J SPORTS MED PHYS FITNESS 2011;51:633-8

Echocardiographic study of structure and functional cardiac profile of football referees

J. A. RUIZ CABALLERO [1], E. BRITO OJEDA [1], J. M. GARCÍA-ARANDA [2], J. MALLO [3], W. HELSEN [4], S. SARMIENTO [1], J. M. GARCÍA-MANSO [1], M. E. NAVARRO VALDIVIELSO [1]

[1]Physical Education Department, University of Las Palmas of Gran Canaria, Spain
[2]Refereeing Department International Federation of Football Association (FIFA), Switzerland
[3]Faculty of Physical Activity and Sport Sciences (INEF) Technical University of Madrid (UPM), Spain
[4]Biomedical Kinesiology Department Katholieke Universiteit Leuven, Belgium

***Aim*. The aim of this study was to analyze, through echocardiography, the structure and functional cardiac profile of national category Spanish soccer referees.**

***Methods*. The sample consisted of 54 licensed referees, who belonged to the Football Inter-Insular Federation of Las Palmas. The sample presented a mean age of 28.52±6.39 years, a height of 1.76±0.07 m, a body mass of 77.26±10.74 kg and a Body Mass Index of 24.90±2-73 kg/m^2. The diastolic and systolic dimensions of the left ventricle were 50.03±4.79 mm and 33.74±5.23 mm, respectively. The thicknesses of the interventricular septum and the posterior wall of the left ventricle were 9.77±1.53 mm and 9.47±1.54 mm, respectively. The left ventricular mass was 112.80±26.53 g/m^2, the diastolic volume of the left ventricle 135.09±39.63 mL and the ejected volume 47.34±12.44 mL/m^2.**

***Results*. This study shows that the echocardiographic profile of football referees is characterized by presenting an increase in the left ventricular mass caused by an increase of the cardiac chambers and a normal systolic and diastolic function. The values obtained by football referees were higher than those found in sedentary people and lower than in professional football players.**

***Conclusion*. These differences may be due to the different physical training workloads employed by football players and referees.**

Key words: Soccer - Echocardiography - Heart.

The cardiac adaptations which are caused by training have led to a great deal of research for over a century. The results of these studies have been used to develop protocols which enable training sportspeople from a more scientific viewpoint. The technological advances used in modern cardiology have led to the improvement of the analysis of the structure and functional adaptations of the trained heart. Initially, with the coming of radiology and electrocardiography, important advances in the cardiac adaptations to training sessions were attained, but it has been echocardiography which has eventually enabled a greater development in the field of cardiology research in sports.

Echocardiography has been used for over 30 years to evaluate the cardiac adaptations induced by training in sportsmen. Several studies have proved that systematic training generates changes in the diameters of the chambers (volume) and the thickness of the ventricular walls of the heart.[1, 2] The first of them appear more often in those sportspeople who base their training on a high physical workload of moderate intensity, whereas the second appear more often in sportspeople who perform an anaerobic type of exercise.[2] In addition to the type of exercise being performed, parameters such as the hours dedicated to physical activity and seniority in the practice of sports can have a significant influence on the echocardiographic pattern that characterizes the heart of sportspeople.[3]

Received on June 14, 2010.
Accepted for publication on July 6, 2011.

Corresponding author: J. Mallo Sainz, Politechnical University of Madrid. E-mail: javier.mallo@upm.es

To our knowledge, the greater part of research has been focused on the structure and functional cardiac profile of sportspeople of a determined sport modality. Seldom do we find studies focusing on the cardiac characteristics of the sports officials. Neither frequent are the studies focusing on the heart of football referees, even though the latter's cardiocirculatory system is severely activated during a football match. Football referees have been subjected to studies from various perspectives, thus leading to works which analyze, primordially, their anthropometric profile, their morpho-functional characteristics and physical performance.[4-9] Another line of study focuses on the analysis of the physical demands which main and assistant referees experience during a football match.[10-15] All these studies have served to establish, in a scientific way, appropriate training protocols which enable to improve the performance of a football referee.

