

# Ambulatory electrocardiographic recording in endurance athletes

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**SUMMARY** Data from ambulatory electrocardiographic recording in 35 highly trained endurance athletes and in 35 non-athletic controls of similar ages are given. The minimal, mean hourly, and maximal heart rates were significantly lower in the athletes. Thirteen athletes (37.1%) but only two controls (5.7%) had sinus pauses exceeding 2.0 seconds. First degree atrioventricular block was observed in 13 athletes (37.1%) and five controls (14.3%), second degree Wenckebach type block in eight athletes (22.9%) and two controls (5.7%), and second degree block with Mobitz II-like pattern in three athletes (8.6%) and no control. All athletes with Mobitz II-type pattern also had first degree and Wenckebach-type second degree atrioventricular block. The behaviour of sinus rate on development of atrioventricular block varied, not only interindividually but also intraindividually, from absence of change to an increase or decrease in most subjects in both study groups. A decrease in sinus rate on appearance of atrioventricular block was found constantly in only two athletes and one control. Atrioventricular dissociation with junctional rhythm occurred in seven athletes (20%) and with ventricular rhythm in one athlete. Neither of these phenomena was seen in the group of controls. The athletes had slightly fewer ventricular extrasystoles than controls, and no athlete had ventricular tachycardia, whereas two controls had ventricular tachycardia.

The spectrum of changes in conventional resting electrocardiograms in athletes is wide, and relatively well documented.<sup>1-14</sup> Knowledge concerning variations in rhythm and conduction and the incidence of ventricular extrasystoles in athletes, however, is still deficient. Because variations usually occur transiently, the chance of detecting them via conventional resting or exercise electrocardiograms is slight. Studies using ambulatory electrocardiographic recording have shown that a wide range of transient variations and disturbances in cardiac rhythm and atrioventricular conduction can be detected even in ordinary healthy subjects.<sup>15-18</sup> As far as the authors know the only studies so far published concerning changes detected by ambulatory electrocardiographic recording in athletes are a few abstracts containing only limited amounts of information.<sup>19-21</sup> The present study was undertaken to discover what range of changes in cardiac rhythm and atrioventricular conduction, and what incidence of ventricular extrasystoles might be detected by ambulatory

electrocardiographic recording in endurance athletes as compared with controls.

## Subjects and methods

### SUBJECTS

Volunteers for this study consisted of 35 male endurance athletes, aged  $23.1 \pm 6.1$  (mean  $\pm$  SD) years, and 35 controls, aged  $23.0 \pm 5.8$  years. The athletes were top-class national long-distance runners, skiers, and basketball players. To obtain the athletes for the study, a club for runners and skiers and a particular sports group of army conscripts were approached. Athletes fulfilling the following criteria were accepted for the study: at least five years of intensive physical training, absence of history of cardiovascular disease, and of any other disease known to affect the cardiovascular system; normal findings on a clinical examination, no changes in 12 lead resting electrocardiogram, and chest x-ray film not attributable to an athletic heart<sup>18-14 22-24</sup>; not permanently under medication, and not under medication at the time of the study; non-smoker; absence of upper respiratory infection during a one month period before the study.

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The controls were medical students and army conscripts. The criteria for acceptance were the same as those listed above, with the following exceptions: no regular intensive physical training; normal 12 lead electrocardiogram and chest x-ray.

#### AMBULATORY ELECTROCARDIOGRAM

The recordings were performed using a two-channel electrocardiographic tape recorder (Model 445, Avionics). The exploring electrodes were placed on the lower end of the sternum and on the fifth rib at the left anterior axillary line. Recordings were started at 4.00 pm and concluded at 8.00 am. The subjects were directed to go to bed around 10.00 pm and rise around 6.00 am. Activities during recording were not restricted, except that physical training was not allowed. Consumption of alcoholic beverages was forbidden.

