Prevalence and dynamic changes of vagotonic T waves during exercise in elite soccer player population

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Summary

Introduction: The characteristics of the athlete's electrocardiogram are still today the subject of multiple publications whose physiological meaning has been clarified as the different variants have been correlated with a sophisticated cardiological evaluation and a prolonged follow-up. There are different alterations of repolarization described in the sports population, among them the most frequently reported in the literature are: early repolarization, vagotonic T waves, ST-T alterations, etc. Vagotonic T waves are a common finding in the athlete population, although currently, the dynamic changes of this finding during exercise, have an uncertain meaning. The aim of our study was to determine its prevalence in a population of elite athletes and analyze their behavior at different stages of the exercise.
Methods: A population of 91 male, professional soccer players of a team of the first division of the Spanish football league (age 26 years ± 4.49 years) were analyzed. The presence of vagotonic T waves was assessed at baseline electrocardiogram and their association with different electrocardiographic and echocardiographic variables was also analyzed. The dynamic changes of the morphology of these waves were studied at different stages during a maximal effort trial.
Results: The presence of vagotonic T waves was identified in the baseline ECG in 14 (15%) subjects. In 13 out of 14 athletes (92%), a dynamic behavior of the vagotonic waves was observed. It had a progressive disappearance during exercise and it reappeared at the early stages of recovery, with similar voltages to that observed at the baseline electrocardiogram.
Conclusions: This study evidence that vagotonic T waves are mainly due to the predominance of parasympathetic tone. The exercise can be considered a useful strategy when study.

Key words:
Vagotonic T waves. Athlete. Electrocardiogram. Cardiology sport.

Prevalencia y cambios dinámicos de las ondas T vagotónicas durante el ejercicio en una población futbolista de élite

Resumen

Introducción: Las características del electrocardiograma del deportista son aún hoy en día objeto de múltiples publicaciones cuyo significado fisiológico se ha ido esclareciendo a medida que se han correlacionado las diferentes variantes con una evaluación cardiológica sofisticada y un seguimiento prolongado. Existen diferentes alteraciones de la repolarización descritas en la población deportista. Las ondas T vagotónicas son un hallazgo frecuente en esta población, aunque la dinámica de dichos hallazgos durante el ejercicio tiene actualmente un significado incierto. El objetivo de nuestro estudio fue determinar su prevalencia en una población de deportistas de élite y analizar su comportamiento en diferentes estadíos del ejercicio.
Métodos: Se analizó una población de 91 futbolistas profesionales varones de un equipo de la máxima categoría de la liga de futbol española (edad 26 años ± 4,49 años). Se evaluó en el electrocardiograma basal la presencia de ondas T vagotónicas, así como su asociación con diferentes variables electrocardiográficas y ecocardiográficas. Además, se estudió la dinámica de la morfología de estas ondas durante las distintas etapas de una prueba de esfuerzo maximal.
Resultados: Se identificaron 14 sujetos (15%) con presencia de ondas T vagotónicas en el ECG basal. En 13 de los 14 atletas (92%) se objetivó un comportamiento dinámico de las ondas, con desaparición progresiva durante el esfuerzo y posterior reaparición desde etapas precoces de la recuperación, con voltajes similares al electrocardiograma basal.
Conclusiones: Este estudio evidencia que las ondas T vagotónicas se deben fundamentalmente al predominio del tono parasimpático. El ejercicio puede considerarse una estrategia de gran utilidad a la hora de su estudio.

Palabras clave:
Ondas T vagotónicas. Atleta. Electrocardiograma. Cardiología del deporte.

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Introduction

Today, numerous publications have been released describing the characteristics of the electrocardiograms of athletes, the physiological significance of which has become clearer as the different variants have been correlated to a sophisticated cardiology assessment and extended follow-up. Despite having been described on numerous occasions in literature, current guides and criteria do not include vagotonic T waves as a physiological adaptation and variant of normality in athletes[1].