The aim of this study has been to describe and analyze, through echocardiography, the structure and functional profile of the heart of Spanish football referees of national category who belong to the Inter-Insular Football of Las Palmas (FIFLP).

Material and methods

The sample consisted of 54 national category football referees examined during the 2008/2009 season. All of them had at least five years of seniority practice as referees in national categories and participated weekly in official events. Moreover, they had previous experience in the performance of physical and medical evaluation protocols, since they needed to succeed in the annual tests to renew their federal licenses. The average age of the referees was 28.52±6.39 (19-45) years, with a height of 1.76±0.07 (1.55-1.90) m, a body mass of 77.26±10.74 (50-98) kg and a body mass index of 24.90±2.73 (17.30-31.51) kg/m^2.

The subjects carried out a previous medical examination to prove that they had no cardiovascular pathology in their medical history or symptoms which could condition their participation in the research. All of them signed an informed consent whereby they accepted to take part in the study. This study was carried out according to the ethics principles contained in Helsinki's statement of World Medical Association for the research with human beings.

The echocardiographic studies were carried out with a Toshiba Sonolayer SSH-140A echocardiograph (Toshiba Medical System Inc, Japan), which incorporates a mono and bidimensional image and a pulsed-wave and continuous colour Doppler. Measurements were carried out by following the American Society of Echocardiography (ASE) guidelines.[16]

The measured echocardiographic parameters were the systolic (SDLV) and diastolic diameter (DDLV) of the left ventricle, the diameter of the left atrium (DLA) and the posterior wall of the left ventricle thickness (PW) and the interventricular septum thickness (IVT). From these measurements, calculations were made to determine the necessary functional indicators and echocardiographic indexes according to the following equations:

— Diastolic volume of left ventricle: DVLV = DDLV^3 * 1.05

— Systolic volume of left ventricle : SVLV = SDLV^3 * 1.05

— Ejected volume: EV = DVLV - SVLV

— Shortening fraction: Sf = ((DDLV-SDLV)/ DDLV) * 100

— Ejection fraction: Ef = ((DDLV^3 – SDLV^3)/ DDLV^3) * 100

— The left ventricle mass was calculated with the equation provided by Devereux[17-18], where: LVM = 1.04 * [(DDLV+ PW + IVT)^3 - (DDLV)^3] – 13.6.

— Asymmetric septal hypertrophy index: ASHI = IVT / PW

— Concentric hypertrophy of the left ventricle index: CHLVI= PW / DDLV

— H/R index = (IVT + PW) / DDLV

Statistical analysis

The statistical package SPSS for Windows version 14.0 (SPSS, Inc, Chicago, IL) was used for the analysis of the data. Descriptive statistics (means, medians, typical deviations and maximum and minimum ranges of the corresponding values) were employed to study the different variables.

Results

The basal cardiocirculatory system parameters were the following: heart rate at rest (HR) 58.55±7.36 [40-80] beats·min^{-1}, diastolic arterial pressure (DAP)

TABLE I.—*Basic cardiocirculatory and echocardiographic data of the referees (N.=54).*

Variable	HR (beats·min^{-1})	DAP (mmHg)	SAP (mmHg)	SDLV (mm)	DDLV (mm)	PW (mm)	IVT (mm)
MEAN	58.55	73.86	115.00	33.74	50.03	9.47	9.77
SD	7.36	9.12	10.91	5.23	4.79	1.57	1.53
MIN	44.00	60.00	100.00	21.60	42.20	4.50	5.00
MAX	80.00	95.00	140.00	42.80	60.00	11.70	12.00

HR: heart rate; DAP: diastolic arterial pressure; SAP: systolic arterial pressure; SDLV: systolic diameter left ventricle; DDLV: diastolic diameter left ventricle; PW: posterior wall thickness left ventricle; IVT: interventricular septum thickness.