Tapes were analysed using a commercial analyser (Electrocardioscanner Model 660, Avionics). All tapes were assessed by the authors. Initial scanning was performed at 60 times normal speed. In cases of definite or suspected findings, the scanner was switched to normal speed, and the findings printed on an electrocardiographic chart (speed 25 mm/s) for detailed analysis. All findings reported here were taken from such electrocardiographic charts. Each tape was screened between three and 10 times at 60 times normal speed. Mean hourly heart rates (number of heart beats per hour divided by 60) were counted by the scanner.

#### DEFINITIONS

Definitions and criteria used in the present study are

given at the beginning of each results section concerned.

#### STATISTICAL METHODS

Student's unpaired t test and the  $\chi^2$  test were used in statistical analysis of the results.

#### Results

##### HEART RATE

Mean hourly heart rates for both groups studied are shown in Fig. 1. The lowest nocturnal heart rate, calculated using the six slowest consecutive sinus beats, was  $37.7 \pm 4.3$  (mean  $\pm$  SD) beats/min (range 24 to 48) for athletes and  $45.4 \pm 6.3$  beats/min (range 33 to 63) for controls ( $p < 0.001$ ). The maximal heart rate when awake, calculated analogously, was  $124.5 \pm 17.3$  beats/min (range 100 to 164) for athletes and  $137.3 \pm 18.5$  beats/min (range 87 to 168) for controls ( $p < 0.01$ ).

##### SINUS PAUSES

Thirteen athletes (37.1%) and two controls (5.7%) had PP intervals exceeding 2.00 s in sinus rhythm without second degree atrioventricular block ( $p < 0.01$ ). The longest PP interval among athletes was 2.76 s and among controls 2.60 s. All sinus pauses exceeding 2.00 s occurred between 10 pm and 6 am.

##### ATRIOVENTRICULAR CONDUCTION

First degree atrioventricular block (PR interval  $> 0.22$  s) was detected in 13 athletes (37.1%) and five controls (14.3%) ( $p < 0.05$ ) (Table 1 and Fig. 2). In five athletes and two controls the PR interval was prolonged con-

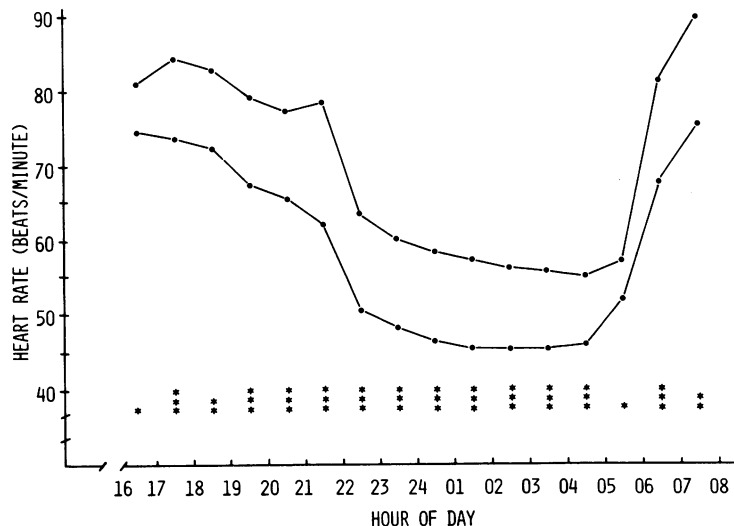


Fig. 1 Mean hourly heart rates in athletes (lower line) and controls (upper line). \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Table 1 Occurrence of atrioventricular block in athletes and controls

Subject No.	First degree AV block	Second degree Wenckebach AV block	Second degree AV block with Mobitz II pattern
<b>Athletes</b>			
1	+(0.28)*		
2	+(0.32)	+	+
4	+(0.32)		
8	+(0.24)		
12	+(0.42)	+	+
13	+(0.40)	+	
15	+(0.28)	+	
16	+(0.26)	+	+
18	+(0.36)	+	
21	+(0.36)	+	
22	+(0.32)	+	
23	+(0.28)		
35	+(0.54)		
	13/35 37.1%	8/35 22.9%	3/35 8.6%
<b>Controls</b>			
2	+(0.24)		
13	+(0.40)		
17	+(0.32)	+	
20	+(0.36)	+	
23	+(0.26)		
	5/35 14.3%	2/35 5.7%	-

\*Numbers in parentheses indicate the longest PR interval.

stantly for at least an hour. In all the other subjects prolongations lasted for only a few seconds or minutes.