Diverse tests that include continuous electrocardiographic monitoring - both whilst resting and under stress - as well as image techniques (transthoracic echocardiogram, cardiac resonance, thoracic CT), have been extremely useful when discerning the physiological electrocardiographic variants in athletes from the presence of underlying heart disease. On the other hand, introducing the genetic study in groups of athletes with a suspected family history of cardiomyopathies or channelopathies has constituted an important step in deepening the aetiological study of athletes.

The global prevalence of repolarisation alterations in athletes is relatively frequent and variable in the different series published in literature[2]. Today, there are established criteria that are greatly useful when it comes to assessing when we should perform a more detailed study on an athlete that presents electrocardiographic alterations. Traditionally, the Seattle[3] criteria have been used, as well as the European Society of Cardiology Criteria[4]. In recent years, some unified criteria have been established – so-called refined criteria - which are more specific and sensitive when distinguishing the presence of cardiopathies in this population subgroup[5].

Different repolarisation alterations have been described in the athletic demographic, among which, those most frequently reported in literature are: early repolarisation, vagotonic T waves, U waves, elevation of the ST segment and negative T waves.

Vagotonic T waves are defined as high, symmetrical and narrow T waves, of more than 5 mm in limb leads or more than 10 mm in precordial leads6 (Figure 1), and are frequently observed in asymptomatic athletes subjected to high loads of physical activity. There is a prevalence of 14% among competing athletes6. These alterations usually disappear over time, when the high-intensity physical activity stops[1], though there is currently no thorough data regarding the frequency and dynamic in which these changes occur.

For this reason, the aim of our study was to establish the prevalence of vagotonic T waves in a population of elite athletes, as well as analysing their dynamic behaviour in different states of exercise.

Material and method

From June 2010 to June 2015, a medical team comprising sports doctors and cardiologists performed a thorough assessment of 91 professional male football players - all members of the Spanish First Division - prior to the start of the season. During this time, a study was carried out on all of them, including a detailed individual and family clinical history, a physical exploration, a 12-lead electrocardiogram, a 2-dimensional transthoracic echocardiogram, cardiopulmonary exercise test with oxygen consumption assessment (VO_2max), routine analysis, as well as an anthropometric study and collection of morphologic data.

This group of elite athletes is defined as professional football players whose main income is earned from their physical activity, and they compete in first or second division categories in the Spanish National Football League. They all have basic training requirements of over 10 hours each week.

An informed consent form was provided, agreeing to the sports assessment. A 12-lead electrocardiogram at 25 mm/s and 10 mm/mV was carried out on participants. All of the electrocardiograms were interpreted by two cardiologists with experience in the field of sporting cardiology. In the transthoracic echocardiogram analysis, the majority of the studies were performed using Siemens Vivid T7 ultrasound equipment. The ejection fraction was estimated using the Teichotz method. The diameter of both ventricles and the left atrium were measured, as well as the wall thickness in the long parasternal axis.

Cardio-pulmonary exercise testing was performed (Philips equipment) on 91 athletes, using a sporting protocol (4-minute warm-up, progressive increase of the exertion load, with an increase of 1 km/h each minute, maintaining a constant gradient of 1% and an active 3-minute recovery stage). The maximum oxygen consummation during the test was calculated for all of them, as well as the aerobic and anaerobic thresholds reached. The gases breathed were analysed using Ergometrix Cx equipment. In all of these tests, efforts were made to achieve maximal cardiac stress.

Likewise, to study the behaviour and dynamic pattern of the vagotonic T waves during exercise, we have established four different stages: basal, stage 5 of the exercise (speed 10 km/hour), stage 9 of the exercise (speed 14 km/hour) and the second minute of the recovery stage. To define the changes of these waves during the exertion, we have used the decline criteria of equal to or more than 50% of the voltage during the exertion in relation to the basal voltage.