TABLE II.—*Echocardiographic structure and functional indexes of the referees (N.=54).*

Variable	DVLV (mL)	EVI (mL/m^2)	Sf (%)	Ef (%)	LVM (g/m^2)	ASHI	CHLVI	H/R I
MEAN	135.09	47.34	32.75	68.73	112.80	1.05	0.19	0.39
SD	39.63	12.44	6.62	8.88	26.53	0.22	0.03	0.06
MIN	78.91	20.55	20.38	49.52	43.96	0.65	0.09	0.19
MAX	226.80	75.68	49.30	86.96	160.00	2.00	0.24	0.51

DVLV: diastolic volume of left ventricle; EVI: ejected volume index; Sf: shortening fraction; Ef: ejection fraction; LVM: left ventricle mass; ASHI: Asymmetric septal hypertrophy index; CHLVI: concentric hypertrophy of left ventricle index; H/R I: H/R index.

73.86±9.12 (60-95) mmHg and systolic arterial pressure (SAP) 115.00±10.91 [100-140] mmHg. The most relevant cardiocirculatory and echocardiographic data (structure indicators) are shown in Table I. The systolic diameter of the left ventricle was 33.74±5.23 (22-43) mm, whereas the diastolic diameter of the left ventricle averaged 50.03±4.79 (42.2-60) mm and the diameter of the left atrium 29.84±4.06 (20-42) mm. The average thickness observed for the interventricular septum was 9.77±1.53 (5-12) mm, while the posterior wall of the left ventricle was 9.47±1.57 (5-12) mm (Table I).

The average diastolic volume of the left ventricle was 135.09±39.63 (79-227) mL. Furthermore, the ejected volume averaged 91.91±26.22 (39-152) mL and the ejected volume index related to the body surface of each subject was 47.34±12.44 (21-76) mL·m^{-2}. The average calculations of the shortening fraction and the ejection fraction of the sample were 32.8±6.6 (20-49)% and 68.7±8.9 (50-87)%, respectively. These echocardiographic structural and functional indexes are shown in Table II. The average values of the LVM were 219.32±57.12 (86-349) g. The value related the body surface of each subject showed a mean value of 112.80±26.53 (44-160) g·m^{-2}. The average values of the CHLV, ASH and H/R indexes were 0.19±0.03 (0.09-0.24), 1.05±0.22 (0.65-2) and. 0.39±0.06 (0.19-0.51), respectively (Table II).

Discussion

There are various studies which have employed echocardiography for the structural and functional research of the sportspeople heart,[1, 19, 20] whereas few studies have analyzed the heart of football referees.[22-24] When structural and functional adaptations take place in a football referee we must think of changes caused by their professional activity and by the effect of the physical workloads used in the training sessions. This will be more frequent among those subjects who carry out a greater volume of training and have been refereeing for longer time. The chronological age of the referees subjected to study (28.5 years) was slightly lower than those reported in other studies that have analyzed football referees of the same level.[7, 9, 25] This difference is even greater regarding top-class referees selected for the final round of international tournaments, with a mean age of around 40 years.[14, 15, 26] With respect to the morphological characteristics, the body mass index averaged 24.9 kg·m^{-2} which is a lower value than those reported in other studies carried out with professional soccer referees.[7, 9]

The basal values of the cardiocirculatory system found showed a moderate bradycardia (58.55±7.36 beats·min^{-1}), characteristic of subjects who perform prolonged activities of low and moderate intensi-

ty. The average HR data of the actual referees were slightly lower than those reported by Galanti *et al*.[23] for 35 first division referees and 35 elite Italian players (61.7±16.9 and 59.3±8.6 beats·min^{-1}, respectively). The average values of diastolic and systolic arterial pressure were within the population's reference values regarded as normotensive (DAP: 73.86±9.12 mmHg; SAP: 115.00±1.91 mmHg) but slightly lower than those of the Italian referees previously reported.[23]