Among athletes, there was first degree atrioventricular block during sleep in six cases, during sleep and while awake in four cases, and while awake in three cases. Among controls, atrioventricular block occurred

only during sleep. More than one short period of first degree atrioventricular block was found in 11 of the 13 athletes concerned and in all controls. Heart rate at the time of block, calculated from the PP interval preceding appearance of block, varied from 29 to 103 beats/min in athletes and from 33 to 83 beats/min in controls. In all subjects, the PR interval returned to less than 0.20 s with increase in heart rate.

Second degree Wenckebach-type atrioventricular block, defined as gradual prolongation of the PR interval terminating in a nonconducted P wave and a dropped ventricular beat (Fig. 3), was found in eight athletes (22.9%) and two controls (5.7%) ( $p < 0.05$ ) (Table 1). The three cases (athletes 12 and 16 and control 20) in whom there was, in addition to typical Wenckebach-type block, disorganised prolongation of successive PR intervals terminating in a blocked beat, a phenomenon sometimes called type III second degree atrioventricular block,<sup>25</sup> were classified here as having second degree Wenckebach-type atrioventricular block. In athletes, block was detected both when awake and when asleep in two cases, while asleep in five cases, and while awake in one case. Among controls, block occurred in all cases during sleep only. In five athletes and one control, block was observed more than once. The level of heart rate when PR prolongation began varied from 33 to 88 beats/min in the athletes and from 45 to 75 beats/min in the controls.

Second degree atrioventricular block with Mobitz II pattern, defined as a nonconducted P wave and a dropped ventricular beat preceded by a constant and

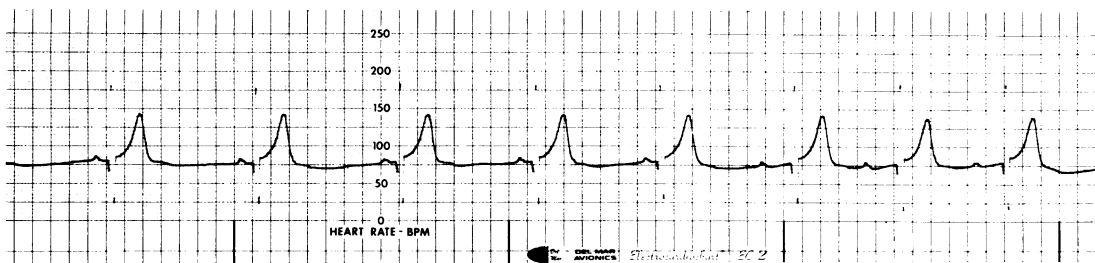


Fig. 2 First degree atrioventricular block (athlete no. 13) with sinus node acceleration on appearance of atrioventricular block.

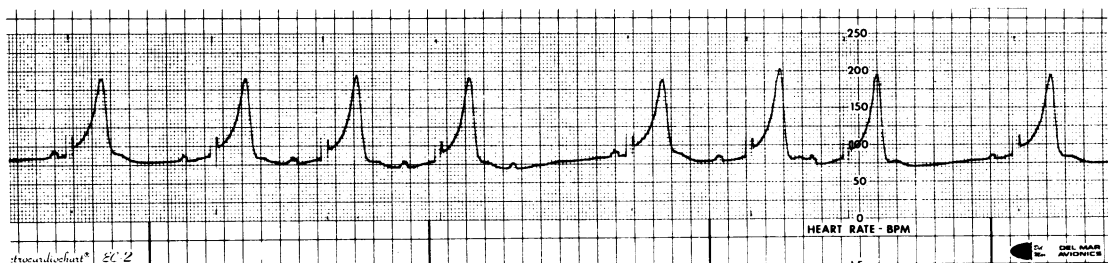


Fig. 3 Second degree Wenckebach-type atrioventricular block (athlete no. 12).

