]. In the libero, the principal central player and the secondary central player the average increase from when they come onto court until they leave is 6, 24 and 30 heart beats respectively.

With regard to mean heart rate when the players are on court, it is evident that although the two central players do not show significant differences, they do differ from the libero. The central players have a mean heart rate of about 150 bpm, whereas the libero's mean is only 137 bpm. These differences are also evident with regard to maximal values with a difference of 16 beats between the libero and the central players. Once again this is mainly due to the position that they occupy [28], as with the new rules, the libero only participates in the game at the back of the court whereas the central players play at the front where heart rate is higher than in the rest of the court, as this is where the greatest number of high intensity actions are carried out [15,19].

When analysing the heart rate of players during the average time spent on court with regard to the order of the set, we find that this tends to decrease in the last sets in all the positions analysed, but especially in the principal central player. This player registers the lowest values in the last set [142.47 bpm) with considerable differences, of up to 14 bpm between the 2nd (156.17] and the fourth (142.47] sets. This can be explained by the high rate of participation in the game of the central players under the new rules, especially the principal central player [29,42]. This participation, due to the increase in fatigue produced, gradually diminishes until it reaches its lowest point in the last set, which logically is when the player presents the lowest heart rate values [1,4].

When heart rate is analysed in relation to the result of the set there are no significant differences between the central players, however, we find higher levels in the libero when the set is lost. This is due to the fact that when the set is lost there is greater dominance of the opponent's serve and attack and, therefore, greater participation by the receivers and defence, actions in which the libero is highly involved [21].

When comparing heart rate values obtained in this study with those of previous studies 127 bpm [40], 144 bpm [15], 143 bpm [19], it can be seen that mean heart rate (137 bpm) of the liberos is similar to the intermediate values previously found. However, the players who occupy the positions of principal central player and

secondary central player record mean heart rates (148 bpm and 149 bpm respectively) which are higher than those previously found. These high values recorded in competition by the central players are the consequence of an increase in physiological demands due to the numerous and varied actions of high intensity [21] which have increased as a result of the new rules [29,42].

Blood lactate concentration: When the mean blood lactate concentrations obtained in the study are considered for each position, there are no significant differences between the principal central player and the secondary central player, but there are between these and the libero. Thus the mean found in players in the secondary central position was 4.32 $mmol \cdot l^{-1}$, in that of principal central 3.92 $mmol \cdot l^{-1}$ and in the position of libero 3.23 $mmol \cdot l^{-1}$, which indicates that these differences are fundamentally caused by the position occupied [39], and the actions which characterise these positions as the game played in the central position is of greater intensity than that played by the libero [21].

With regard to the percentages obtained in the samples taken for each one of the positions studied, it can be seen that in the liberos, in general terms, 68.73% of the samples did not surpass the level of the aerobic/anaerobic threshold, although there is a considerable percentage, 31.27% of high values. With regard to the principal central player the percentage of values which surpass 4 $mmol \cdot l^{-1}$ is higher than that of the liberos and represents 43%. But it is in relation to the secondary central player that the greatest percentage of samples surpass the anaerobic threshold with a figure of 50.63%. Thus in both central players, almost half the samples taken (about 100 in each positions), are situated above the aerobic/anaerobic threshold. The most marked differences between both positions are found in the most extreme values. Thus, in the secondary central player, 9.61% of the values are between 0 and 2 $mmol \cdot l^{-1}$, compared with 3.5% for the principal central player. In the concentrations of over 8 $mmol \cdot l^{-1}$, the secondary central player has a higher percentage, 4.1% than the principal central player (2.3%). That is to say that the secondary central player has a greater percentage of the higher concentrations and also of the lower ones, being therefore the player who presents the greatest fluctuations in their concentrations.

In general it should be emphasised that high levels of over 8 $mmol \cdot l^{-1}$ have been found, although only in a small percentage of the samples, in all the positions, representing 2.2% for the libero, 2.3% for the principal central player and 4.1% for the secondary central player.