Statistics

The average and standard deviation or the median and percentile 25 and 75 were calculated to describe the quantitative variables in accordance with the normality of the data. The Shapiro-Wilk test was used to check the normality of the data of the quantitative variables. The frequency and percentage in the qualitative variables were calculated. The student t test was used to compare the quantitative data, and in the cases in which the variable did not follow a normal distribution, the Mann-Whitney U test was used. To compare the qualitative data, we used the Chi-square test. A p-value < 0.05 was considered significant. The statistics programme used was R Core Team (2014).

Results

A thorough study was performed on the 91 athletes in our series. It is a demographic of athletes - mainly Caucasian (91.2%) - with an

average age of 26 years ± 4.49 years and a body mass index of 23.28 ± 1.62 Kg/m^2. The follow-up time was 36 ± 9 months. None of these athletes needed to suspend their physical activity as a result of pathological findings at the time of our assessment, or during the follow-up, and no cardiovascular incidents occurred during this time. A greater trend towards the presence of vagotonic T waves was detected in athletes that performed more hours of training (Table 1).

Electrocardiogram

With regards to the characteristics of the electrocardiogram, 98% of the subjects had a sinus rhythm, of these (the other two patients had a low auricular rhythm), 61% presented sinus bradycardia at the time of the assessment.

85 football players (93%) were identified with basal repolarisation disorders. The most frequently revealed disorder in our demographic of athletes was the presence of U waves in precordial leads (79 athletes (87%)). The second most frequent repolarization disorder was the presence of early repolarisation, identified in n=67 (74%). The following most frequently identified repolarisation alterations, in descending order, were: rise in ST n=24 (26%), vagotonic T waves n=14 (15%) and asymmetrical negative T waves n=7 (8%). As previously mentioned, the vagotonic T waves were identified in 15% of the subjects, whilst 77 athletes (85%) did not present this finding (Table 2).

The patients that presented these basal alterations, revealed a higher presence of right cardiac axis deviation on the surface electrocardiogram, as well as a greater tendency for sinus bradycardia, 1st degree AV block and signs of left ventricular hypertrophy (Table 3).

Echocardiogram

The echocardiographic study performed did not reveal the presence of structural heart disease in any of the patients that presented vagotonic T waves. Nor were significant differences identified between the different echocardiographic variables in both groups. All the echocardiographic parameters analysed in the study are included in Table 4.

Despite both the appearance of vagotonic T waves and the dilation of the right cavities being widely described discoveries in athletes, in this analysis it is observed that the right ventricle end-diastolic diameter (RVEDD) is lower in the group of vagotonic T waves (31 mm *vs.* 35 mm) with an almost significant *p* value (0.08).

Cardiopulmonary exercise testing

None of the stress tests exceeded an exercise time of 12 minutes, with these test practically all ending due to the exhaustion of the athlete.

Patients of the study sample performed a maximum oxygen consumption of 57 ± 6 ml/Kg/min (Table 5). Upon analysing the behaviour of the vagotonic T waves against the exercise during the maximal-type cardiopulmonary exercise tests, using the four previously described stages, their dynamic behaviour was identified (Figure 2). Their progressive disappearance was observed during the exertion as well as their later reappearance from the second minute of the recovery stage, with similar voltages to those of the basal electrocardiogram (Figures 3 and 4) in 93%

Table 1. Basal characteristics.

	Vagatonic T waves		
	Yes	No	*P* value
Age, years	28 (23.3 - 30)	26 (23 - 29)	0.36
BMI, Kg/m^2	23.05 (22.12 - 23.6)	23.08 (22.22 - 22.4)	0.9
HR, bpm	56 (50 - 60.8)	58 (52 - 68)	0.21
SBP, mmHg	125 (114 - 130)	125 (115 - 132)	0.73
DBP, mmHg	64 (59 - 76)	67 (60 - 72)	0.65
Time spent training weekly, hours	18.5 (15.75 - 21.25)	14 (12 -14)	0.38
CVRF	0 (0/14)	0 (0/77)	1
FA sudden death	0 (0/14)	0 (0/77)	1

BMI: body mass index. HR: heart rate. SBP: systolic blood pressure. DBP: diastolic blood pressure. CVRF: cardiovascular risk factors. FA: family antecedents.