In our study, the echocardiographic structural parameters showed results (SDLV: 33.74±5.23 mm; DDLV: 50.03±4.79 mm; PW: 9.47±1.57 mm; IVT: 9.77±1.53 mm) similar to those reported by Galanti *et al.*[23] (SDLV: 32.8±2.7 mm; DDLV: 54.2±3.5 mm; PW: 9.24±0.6 mm; IVT: 9.78±0.6 mm). This study [23] reported that the diameters of the ventricular chambers (SDLV and DDLV) were bigger in referees than in football players, although the thickness of IVT and PW were bigger in players than in referees. According to these authors this could be due to the different training physical workloads used by both players and referees, as football referees trained on average 3.6 times a week whereas players trained 5.6 times a week. The data of our subjects are more similar to those we can find among sportspeople than those presented in sedentary subjects. The comparison of the SDLV values reported in the literature seems controversial. The discrepancies found in the echocardiographic results of the sportsmen caused by training can be partially explained by the methodology of the evaluation and the resolution power of the echocardiographic method used in the studies.[1] In some studies, the SDLV shows a significant increase in sportsmen, whereas in other studies this increase only occurs in certain sports modalities (strength).[1] On several occasions we can see that there are not significant differences between sedentary and sportspeople, or else we can even see that in the latter the values are significantly lower.[3] In our study, with the exception of some cases with higher values than those registered in the sedentary population, the values can be considered within normality.

The mechanical effect generated in the heart by the increase of the cardiac rhythm involved in the exercise should enhance the cardiac chambers and, consequently, increase the diameters of both the atrium and ventricles. A meta-analysis carried out by Pluim *et al*.[19] showed that there are differences in the diameters of the left ventricular chamber and the thickness of the interventricular septum of the practitioners of the different sports modalities. However, the average values found in these studies did not exceed the normal dimensions assumed for the sedentary population. Probably, relevant changes would only be found in the diameter of sportspeople with a high volume of aerobic training. In our study, we found a left atrium diameter of 29.84±4.06 mm, which implies significantly lower values than those registered in the study by Pellicia *et al*.[27] Complementarily, the thickness of the PW and IVT in sportspeople shows significant differences when compared to sedentary population. The average values of football referees were 9.47±1.57 mm and 9.77±1.53 mm for PW and IVT, respectively. In the present study, only two of the referees (3.7%) showed a IVT equal to 12 mm. The increase in the thickness of the PW and IVT, alongside with the physiological relation between the septum and the posterior wall is an indicator of physiological hypertrophy of the heart.[28] In a study of almost 1000 elite sportspeople of both sexes and 27 different modalities, Pellicia *et al*.[27] found that only 16 subjects (2.2%) presented a septal thickness greater than 12 mm. Most of the echocardiographic studies with sportspeople show 12 mm as a value of normality, being frequent to find higher values among sportspeople.[29] In the light of this research, we can point out that the average values of hypertrophy of the cardiac walls which we found in our sample were within the normality for the sedentary or moderate trained subjects, which is far from what it is usual described for top-level sportspeople.

The average value of the left ventricular mass (219.32±57.12 g) lies within the boundaries (194–325 g) established by different research on sportsmen, although representing a lower value than that reported by Galanti *et al*.[23] in football referees (231±37.1 g) and players (268.5±40.4 g). These values were similar to those reported by other authors[2] for sprint athletes (224±46.9 g), but clearly lower than those found by the same author in endurance sports specialists (287±81.2 g). However, when we analyze this parameter with respect to the body surface, the average value (112.80±26.53 g/m^2) was similar to that reported by Galanti *et al*.[23] for referees (115.1±16.7 g/m^2). The average of our sample was slightly lower than that considered as normal by some authors[30] who set out 134 g/m^2 as the average value with maximum limits of 163 g/m^2 for males.

To study the cardiac adaptive response to training workloads it is habitual to use the cardiac hypertrophy indexes (ASH, CHLV and H/R) as a criterion. The average value of the CHLV index reported by our sample (0.19±0.03) was significantly lower than those reported by some authors [31] who suggested ranges from 0.30 to 0.45 for sportspeople, likely to be higher than these in predominantly anaerobic sports. The average value of the ASH index in the actual study (1.05±0.22) lies within the ranges of normality described. This index relates the thickness of the ventricular septum and the posterior wall of the left ventricle, considering values of normality between 0.9 and 1.3.[31] This relationship (PW *vs.* IVT) does not change when bringing the trained and untrained population face to face. In our study, the average value of the H/R index was 0.39±0.06, which means a predominance of the cardiac chambers with respect to the thickness of their walls. The H/R index, which shows the sum of the walls divided by the diastolic diameter of the left ventricle, presents higher values than 0.36 in anaerobic sports and lower than 0.32 in those of aerobic predominance.[31]