followed by the same or a slightly shorter PR interval (Fig. 4), was found in three athletes (8.6%) but no controls (Table 1). In one athlete, block was found several times when awake and when asleep, in another several times only while awake, and in a third twice during sleep. The level of heart rate at the time of the occurrence of block varied from 48 to 93 beats per minute.

As shown in Table 2, the changes in sinus rate at the time of the appearance of atrioventricular block, calculated from the last PP interval before block and the first PP interval during block, varied from none to an increase (Fig. 2) or decrease. Only three athletes constantly had the same kind of sinus rate behaviour on development of block. Two (athletes 15 and 21) had a decrease in sinus rate and one (16) no change. Among the controls, sinus rate behaviour was always the same in two cases. One (control 23) had a decrease and one (control 2) an increase in sinus rate.

Atrioventricular dissociation with junctional or ventricular rhythm, also called interference dissociation,<sup>25</sup> is defined as dissociation of sinus rhythm from

Table 2 Subjects with atrioventricular block grouped according to changes in sinus rate at time of appearance of block

	First degree AV block		Second degree Wenckebach AV block		Second degree AV block with Mobitz II pattern	
	A*	N†	A*	N†	A*	N†
O	3		1	1	2	
↑	1	1	2			
↓	2	1	3		1	
O↑	3					
O↓	1					
↓↑		1	1	1		
O↑↓	3	2	1			
Total	13	5	8	2	3	

O, No change in sinus rate; ↑, increase in sinus rate; ↓, decrease in sinus rate; O↑, no change in a given subject on one occasion, increase on another.

\*Athletes.

†Controls.

a slightly faster junctional or ventricular rhythm, and results either from slowing of sinus node or a slight acceleration of the lower rhythm (Fig. 5): this was

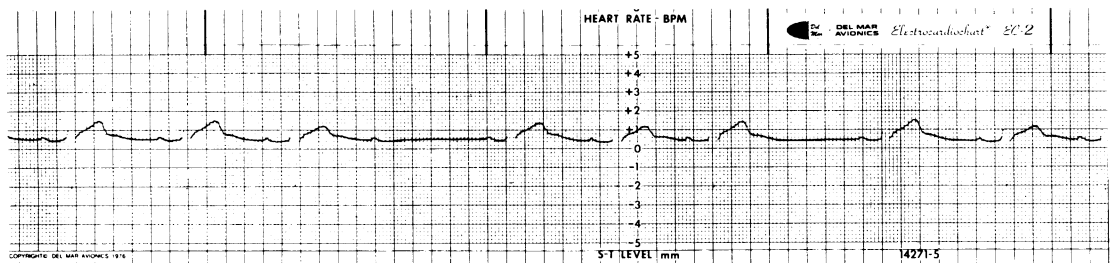


Fig. 4 Second degree atrioventricular block with Mobitz II-like pattern (athlete no. 16). Note slightly shorter PR interval in the first conducted beat after block.

