REVISTA ESPAÑOLA DE FISIOLOGIA, 46 (3), 255-260, 1990

Variations Caused by Physical Training in the Electrocardiographic Outline of Swine (Landrace X White Belgian)

J. Ibáñez, M. D. Rubio, P. Tovar, F. Castejón and R. Santisteban*

Departamento de Biología Animal
Sección de Fisiología Animal
Facultad de Veterinaria
14005 Córdoba (Spain)

(Received on February 13, 1990)

J. IBÁÑEZ, M. D. RUBIO, P. TOVAR, F. CASTEJÓN and R. SANTISTEBAN. *Variations Caused by Physical Training in the Electrocardiographic Outline of Swine (Landrace × White Belgian).* Rev. esp. Fisiol., 46 (3), 255-260, 1990.

To find the effect of exercise on the ECG, the electrocardiographic outlines in a training group of 7 two-month-old pigs (Landrace X White Belgian) were analyzed, compared with a nontraining control group of similar characteristics. In training animals a resting bradycardia was observed with a corresponding increase in the duration of the RR interval, as well as a duration increase in the ventricular activation time. On the contrary, the programmed training in this experiment has not influenced the amplitude of the electrocardiographic waves and the magnitude and orientation of the cardiac vectors.

Key words: Cardiac activation, Exercise, Heart, Pig, ECG.

Electrocardiography is an important mode of diagnosis for the detection of cardiac hypertrophy in species from category I (primates, carnivores and rodents) since the activation of both ventricles largely contributes to the production of the potentials on the body surface. However, in animals of category II (swine, ruminants and equines) in which the Purkinje fibres penetrate more deeply into the ventricular myocardium, the greater portion of the ventricular walls are activated in one «burst» of depolarization which originates an electrocardiographic «silence» (12, 13) rendering the electrocardiographic interpretation of the cardiac hypertrophy in these species difficult.

Cardiac hypertrophy can be defined as an increase in the heart mass but not of the number of myocardial cells since the ability of the cardiac muscular fibre to split up rapidly ceases after birth (14). Physical exercise is one of the causes of cardiac hypertrophy as it originates an increase in the effort made by the cardiac muscle to pump a greater quantity of blood to the rest of the body. In humans the conse-

* To whom all correspondence should be addressed.

quences of physical exercise on the heart have been closely studied in the world of sport, especially the type of exercise most likely to cause a determinate type of hypertrophy. In the case of long-distance runners the heart tends to increase the cardiac cavity and maintain the thickness of the wall (dilatation), whilst in track runners the cavity remains normal and the thickness of the cardiac muscle increases (hypertrophy) (9).

In individuals of category I, such as dog and man, the alterations produced by cardiac hypertrophy in the electrocardiographic outline have been very well determined (2, 6, 8, 10, 20). However, in individuals of category II these alterations have rarely been specified. The aim of this study, therefore, is to elucidate if the possible hypertrophy caused by physical exercise in swine is electrocardiographically detectable.

Materials and Methods

Fourteen pigs, apparently healthy, 2 months old at the beginning of the experiment were used (6 males and 8 females Landrace × White Belgian). The animals were divided into two groups of 7 individuals each in order to have one experimental group (training group) and the other as a control (nontraining group). Both groups were formed without taking sex into consideration because it had previously been demonstrated that there were no electrocardiographic differences between males and females (4, 17, 18, 21).

The first group was daily subjected to a trot whose duration was increased as described: 2 min during the 1st week; 4 min during the 2nd week; 8 min during the 3rd week; and 15 min from the 4th week.

The experiment lasted 14 weeks. At the beginning of the training program an initial electrocardiographic test was made both on the training group and on the nontraining group. Subsequently, a test was made every fortnight, and therefore 8 tests for each individual were obtained.

The electrocardiographic outlines were carried out with a Cardioline electrocardiograph, with three channels for the recording of bioelectric signals, a circuit of filters for muscular tremors and thermic pen writing on thermosensitive paper. The paper speed was 50 mm/s and a graduated sensitivity of 10 mm/s.