The increase of the cardiac chambers in sportspeople leads to a potential increase of its maximum volumes. We must take into account that the diastolic volume of the left ventricle is an excellent functional indicator of the aerobic capacity of a subject. In our study we found that football referees present an average value of VDVI (135.09±39.63 mL) similar to those reported by Almenares *et al*.[31] for Olympic judo experts. A functional indicator closely related to the capacity of performance of a sportsperson, and especially with the cardiac debilitation is the ejected volume [32, 33] which represents the difference between the final diastolic volume and the final systolic volume. The EV obtained in this study (91.91±26.22 mL) is similar to that reported for Cuban Olympic judo experts.[31] The average values of EV which are proposed by the previous authors for sportspeople lie between 65-80 mL, which appear to be lower than those provided in other studies. The indicators of the systolic function of the left ventricle, the shortening fraction (Af) and the ejection fraction (Ef), showed 25-50% higher values in the actual referees than those regarded as of normality (Af: 32.75±6.62 *%;* Ef: 68.73±8.88 %). However these values are in the range of those presented for other sportsmen.[33]

Conclusions

The results of the present study show that the national category Spanish referees have an adequate structure and functional adaptation of the heart to the training workloads of an aerobic type, showing an increase of the cardiac chambers without hypertrophy of the left ventricle walls. The values of the left ventricular chambers and walls obtained by the sample were similar to those found in football referees of a professional level. In addition, this study shows that the echocardiographic profile of football referees is characterized by showing an increase of the left ventricular mass caused by an increase of the cardiac chambers and, a normal systolic and diastolic function. The values obtained by football referees were higher than those found in the sedentary and lower than those of professional football players. These differences could be due to the different training workloads employed by football players and referees.

References

1. Calderón Montero FJ, Benito Peinado PJ, Di Salvo V, Pigozzi F, Mafulli N. Cardiac adaptation to training and decreased training loads in endurance athletes: a systematic review. Br Med Bul 2007;1-11.
2. Calderón FJ. Análisis comparativo mediante ecocardiografía doppler color entre atletas de resistencia y velocidad. Tesis Doctoral. Facultad de Medicina. Universidad Complutense de Madrid; 1991.
3. Molina Ll, Pons S. Ecocardiografía del deportista. In: Bayés de Luna A, Furlanello F, Maron BJ, Serra Grima JR, editors. Cardiología deportiva. Barcelona: Mosby-Doyma; 1994. p. 62-83.
4. D'Ottavio S, Castagna C. Physiological load imposed on elite soccer referees during actual match play. J Sports Med Phys Fitness 2001;41:27-32.
5. Castagna C, Abt G, D'Ottavio S. Relation between fitness tests and match performance in elite Italian soccer referees. J Strength Cond Res 2002;16:231-5.
6. Weston M, Brewer J. A study of the physiological demands of soccer refereeing. J Sports Sci 2002;20:59-60.
7. Da Silva AI, Fernandez R. Dehydration of football referees during a match. Br J Sport Med 2003;37:502-6.
8. Castagna C, Abt G, D'Ottavio S, Weston M. Age-related effects on fitness performance in elite-level soccer referees. J Strength Cond Res 2005;19:785-90.
9. Fernández GE, Da Silva AI, Arruda M. Perfil antropométrico y aptitud física de árbitros del futbol profesional chileno. Int J Morphol 2008;26:897-904.
10. Castagna C, D'Ottavio S. Effect of maximal aerobic power on match performance in elite soccer referees. J Strength Cond Res 2001;15:420-5.
11. Krustrup P, Bangsbo J. Physiological demands of top-class soccer refereeing in relation to physical capacity: effect of intense intermittent exercise training. J Sports Sci 2001;19:881-91.
12. Mallo J, Navarro E, García-Aranda JM, Gilis B, Helsen, W. Activity