Table 2. Prevalence of repolarisation alterations.

Repolarisation alteration, %	**93 (85/91)**
U waves	87 (79/91)
Early repolarisation	74 (67/91)
Elevation of the ST-T	26 (24/91)
Vagatonic T waves	15 (14/91)
Asymmetrical negative T waves	8 (7/91)

Table 3. Electrocardiographic variables.

	Vagatonic T waves		
	Yes	No	*p*-value
Sinus rhythm, %	100 (14/14)	97 (75/77)	1
HR < 60 bpm, %	71 (10/14)	60 (46/77)	0.55
Signs of LVH, %	64 (9/14)	43 (33/77)	0.16
PR, ms	144 (136 - 156)	156 (142 - 176)	0.15
QRS, ms	109 (104 - 113)	108 (100 - 114)	0.77
QTc, ms	408 (389,3 - 413,8)	404 (387 - 416)	0.79
1st degree AVB, %	14 (2/14)	5 (4/77)	0.23
Axis deviated to the right	71 (10/14)	36 (28/77)	0.04

HR: heart rate, LVH: left-ventricular hypertrophy. AVB: atrio-ventricular block.

Table 4. Echocardiographic variables

	Vagatonic T waves		
	Yes	No	*p*-value
EF of left ventricle, %	63 (59,3 - 66,3)	64 (60 - 68,3)	0,53
LVEDD, mm	53 (50 - 55,7)	53 (50,9 - 56)	0,42
LVESD, mm	33 (32 - 34,38)	34 (31 - 36)	0,53
IVS, mm	10 (9,25 - 10)	10 (9,38 - 11)	0,51
PLW, mm	10 (9 - 10)	10 (9 - 10)	0,98
LA diameter, mm	38 (36 - 38)	37 (36 - 38)	0,93
RVEDD, mm	31 (30 - 34)	35 (32 - 36,5)	0,08

EF: ejection fraction, LVEDD: left ventricle end-diastolic diameter, LVESD: left ventricle end-systolic diameter. IVS: interventricular septum. PLW: posterolateral wall. LA: left atrium. RVEDD: right ventricle end diastolic diameter.

Figure 1. ECG of an athlete presenting vagotonic T waves.