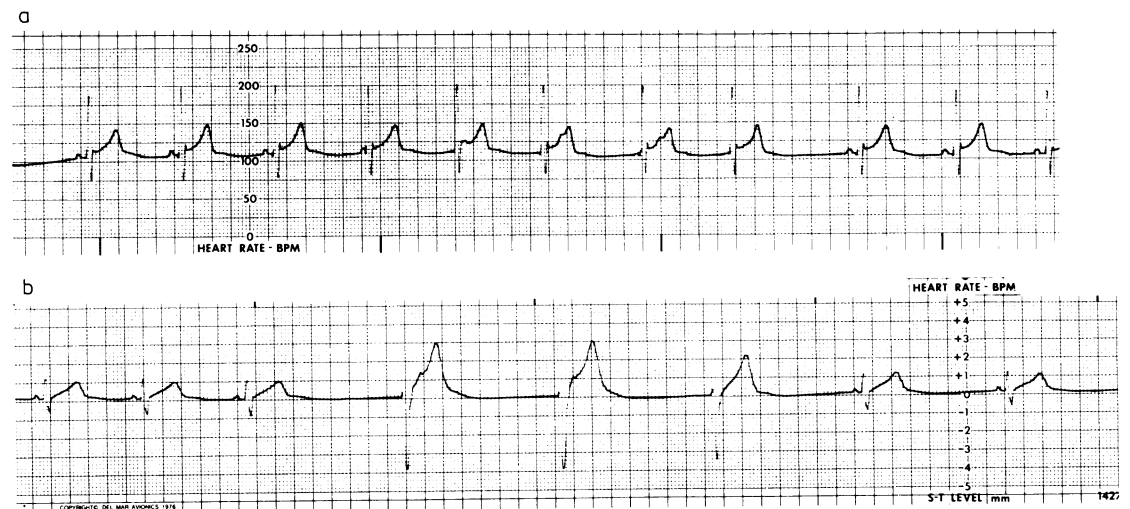


Fig. 5 Atrioventricular dissociation with (a) junctional rhythm and (b) ventricular rhythm (athletes nos. 5 and 7). Note the positive P wave after QRS complexes in the centre of the electrocardiographic traces.

found in seven athletes (20.0%) but not in the controls. All athletes had junctional rhythm, and one also had periods of ventricular rhythm. All showed the phenomenon several times. In three of the cases with junctional rhythm and in the case with ventricular rhythm, dissociation was observed both when awake and asleep. Three athletes showed dissociation only during sleep and one only while awake. Of these seven athletes, two had transient first degree atrioventricular block and one had both first and second degree Wenckebach-type atrioventricular block. In all seven athletes, atrioventricular dissociation was attributed to slowing of sinus rate. In one case with junctional rhythm and in the case with ventricular rhythm, dissociation was also occasionally caused by slight acceleration of the lower rhythm. The sinus node rate at which dissociation occurred varied from 26 to 56 beats/minute, when dissociation resulted from slowing of sinus node rate. The rate of junctional rhythm varied from 27 to 68 beats a minute and of ventricular rhythm from 32 to 44 beats a minute. In cases where dissociation resulted from slight acceleration of lower rhythm, it occurred at sinus node rates of between 40 and 51 beats a minute.

#### VENTRICULAR ARRHYTHMIAS

Table 3 shows ventricular extrasystoles classified according to Jelinek *et al.*<sup>26</sup> The ventricular tachycardias observed in two controls consisted of three and seven beats. One (no. 12) had no additional ventricular extrasystoles. The other (no. 14) had one single ventricular extrasystole in addition to tachycardia. Two controls (nos. 18 and 25) but no athlete had frequent ventricular extrasystoles (on average five an hour). Of the two controls, the first had only unifocal single ventricular extrasystoles and the second had unifocal extrasystoles, both single and in the form of bigeminy. The few ventricular extrasystoles observed in athletes occurred at random throughout the period of recording.

Table 3 Ventricular extrasystoles in athletes and controls classified according to Jelinek *et al.*<sup>26</sup>

Grade*	Athletes	Controls
0	23	20
1	10	11
2	0	1
3	2	0
4a	0	1
4b	0	2
5	0	0

\*Grade 0, no arrhythmia; grade 1, isolated unifocal ventricular extrasystoles less than 30/h or 1/min; grade 2, isolated unifocal extrasystoles more than 30/h or 1/min; grade 3, multiform ventricular extrasystoles; grade 4a, couplets; grade 4b, ventricular tachycardia; grade 5, early cycle ventricular extrasystoles.