The lead system employed was the semiorthogonal one described by HAMLIN and SMITH (11) constituted by leads I, aVF and V_{10}. The electrodes were placed by the subcutaneous implantation of needles on both elbow joints (lead I), on the left stifle joint (lead aVF) and on the spinal process of the seventh thoracic vertebrae (lead V_{10}).

The ECG were recorded, with the animal in right lateral decubits, insulated from the ground and by prior immobilization through intramuscular administration of azaperone at a dose between 4 and 8 mg/kg b.w. according to the age of the animals (4 mg/kg b.w. up to 3 months of age and 8 mg/kg b.w. from that age).

In the ECG obtained the following details were analyzed: the heart rate, the amplitude and morphology of electrocardiographic waves, the duration of the different electrocardiographic segments and intervals, and the magnitude and orientation of the cardiac vectors both on the horizontal plane and in space.

In the statistical analysis a t-Student test was carried out to find out if there were any electrocardiographic differences between sexes in the initial testing. As there were none the statistical analysis was then made without any distinction between the sexes. The basic statistics of all parameters studied (mean ± S.D.) were obtained. A variance analysis (ANOVA) was made among the tests of each group in order to determine which electrocardiographic parameters presented significant differences. Lastly, the t-Tukey test established significant differences between tests with a maximun error of 0.05. Likewise, an ANOVA test to compare both training and nontraining groups was applied in order to detect differences due to physical training.

Results

The ANOVA test, if the 8 tests conducted are considered together shows significant differences for heart rate ($F(7, 48) = 3.51$; $p \leq 0.01$) in the training individuals. The t-Tukey test indicates that the differences exist between the initial and the last test ($p \leq 0.01$) (fig. 1A). In the nontraining group these differences do not exist (fig. 1B).

By comparing both training and nontraining groups at the same stage, it is seen that the heart rate in the last test is significantly lower ($p \leq 0.05$) in the group subjected to physical training (fig. 1). The same results are obtained for the RR interval, but its duration in the last test of training is greater with respect to the inverse relation with the heart rate (fig. 2).

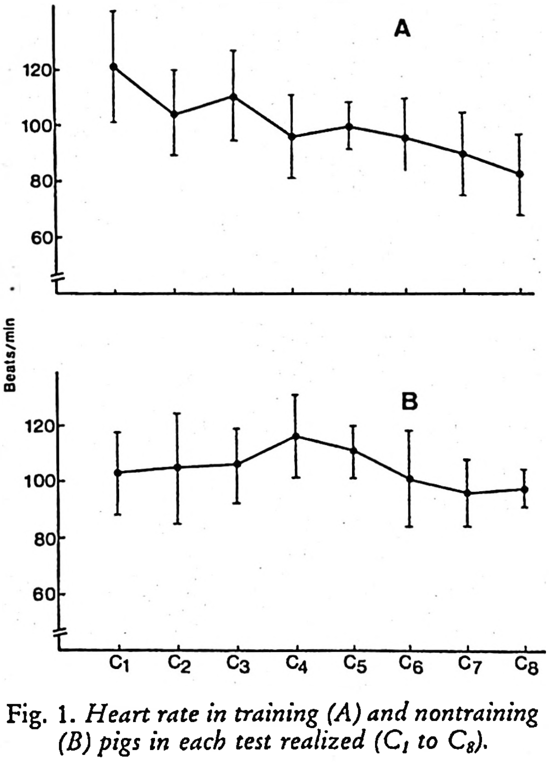

Fig. 1. *Heart rate in training (A) and nontraining (B) pigs in each test realized (C_1 to C_8).*