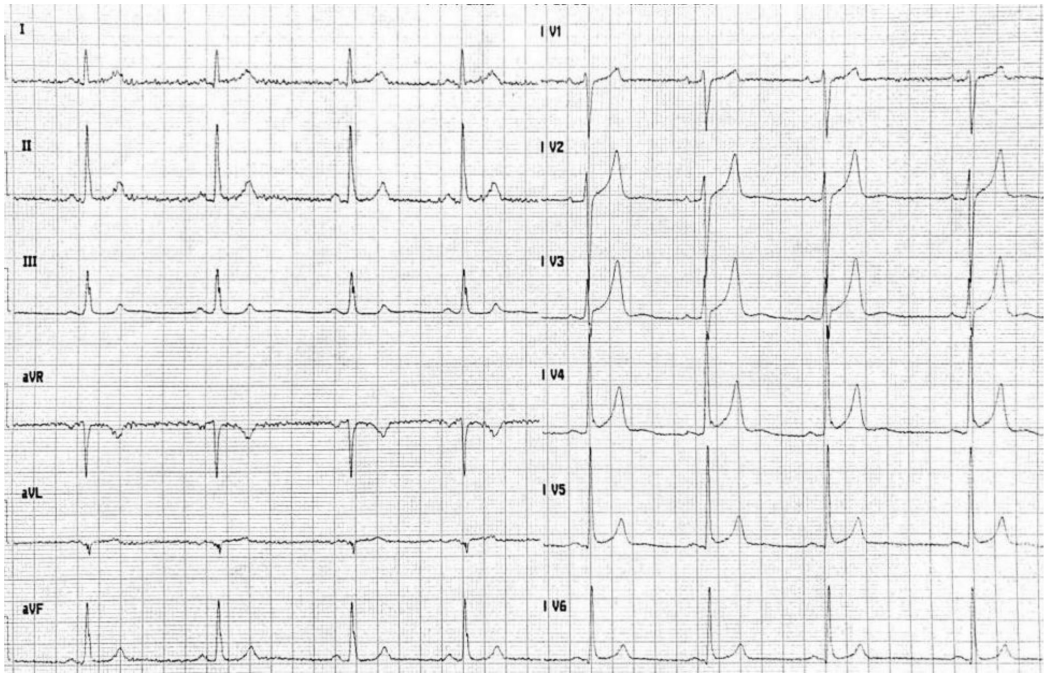


Table 5. Cardiopulmonary Exercise Stress Test variables.

	Vagatonic T waves		*p*-value
	Yes	No	
HR basal, beats/min	56 (50 - 60,75)	58 (52 - 68)	0,21
HR maxima, beats/min	181 (172,5 - 184,3)	185,5 (178 - 189,8)	0,19
SBP maximum, mmHg	169 (162,5 - 173)	174 (165 - 186)	0,1
DBP maximum, mmHg	71 (70 - 77,5)	80 (71 - 90)	0,05
METS	19,1 (18,3 - 19,4)	19,1 (18 - 20,1)	1
VO_2max, ml/Kg/min	56,7 (54,7 - 62,3)	57,8 (54,5 - 61,7)	0,9
VO_2max, ml/Kg/min	1,09 (1,04 - 1,12)	1,11 (1,09 - 1,14)	0,32

HR: heart rate, SBP: systolic blood pressure, DBP: diastolic blood pressure, VO2: oxygen consumption, RQ: respiratory quotient.

(n=13) of these athletes, with these changes reaching significant range in 11 (79%) of the footballers in our series (Tables 6 and 7).

Moreover, although both groups reached similar maximum oxygen consumption levels and workloads, the group of athletes that presented vagotonic T waves tended to present a maximal HR that was lower than the other athletes in our series (Table 5).

Table 6. Voltage of vagotonic T waves (mV) of the 14 football players in four different stages during the stress test: basal, stage 5 of exercise, stage 9 of exercise and recovery (at 2 minutes).

Athlete	Basal	Stage 5	Stage 9	Recovery (minute 2)
1	13	7	5	11.5
2	10	8	8	12
3	12	8.5	6	14
4	15	8	6.5	12.5
5	11	6	5	12
6	18	8	8	14
7	10	10	11	6
8	18	8	8.5	16
9	14	6	5	11
10	14	9	7	16
11	11	4	5	10
12	16	9	8	14
13	17	8	6	15
14	12	6	6.5	11

Discussion

In this study, after 5 years of follow up, none of the athletes have needed to stop their physical activity, reinforcing the banality of the frequently encountered electrocardiographic alterations found in this demographic.

Table 7. Heart rate (beats per minute) of the 14 football players in four different stages during the exertion test: basal, stage 5 of the exercise, stage 9 of the exercise and recovery (after 2 minutes).

Athlete	Basal	Stage 5	Stage 9	Recovery (minute 2)
1	49	130	160	106
2	90	164	192	139
3	43	121	162	115
4	61	119	174	130
5	58	148	172	132
6	50	155	172	121
7	70	137	177	131
8	54	139	157	105
9	52	130	164	112
10	60	147	181	130
11	47	138	170	120
12	64	154	186	134
13	55	155	178	124
14	50	124	150	101

Figure 2. Graph that displays the dynamic pattern of the vagotonic T waves (in the left column we can see the variation of the voltage of the T waves measured in mV) in the 14 athletes during the different stages of the cardiac stress test.