## Discussion

### RATE AND SITE OF IMPULSE FORMATION

Resting bradycardia in athletes has been attributed both to a relative increase in parasympathetic dominance on pacemaker frequency<sup>27 28</sup> and also to independent slowing of the intrinsic rate of the pacemaker.<sup>29</sup> Despite the significantly lower mean hourly heart rate throughout the period of recording in this study, the pattern of circadian variation in athletes was similar to that in controls. Attainment of minimal heart rates relatively early during the night may reflect overall lower sympathetic tone in athletes.

Sinus pauses exceeding two seconds without second degree atrioventricular block are relatively rare in healthy individuals. They have been seen during ambulatory electrocardiographic recording in two of 50 healthy medical students<sup>16</sup> and in two of 259 healthy subjects aged 40 to 79 years.<sup>30</sup> In the present study they were seen in two of 35 nonathlete controls. In endurance athletes, the incidence of sinus pauses greater than two seconds is significantly greater than in controls. In a group of 20 athletes, the mean of the longest sinus pauses during ambulatory electrocardiographic recording has been found to be two seconds (range 1.60 to 2.80 s).<sup>21</sup> In the present study, 13 of 35 athletes (37.1%) had sinus pauses greater than two seconds. Though the exact mechanisms predisposing to long sinus pauses in athletes remain unclear, they are probably related to factors responsible for sinus bradycardia.

Sinus bradycardia is obviously also the factor making it possible for atrioventricular dissociation with junctional or ventricular rhythm to occur in athletes. Though atrioventricular dissociation with junctional rhythm was not seen in any control in the present study, it cannot, however, be regarded solely as a peculiarity of the athletic heart, because in a population of 122 043 healthy air force personnel, its incidence has been reported to be 0.7/1000.<sup>31</sup> Though the intrinsic pacemaker rate of the atrioventricular node in healthy subjects is usually between 40 and 60 beats a minute,<sup>25 32</sup> the results of the present study show that even in healthy individuals it can fall to as slow as 27 beats a minute.

### ATRIOVENTRICULAR CONDUCTION

First degree atrioventricular block has been reported in resting electrocardiograms in athletes<sup>1 4 5 8</sup> and second degree Wenckebach-type atrioventricular block occasionally.<sup>1 7 11</sup> Ambulatory electrocardiographic recording has shown that these types of atrioventricular blocks are by no means exceptionally rare, even in healthy controls. First degree atrioventricular block has been reported to occur in four of 50 (8.0%) medical students,<sup>16</sup> in 11 of 131 (8.4%) boys aged 10 to 13

years,<sup>17</sup> and in nine of 92 (9.8%) boys aged 7 to 11.<sup>18</sup> In the present study it occurred in five of 35 (14.8%) controls. Second degree Wenckebach-type atrioventricular block has been reported to occur in two of 86 (2.3%) instances in a population aged 16 to 65 years,<sup>15</sup> in three of 50 (6.0%) medical students,<sup>16</sup> in 14 of 131 (10.7%) young boys,<sup>17</sup> and in three of 92 (3.3%) boys aged 7 to 11.<sup>18</sup> It occurred in two of 35 (5.7%) controls in the present study. Second degree atrioventricular block of the Mobitz type II was reported to have occurred in one subject in the healthy population studied by Clarke *et al.*<sup>15</sup> but was not reported in any of the other studies mentioned above. It did not occur in the controls in the present study. Using ambulatory electrocardiographic recording, first degree atrioventricular block has previously been found in two of 25 (8.0%)<sup>20</sup> and second degree Wenckebach-type block in three of 25 (12.0%)<sup>20</sup> and eight of 20 (40.0%)<sup>21</sup> athletes. In the athletes in this study the respective incidences were 13 of 35 (37.1%) and eight of 35 (22.9%). In addition, three athletes (8.6%) had second degree atrioventricular block with Mobitz II-like pattern.