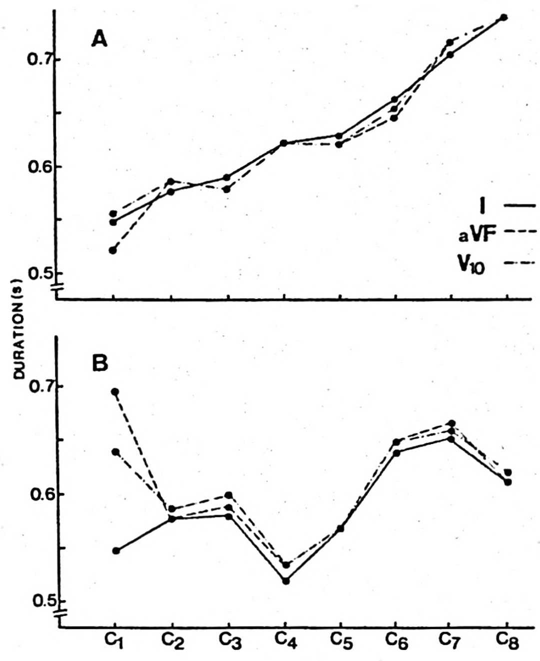

Fig. 2. *RR interval duration in training (A) and nontraining (B) pigs in each test realized (C_1 to C_8).*

The ANOVA test in both training ($F(7, 48) = 3.46$; $F(7, 48) = 4.42$; $F(7, 48) = 6.28$, in I, aVF and V_{10} leads) and nontraining groups ($F(7, 48) = 4.42$; $F(7, 48) = 6.20$, in aVF and V_{10} leads) gives significant differences ($p \leq 0.01$) for the QRS interval when data of 8 tests are considered together. In trained individuals the QRS interval of 2nd test is significantly ($p \leq 0.05$) lower than that obtained in the 5th, 6th and 7th tests in lead I. In lead aVF the differences exist between the initial and the 3rd, 4th, 5th, 6th, 7th and 8th tests ($p \leq 0.05$). Likewise, in V_{10} lead the QRS interval at the initial test is signifi-

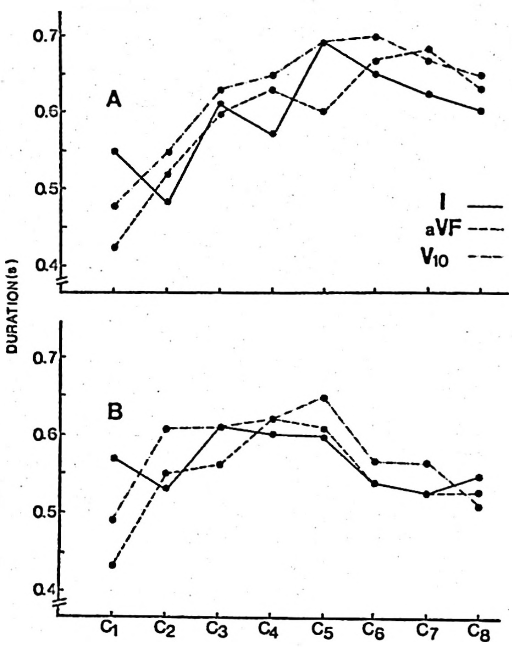

Fig. 4. *R wave duration in V_{10} lead in training and nontraining pigs in each test realized (C_1 to C_8).*

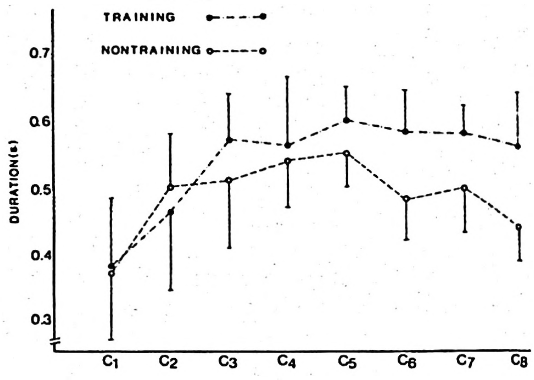

Fig. 3. *QRS interval duration in training and nontraining pigs in each test realized (C_1 to C_8).*

cantly lower ($p \leq 0.01$) than that obtained in tests 3rd to 8th, and the differences also appear ($p \leq 0.05$) when the 2nd test is compared with tests 4th to 8th (fig. 3A). In the nontraining group the QRS duration at the initial test is significantly lower ($p \leq 0.05$) than that registered in tests 2nd to 6th in aVF and V_{10} leads (fig. 3B).