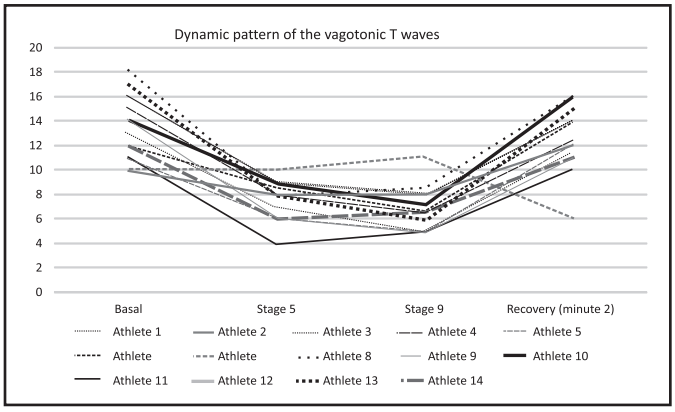
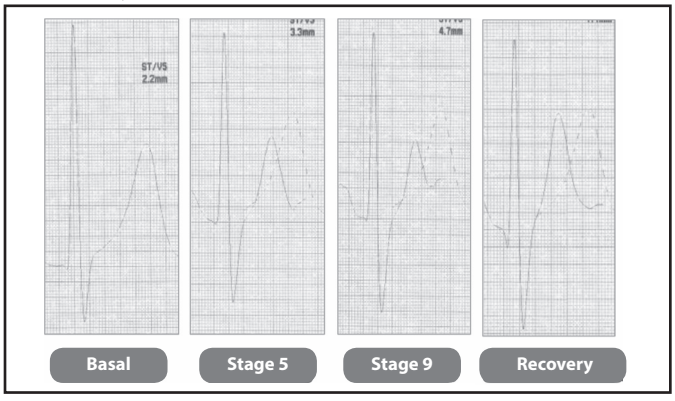


Figure 3. Dynamic changes of the vagotonic T waves during the cardiopulmonary exercise test. The dotted lines show the morphology of the basal vagotonic T waves.



The prevalence of vagotonic T waves in the basal ECG is 15% in our series, similar data to the prevalence obtained previously in the literature of other series[1].

The relationship is described between the vagotonic T waves and vagal hypertonia, and its association with other electrocardiographic findings typical among athletes. In our series, we discovered a certain association between the vagotonic T waves and the presence of sinus bradycardia, signs of ventricular hypertrophy, 1st degree AV block, etc., though without reaching statistical significance. Furthermore, it was observed that the athletes with vagotonic T waves were more likely to present deviation of the right axis, with both findings being relatively frequent among athletes.

However, significant differences were not identified between both groups regarding the echocardiographic findings that are common in the "heart of athletes" (dilation of right cavities, increase of wall thickness and/or dilation of the left atrium).

In the cardiopulmonary tests performed, the group of athletes with vagotonic T waves tended to display a lower maximal HR, despite reaching a similar workload and oxygen consumption level. This could be yet another finding that explains the predominance of the parasympathetic tone in this group of athletes.

In different publications, the presence of electrocardiographic changes is described - predominantly repolarisation alterations - which are induced with exercise and the increase of the heart rate, as well as the shortening of the QTc interval and the correction of T wave negativity[6].