If the blood lactate concentrations obtained in this study are considered independently of the position, it can be seen that 5.9.1% of these values are under 4 $mmol \cdot l^{-1}$ and 40.9% are higher than 4 $mmol \cdot l^{-1}$. These data are far higher than those

found in previous studies (3.05 mmol·l^{-1} [40], 2.61 mmol·l^{-1} [25], 2 mmol·l^{-1} [41], 2.48 [11], 1.0 mmol·l^{-1} [13]. In the majority of these the blood lactate concentrations found have been low. This is basically due to the point in time at which the samples are taken. In the majority of studies carried out in volleyball, referred to above, the blood samples were taken at the end of the match or between sets, and thus only represent the activity previous to the sampling [2].

The new rules have permitted sampling to be carried out when the substitutions of the central players by the libero were being made, without having to alter the dynamics of the competition itself. Also, it should be emphasised that the substitution of the players who occupy the central position by the libero is made at the end of their turn in the area near the net, where the action is of greater intensity, which has made it possible to find high lactate concentrations, as it has been shown that these are related to the high intensity of the actions carried out in the time immediately before sampling [16].

On the other hand, as the number of substitutions by the libero is unlimited, it has been possible to take many samples from each player (between 2 and 3 in each set and from 8 to 11 in the whole match), which can give a good indication of the type of exercise intensity that the player studied carried out during the whole match [12].

A great deal of variety has also been found in the lactate values of players who occupy the same position. Thus some players who play in the position of libero present values of about 1.21 mmol·l^{-1}, and others of up to 8 mmol·l^{-1}. In the central players the variations are more pronounced and can oscillate between 0.82 and 11.4 mmol·l^{-1}. However, this variation is even seen in the same set and in the same player (2.44 to 8.19 mmol·l^{-1}). This is due to the relationship between the value obtained and the intensity of the actions taken immediately before sampling, and to the fact that the time spent by the player off court permits rapid elimination of the high muscle lactate accumulated at some moments, as it has been shown that in sports of an intermittent character its elimination after exercises of high intensity is very significant and greater than in more continuous type sports [18].

This rapid elimination referred to above is also the reason why significant differences have not been found between the first and the last sets in the samples taken of all players. This seems to confirm that in volleyball lactic acid is not a factor which by itself induces fatigue, rather that there are also other factors which together cause it; like aspects of a nervous nature [14,38], or a decrease in muscle glycogen [13].

The blood lactate values found in this study permit the statement that high concentrations are produced in volleyball, contrary to the conclusions of the

authors of previous studies, who related the low concentrations of lactate found with the duration of the active phases, indicating that their brevity impeded high accumulations. However, there exists sufficient scientific evidence to state that the production of lactic acid begins at the start of the activity [8,24,27,30,36], and that the breakdown of creatine phosphate and anaerobic glycolysis are activated from the beginning of high intensity activity [8,36].

Even so it should not be forgotten that although high levels of blood lactate have been found the real production of lactate is probably greater, especially in the muscles most involved (lower limbs) as not all the lactate produced after exercise of high intensity appears in the blood [3,9].

Finally it should be underlined that, although in previous studies it has been concluded that lactic acid concentrations found in volleyball competitions were lower than those of other sports with similar characteristics, in this study, both the high levels found and the significant differences among the different positions and the large variability among the data for the same player, coincide with similar results in other sports of an intermittent nature (Football, Basketball, Handball, Rugby).

Conclusions

In conclusion we can state that under the new rules, although the participation of the central players in the game is lower as a consequence of the continual substitutions by the libero; during the time that they are on court there are more demands placed on them and, therefore, more intensity in their game [21,29,42], which is reflected in the high levels of heart rate recorded. With regard to the libero, their heart rate is always lower than that of the central players and therefore so is the intensity of their game, although they may spend more time on court. However, it should be taken into account that there may be considerable differences among subjects, even when they occupy the same position, given their physical aptitude, the time that they are on court, the intensity of the game itself and their individual characteristics [4,28,39].

With regard to the blood lactate concentrations, we should emphasise the high levels recorded in all players and especially the central players. We can thus state that high levels of lactate are produced in volleyball in spite of the brief duration of the phases of the game.

The data recorded in this study using measurements of heart rate and blood lactate concentrations, have permitted us to determine the intensity of effort to which these players are submitted during a match under the new rules.