When both training and nontraining tests in the same stage are compared, a greater duration for QRS in training individuals is seen from 5th test ($p \leq 0.05$) by using the lead I, and from 6th test ($p \leq 0.05$) with the aVF and V_{10} leads to the conclusion of the experiment (fig. 3).

For the R wave duration, the ANOVA test shows that this parameter experienced variation along the experiment in both training and nontraining ($F(7, 48) = 5.11$; $p \leq 0.01$) groups in V_{10} lead. In two groups the R duration value at the initial test is significantly lower than that obtained in the remaining tests ($p = 0.01$). Lastly, the comparison of training and nontraining tests at the same stage shows that significant differences exist from 6th test to the conclusion of the experiment ($p = 0.05$) with a greater duration for R wave in training individuals (fig. 4).

In the remaining electrocardiographic parameters no significant differences are observed.

Discussion

The heart rate shows a significant decrease when comparing the first and last tests in the group of training animals as well as when comparing training and nontraining animals. However, in the group of nontraining animals no significant differences appear.

The heart rate decrease found indicates the appearance of a resting bradycardia which develops as exercise progresses. FOX and MATHEW (9) indicated that this factor in athletes can be attributed to an increase in the parasympathetic influence secondary to a primary decrease in the sympathetic activity with the exercise. This theory is completed by BADEER (1) and SIGRADSSON *et al.* (19) who point out that the resting bradycardia is due to a slowing —down of the sinoatrial rhythm caused by an increase in the amount of acetylcholine and a decrease in sensitivity to the catecholamines with the exercise.

Parallelly to the decrease in the heart rate, an increase in the RR interval appears due to the close relationship between both parameters.

The duration of the QRS interval shows significant differences from the 6th test when comparing the training and non-training individuals. Also, the differences are significant when comparing the different stages in each one of the groups. Therefore, the differences within the same group can be attributed to physical maturation (17) whilst those that appear between both groups are caused by the effect of the physical training.

Several authors reported for humans (6, 8, 10), dogs (2, 20) and horses (15) that one of the predominating signs of ventricular hypertrophy is the duration increase of the QRS interval. TILLEY (20) attributed the increase in the duration of the ventricular activation in dogs to an increase in the cardiac muscular mass.

The duration ot the R wave in lead V_{10} shows significant differences when the initial test is compared with the rest of the tests in both groups. There are also differences between the training group and the nontraining group from the 6th test. These differences can be attributed to an increase in the mass of the ventricles as a consequence of the physical training, whilst the differences appearing in the non-training group of individuals can be attributed to physical maturation which coincides with the finding of RUBIO (17). The influence of the physical training on the duration of the R wave in lead V_{10} cannot be contrasted with other authors because of the lack of data on this parameter in the literature consulted.

In this experiment no significant amplitude differences appeared between the training and the no-training groups. However, TILLEY (20) and BOLTON (2) observed an increase of the amplitude in ventricular hypertrophy in dogs, although others (8, 10) revealed that interpretations based on the amplitudes were misleading due to the variability of the amplitude according to the conditions in which recording was carried out. LITTLEWORT (15), likewise, did not find any variation of amplitude in ventricular hypertrophy in horses.

The absence of any alteration in the amplitude of the wave in cardiac hypertrophy in individuals of the category II may be due to the high degree of cancellation with which the depolarization of the ventricle is carried out (11).

The magnitude and orientation of the cardiac vectors both on the horizontal plane and in space do not produce any significant differences caused by training, in contrast to those found for dogs (2, 20) and for horses (15). This lack of differences is explained either because the physical effort to which the animals have been subjected is not intensive enough to cause the deviation of the electric axis or because that training causes a generalized hypertrophy without affecting any particular heart cavity so that the vector maintains its initial position.

The morphology of the waves was not seen to be affected by training since there are no differences between the training and nontraining individuals. Furthermore the waves obtained in this experiment, especially for the QRS interval, coincide with those obtained by other authors (7, 16, 17) in untrained swine. These authors observed the great uniformity of the QRS morphology in lead V_{10} and the great variability in the limb leads. However, in horses there are differences on the morphology of the electrocardiographic waves when the animals perform a physical exercise (3-5).