profile of top-class association football referees in relation to performance in selected physical tests. J Sports Sci 2007;25:805-13.
13. Mallo J, Navarro E, García-Aranda JM, Gilis B, Helsen W. Analysis of the kinematical demands imposed on top-class assistant referees during competitive soccer matches. J Strength Cond Res 2008;22:235-42.
14. Mallo J, Navarro E, García-Aranda JM, Helsen W. Activity profile of top-class association football referees in relation to fitness-test performance and match standard. J Sports Sci 2009;27:9-17.
15. Mallo J, Navarro E, García-Aranda JM, Helsen W. Physical Demands of top-class Soccer Assistant Refereeing during High-standard Matches. Int J Sports Med 2009;30:331-6.
16. Sahn DJ, DeMaría A, Kisslo J, Weyman A. Recommendations regarding quantitation in M-mode echocardiography: results of a survey of echocardiographic measurements. Circulation 1978;58:1072-83.
17. Devereux RB, Reichek N. Echocardiographic determination of left ventricular mass in man: anatomic validation of the method. Circulation 1977;55:613.
18. Devereux RB. Detection of left ventricular hypertrophy by Mmode echocardiography. Anatomic validation, standardization and comparison to other methods. Hypertension, 1987; 20:1251-60.
19. Pluim BM, Zwinderman AH, van der Laarse, van der Wall E. The athlete's heart. A meta-analysis of cardiac structure and function. Circulation 2000;101:336-44.
20. Abernethy WB, Choo JK, Hutter AM Jr. Echocardiographic characteristics of professional football players. J Am Coll Cardiol 2003;41:280-4.
21. Catterall C, Reilly T, Atkinson G, Coldwells A. Analysis of work rate and heart rates of association football referees. Br J Sports Med 1993;27:153-6.
22. Reilly T, Gregson W. Special populations: the referees and assistant referees. J Sports Sci 2006;24:795-801.
23. Galanti G, Pizzi A, Lucarelli M, Stefani L, Giannassi M, Di Tante V *et al.* The cardiovascular profile of soccer referees: an echocardiographic study. Cardiovasc Ultras 2008;6:8.
24. Hevia AC, Fernández MM, Palacio JMA, Martín EH, Castro MG, Reguero JJR. ECG as a part of the pre-participation screening programme: an old and still present international dilemma. Br J Sports Med 2010 [Epub ahead of print].
25. Rontoyannis GP, Stalikas A, Sarros G, Vlastaris A. Medical, morphological and funcional aspects of Greek football referees. J Sports Med Physical Fitness 1998;38:208-14.
26. Helsen W, Bultynck JB. Physical and perceptual cognitive demands of top-class refereeing in association football. J Sports Sci 2004;22:179-89.
27. Pelliccia A, Barry J, Maron D, Spataro A, Proschan M, Spirito P. The upper limit of physiologic cardiac hypertrophy in highly trained elite athletes. N Engl J Med 1991;324:295-301.
28. Galanti G, Scarti L, Castellani S, Toncelli L. Application of new criteria of left ventricular hypertrophy in a population of athletes. Cardiologia 1987;32:383-7.
29. Fagard RH. Athlete's heart: a meta-analysis of the echocardiographic experience. Int. Journal Sport Med 1996;17:S140.
30. Magnani B. Hipertrofia cardiaca fisiológica e patológica. Ital Heart J 2000;Suppl 2:42-9.
31. Almenares MA, Berovides O, Silva J, González J, Vargas ER. Evaluación ecocardiográfica en judocas olímpicos. Rev Int Med Cienc Act Fís Deporte 2006;6:1-16.
32. Erol MK, Ugur M, Yilmaz M, Acikel M, SevimLi S, Alp N. Left atrial mechanical functions in elite male athletes. Am J Cardiol 2001;88:915-7.
33. Fisman EZ, Pellicia A, Motro M, Auerbach I, Frank AG, Tenenbaum A. Intensive resistance training on isotonic exercise doppler indexes of left ventricular systolic function. Am J Cardiol 2002;1:887-91.