However, it should not be forgotten that the application of these rules is so recent, that the players' adaptations to them and therefore the attainment of a suitable profile for the position is a task which has not yet been completed. The acquisition of greater experience will permit the clarification and definition of the essential characteristics which are beginning to be seen as necessary for these players.

References

1. Ali A., M.Farrally (1991) Recording soccer players' heart rates during matches. *J.SportsSci*. 9:183-189

2. Bangsbo J., L.Norregaard, F.Thorsoe (1991) Activity profile of competition soccer. *Can.J.Sports Sci.* 16:110-116

3. Bangsbo J., T.E.Graham, B.Kiens, B.Saltin (1992) Elevated muscle glycogen and anaerobic energy production during exhaustive exercise in man. *J.Physiol*. 451:205-222

4. Bangsbo J. (1994) The physiology of soccer, with special reference to intense intermittent exercise. *Acta Physiol.Scand*. 151:619

5. Belyaev A.V. (1985) Methods of developing work capacity in volleyball. *Soviet Sports Rev*. 20:35-38

6. Bergeron M.F., C.M.Maresh, W.J.Kraemer, A.Abraham, B.Conroy, C.Gabaree (1991) Tennis: a physiological profile during match play. *Int.J.Sports Med.* 12:474- 479

7. Bishop P.A., J.F.Smith, J.C.Kime, J.M.Mayo, Y.H.Tin (1992) Comparison of a manual and an automated enzymatic technique for determining blood lactate concentrations. *Int.J.Sports Med.* 13:36-39

8. Bongbele J., A.Gutierrez (1989) Bases bioquímicas de la fatiga muscular durante esfuerzos máximos de tipo anaeróbico (0 a 30 segundos). *Arch.Med.Deporte* 6,21:399-405

9. Boobis L.H. (1987) Metabolic aspects of fatigue during sprinting. In: Maclead D. et al. (ed.) Exercise. Benefits, limits and adaptations. E. & F.N., London/New York

10. Bosco C. (1987) La preparación física en el voleibol y el desarrollo de la fuerza en deportes de carácter explosivo-balístico. *Rev.Voley*

11. Butti L.F.E. (1990) Perfil do lactato no voleibol: interrelacoes entre tests de campo e desempenho em jogo simulado. Tesis Doctoral, Universidade Estadual Paulista

12. Christmas M., S.Richmond, N.Cable, P.Arthur, P.Hartmann (1998) Exercise intensity and metabolic response in singles tennis. *J.Sports Sci*. 16:739-747

13. Conlee R., K.Robinson, C.Mcgown, A.Fisher, G.Dalsky (1982) Physiological effects of power volleyball. *Phys.Sportsmed*. 10:93-97

14. Drauchke K., C.Kröger, A.Schulz, M.Utz (1994) El entrenador de voleibol. Paidotribo, Barcelona

15. Dyba W. (1982) Physiological and activity characteristics of volleyball. *Volleyball Tech*. 6,3:33-51

16. Ekblom B. (1986) The applied physiology of soccer. *Sports Med*. 3:50-60

17. Elliot B., B.Dawson, F.Pyke (1985) The energetics of single tennis. *J.Hum. Mov.Stud.* 11:11-20

18. Essen B., L.Hagenfeldt, L.Kaijser (1977) Utilization of blood-borne and intramuscular substrates during continuous and intermittent exercise in man. *J.Physiol.* 1265:489-506

19. Fardy P.S., HM.G.ritz, H.K.Hellerstein (1976) Cardiac responses during women's intercollegiate volleyball and physical fitness changes from a season of competition. *J.Sports Med.Phys.Fitn*. 16:291-300

20. Fell J.W., J.M.Rayfield, J.P.Gulbin, P.T.Gaffney (1998) Evaluation of the Accusport Lactate Analyser. *Int.J.Sports Med*. 19:199-204

21. González C. (2001) Análisis del esfuerzo en el juego del voleibol, tras los nuevos cambios en el reglamento, mediante una observación sistemática y una medición telemétrica y lactacidémica. Tesis Doctoral del Departamento de Actividad Física y Deportiva de la Universidad de Granada