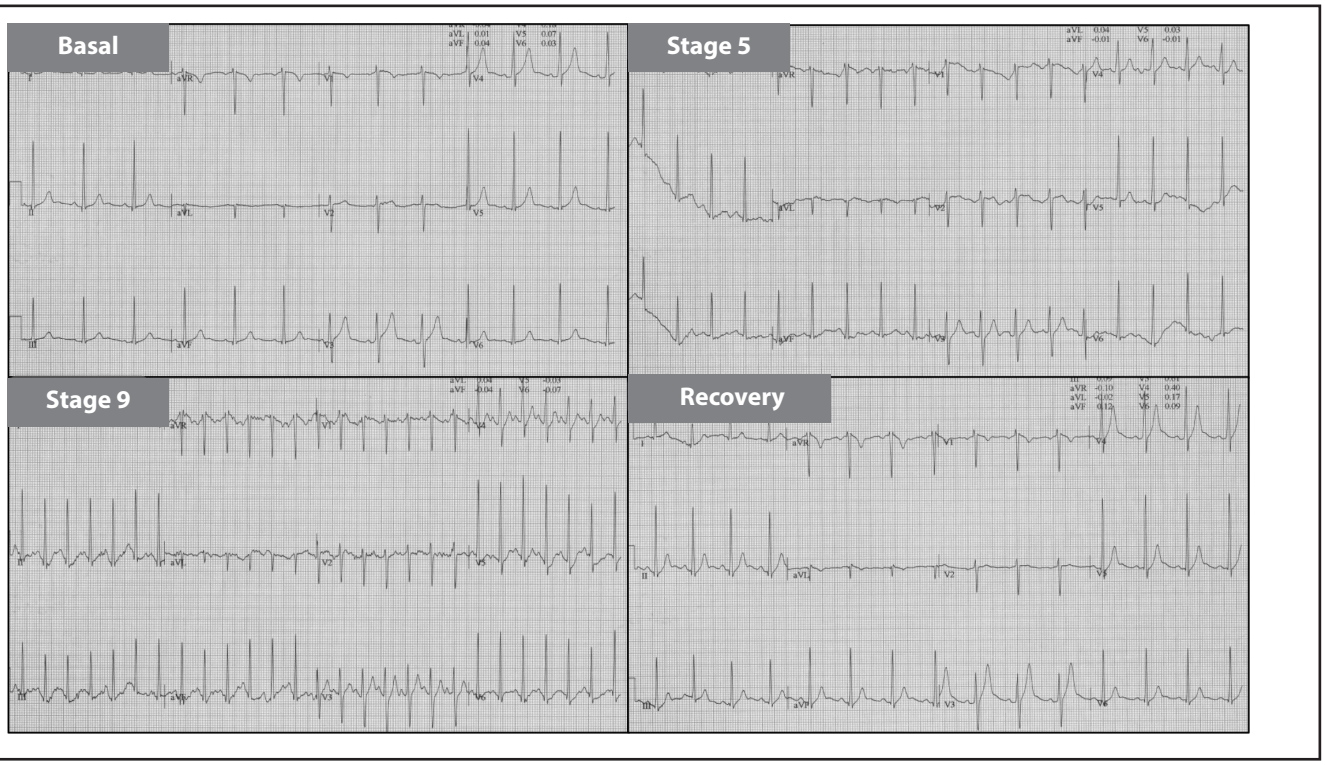
Typically, the disappearance of the vagotonic T waves has been described in the years following retirement from high-performance physical activity[7], with literature frequently reporting that the alterations in the morphology of the vagotonic T waves are related to the degree of training[8]. However, today there is little information regarding the dynamic electrocardiographic changes that occur in patients carrying vagotonic T waves during and after a protocoled exercise.

In this respect, our study reveals the existence of a dynamic pattern of the vagotonic T waves, which is repeated frequently among other athletes from our series, with a progressive disappearance of these waves during the exertion, as well as their later appearance in the early stages of recovery. This is probably due to the increase of the adrenergic stimulus during the successive stages of the exercise and the secondary reduction of the vagal hypertonia. When the predominance of the parasympathetic tone reappears, the vagotonic T waves return to their basal morphology. The observation of their attenuation during exercise, as well as their reappearance in recovery, help confirm the physiological variant character of the athlete's adaptation that has typically been conferred to this finding.

In terms of the study limitations, it is a descriptive study with a limited number of athletes that belong to the same sporting discipline.

In conclusion, these findings suggest that vagotonic T waves are related to a predominance of the parasympathetic tone, presenting dynamic behaviour during physical activity. These waves disappear in the majority of cases with exercise, and reappear in the initial recovery

Figure 4. Electrocardiogram of some of the athletes during the different stages of the stress test. Observe how the progressive disappearance of the vagotonic T waves can be seen during the exertion, and how it recuperates during the early recovery stages.



stages. In this respect, exercise could be considered to be a highly useful strategy when it comes to its study and stratification.

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