There is no unanimity in the medical publications as to whether the definition of second degree Mobitz type II atrioventricular block should include infranodal siting of the block.<sup>33-35</sup> If the site of block is taken into account, there are several occasions on which differentiation between Wenckebach and Mobitz type II blocks in the electrocardiogram is difficult or even impossible, within the limitations introduced by a chart speed of 25 mm/s.<sup>35</sup> The three athletes with Mobitz II pattern in the present study are similar to the subject referred to above in the healthy population studied by Clarke *et al.*,<sup>15</sup> in that all had an abundance of other types of atrioventricular block, third degree block excepted.

The occurrence of atrioventricular block in athletes has been regarded as an expression of relative vagal dominance, and of fluctuation in vagal activity.<sup>25</sup> In animal experiments, vagal stimulation has, indeed, been shown to be capable of producing first and second degree atrioventricular block, Mobitz II pattern included, the site of the block being intranodal.<sup>36</sup> If vagal tone, however, were the sole factor causing atrioventricular block in athletes, a simultaneously demonstrable decrease in sinus rate would also be expected,<sup>33</sup> because the sinus pacemaker may be more sensitive than atrioventricular nodal conduction to vagal influences.<sup>36</sup> Decreases in sinus rate were observed in a number of cases in the present study, but in a substantial number of cases there was no change in sinus rate or an increase at the time of the appearance of atrioventricular block, even in the same subject at different times. Thus, though relative vagal dominance is probably a factor causing atrioventricu-

lar block in athletes and, rarely, in controls, the observed variations in sinus rate on appearance of atrioventricular block suggest that there are additional associated mechanisms involved. Vagally-induced atrioventricular block via a hyporeactive sinoatrial node, a phenomenon that has been reported to occur very occasionally in healthy youngsters,<sup>37</sup> cannot be ruled out in the athlete no. 16 in whom sinus rate did not change on any occasion when atrioventricular block appeared, since no tests which would specifically detect a hyporeactive sinoatrial node<sup>37</sup> were conducted.

#### VENTRICULAR EXTRASYSTOLES

Ventricular extrasystoles up to short bursts of ventricular tachycardia can be found in healthy subjects.<sup>15 16 38</sup> Two studies in healthy middle-aged men suggest that long-term participation in physical exercise may diminish ventricular extrasystoles.<sup>39 40</sup> The results of Talan *et al.*<sup>21</sup> and those of the present study give some slight support to this notion. The proportion of athletes with ventricular extrasystoles was not different from the proportion of controls with ventricular extrasystoles, but none of the athletes had complex forms.

#### FINAL COMMENTS

Through the recent widespread adoption of ambulatory electrocardiographic recording, it has become evident that findings traditionally regarded as indicative of heart disease also occur in healthy individuals. Endurance athletes are a group at one extreme of the physiological spectrum, and though variations in the function of sinus and atrioventricular nodes probably arise through prolonged intensive physical training, their true clinical significance will remain obscure until results of long-term prospective studies become available. Sudden death in competitive athletes, a rare event,<sup>41</sup> has in most cases been associated with structural diseases of the heart, hypertrophic cardiomyopathy and coronary anomalies being commonest.<sup>41</sup> Though the latter might cause electrocardiographic abnormalities similar to those reported here, no data available suggest that such abnormalities in the electrocardiograms of athletes predispose to sudden death.

Results of animal studies,<sup>36</sup> the disappearance of all atrioventricular blocks as heart rate increases, and the observation that second degree Wenckebach-type atrioventricular block appears and disappears in accordance with the starting and stopping of vigorous physical training in top athletes<sup>11</sup> support the concept that at least the transient atrioventricular blocks observed in the athletes represent a physiological phenomenon. It must, nevertheless, be borne in mind that, in rare instances in adolescents, frequent

Wenckebach-type second degree atrioventricular block has been reported to progress to complete heart block.<sup>42</sup>

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