22. González C., F.Navarro, A.Ureña, J.A.Santos, F.Llop (2001) Análisis de los tiempos durante la competición de voleibol, en el líbero y en los centrales. *Rev.Entrenamiento Deport.* 15,4

23 Häkkinen K. (1993) Changes in physical fitness profile in female volleyball players during the competitive season. *J.Sports Med.Phys.Fitn.* 33:223-232

24. Hirvonen, J., S.Rehunen, H.Rusko, D.Harkonen (1987) Breakdown of high-energy phosphate compounds and lactate accumulation during short supramaximal exercise. *Eur.J.Appl.Physiol.* 56:253-259

25. Küntslinger U., H.Ludwig, J.Stegeman (1987) Metabolic changes during volleyball matches. *Int.J.Sports Med*. 8:315-322

26. Laukkanen R.M.T., P.K.Virtanen (1998) Heart rate monitors: state of the art. *J.Sports Sci.* 16:S3-S7

27. Mcardle W., F.Katch, V,Katch (2000) Essentials of Exercise Physiology. Lippincott Williams & Wilkins, Philadelphia

28. Mcinnes S.E., J.S.Carlson, C.J.Jones, M.J.Mckenna (1995) The physiological load imposed on basketball players during competition. *J.Sports Sci*. 13:387-397

29. Montali G. (1999) We need mistake management. Interview by O.Kortmann. *The Coach*. Consulta: 12 noviembre de 2000 de la world wide web: http://www.thecoach-online.com/tc499/montali.htm

30. Navarro F. (1998). La resistencia. Gymnos, Madrid

31. Parnat J., A.Viru, T.Savi, A.Nurmekivi (1975) Indices of aerobic work capacity and cardio-vascular response during exercise in athletes specializing in different events. *J.Sports Med.Phys.Fitn*. 15:100-105

32. Reilly T. (1986) Fundamentals studies on soccer. In: R.Anderssen (ed.) Sportwissenschaft und Sportpraxis. I.Czwalina Verl., Hamburg

33. Rodriguez F.A., M.Banquells, V.Pons, F.Drobnic, P.A.Galilea (1991) Estudio comparativo de diferentes metodos analiticos de lactato sanguíneo. *Apunts: Medicina dell' Esport.* 28,107:41-50

34. Saltin B., B.Essen, P.K.Pedersen (1976) Intermittent exercise: Its physiology and some practical applications. In: E.Jokl (ed.) Medicine and Sports: Advances in Exercise Physiology. Karger , Basel

35. Sergeyevich V., V.Dimitriyevich (1995) Fisiología del deportista. Paidotribo, Barcelona

36. Spriet L.L. (1995) Anaerobic metabolism during high-intensity. In: M. Hargreaves (ed.) Exercise Metabolism. Human Kinetics, Champaign, Il, pp. 1-40

37. Ureña A., J.M.Palao, B.Saénz (2000) Características biológicas y fisiológicas de los esfuerzos en voleibol. *Rev.Entrenamiento Deportivo* 14,4:37-42

38. Ureña A., J.M.Palao, B.Saenz (2001) La fatiga en voleibol. Lecturas en Educación Física y Deportes. *Rev.Digital* 6,30; Http://www.efdeportes.com/efd30a/voley.htm

39. Van Gool D. (1987) De fysieke belasting tijdens een voetbalwedsfrifd: studie van af geledge afstand, hartfrequintie, energieverbruck en lactaatbepaligen (thesis). University of Leuven, Leuven, Netherlands

40. Vittasalo J.T., H.Rusko, O.Pajala, P.Rahkila, M.Ahila, H.Montonen (1987) Endurance requirements in volleyball. *Can.J.Appl.Sports Sci*. 12:194-201

41. Voigh H-F., H.Marees (1985) Zur muskülaren Beanspruchung im volleyball. *Dtsch Z Sportmed.* 6:163-170

42. Zhang B.S., T.Z.Dong, R.Zhang, Y.W.Jue, X.Xin, Y.X.Li, Q.AN (2000). Research on volleyball match patterns under the new FIVB rule**.** *Sport-sci*. 20(2):34-38

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