Resumen

Con el fin de establecer las diferencias producidas por el entrenamiento físico sobre el ECG, se analizan los trazados electrocardiográficos de 14 cerdos (Landrace X Blanco Belga), 7 de los cuales se someten a entrenamiento y 7 se utilizan como grupo control. En los animales ejercitados se observa una bradicardia en reposo, con el consiguiente aumento en la duración del intervalo RR, así como un aumento progresivo en la duración del tiempo de activación ventricular. Por el contrario, el ejercicio programado no influye en la amplitud de las ondas electrocardiográficas, ni en la magnitud y orientación de los vectores cardíacos.

Palabras clave: Activación cardíaca, Cerdo, Corazón, Ejercicio, ECG.

References

1. Badeer, M. S.: In «The Metabolism of Contraction» (Roy, P. E. and Roner, G., eds.). University Park Press. Baltimore, 1975. pp. 553-560.
2. Bolton, G. R.: «Handbook of Canine Electrocardiography» (Edwards, N. J., ed.). W. B. Saunders Company. Philadelphia, 1987.
3. Castejón, F.: *Hygia pecoris*, 2, 69-101, 1978.
4. Castejón, F.: *Hygia pecoris*, 5, 101-127, 1978.
5. Castejón, F., Herrera, F., Santisteban, R. and Riber, C.: *Arch. Zootecnia*, 32, 145-158, 1983.
6. Dubin, D.: In «Electrocardiografía práctica: lesión, trazado e interpretación» (3.ª ed.). Interamericana. Madrid, 1982. pp. 189-204.
7. Dukes, T. W. and Szabuniewicz, M.: *Can. J. Comp. Med.*, 33, 118-127, 1969.
8. Estella, J.: In «Manual de electrocardiografía: vecto, fono y mecanocardiografía» (6.ª ed.). Gráficas Cervantes. Salamanca, 1976. pp. 46-51.
9. Fox, E. L. and Mathews, D. K.: In «The Physiological Basis of Physical Education and Athletics». Saunders Ed. CBS College Publishing. Philadelphia, 1981. pp. 300-301.
10. Goldman, M. J.: In «Principios de electrocardiografía clínica» (5.ª ed.). Manual Moderno, S.A. Mexico, 1975. pp. 88-114.
11. Hamlin, R. L. and Smith C. R.: *Am. J. Vet. Res.*, 21, 701-708, 1960.
12. Hamlin, R. L. and Smith, C. R.: *Ann. N. Y. Acad. Sci.*, 127, 195-203, 1965.
13. Hamlin, R. L. and Smith, C. R.: *Ann. N. Y. Acad. Sci.*, 127, 609-619, 1965.
14. Jubb, K. V. F., Kenedy, P. C. and Palmer, N.: In «Pathology of Domestic Animals» (3rd ed.). Academic Press. London. Vol. 3. 1985. pp. 2-5.
15. Littlewort, M. C. G.: In «Equine Surgery and Medicine» (Mansmann, R. A., McAllister, E. S. and Pratt, P. W., eds.). Academic Press. London, 1986, 2, 40-60.
16. Ranucci, S. and Ranucci, H.: *Riv. Zoot. Vet.*, 9, 91-95, 1981.
17. Rubio, M. D.: «Evolución ontogénica de las variaciones electrocardiográficas en la especie porcina (*Sus scrofa*)». Doctoral These. Facultad de Veterinaria. Universidad de Córdoba, 1987.
18. Santisteban, R.: «Estudio electrocardiográfico en bovinos Holstein-Frisia». Doctoral These. Facultad de Veterinaria. Universidad de Córdoba, 1984.
19. Sigradsson, K., Sranfeld, E. and Kilbom, A.: *Acta Physiol. Scand.*, 101, 481-488, 1977.
20. Tilley, L. P.: «Essentials of Canine and Feline Electrocardiography» (2th ed.). Lea & Febiger. Philadelphia, 1985. pp. 57-71.
21. Tovar, P.: «Estudio electrocardiográfico en ovinos». Doctoral These. Facultad de Veterinaria. Universidad de Córdoba, 1984.