

# Prevalence of Abnormal and Borderline Electrocardiogram Changes in 13, 079 Chinese Amateur Marathon Runners

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## Research article

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# Abstract

The purpose of this study was to assess the prevalence of normal, borderline and abnormal ECG changes in marathon runners. The 12-lead ECG data of 13,079 amateur marathon runners between the ages of 18 and 35 years were included for analysis. The prevalence of ECG abnormalities among different gender groups was compared with chi-square tests. In terms of training-related changes, sinus bradycardia, sinus arrhythmia and left ventricular high voltage were found in approximately 15%, 5% and 3.28% of the participants, respectively. The incidence of right axis deviation in the marathon runners was 1.78%, which was slightly higher than the incidence of left axis deviation (0.88%). No more than 0.1% of the amateur marathon runners exhibited ST segment depression, T wave inversion (TWI), premature ventricular contraction, pathologic Q waves and prolonged QT interval. In conclusion, training-related ECG changes, including sinus bradycardia, sinus arrhythmia and left ventricular high voltage, were common in the amateur marathon runners. Most of abnormal ECG changes, including ST segment depression, TWI, premature ventricular contraction, pathologic Q waves and prolonged QT interval, were infrequently found in the amateur marathon runners.

## Introduction

Originating from a long-distance run from Marathon to Athens in 490 B.C., marathons have become one of the most popular sports in the world. Completing a marathon is a considerable challenge to the human body. Regular and appropriate physical activity is beneficial in reducing all-cause mortality and risk for numerous chronic diseases, including cardiovascular diseases (CVDs)(1, 2). Prolonged vigorous endurance training may lead to adverse functional and morphological cardiac adaptations, especially in amateur runners (3). Such adverse consequences may include atrial fibrillation (4),atrial flutter (5), ventricular arrhythmias(6)and sudden cardiac death (SCD) (7, 8).The incidence of sudden death in marathon runners ranges from 0.54 to 2.1/100,000, with CVDs as leading causes during long-distance races (8–10).Although the risk of SCD during a sporting event is low, it often exerts a large impact on society owing to media coverage. Therefore, numerous sports organisations and academic societies, including the International Olympic Committee, the National Collegiate Athletic Association, the European Society of Cardiology and the American Medical Society for Sports Medicine have endorsed cardiovascular preparticipation screening for athletes to identify CVDs and decrease the risk of SCD (11–14)

The 12-lead ECG, which is a simple, economical and convenient instrument that can provide important diagnostic and prognostic information for a variety of CVDs, has been adopted as an important component of cardiovascular preparticipation screening in addition to personal history, family history and physical education. Over the past three decades, numerous studies have reported the prevalence of ECG abnormalities in athletes of different sports(15–17). Several studies have likewise reported ECG abnormalities in marathon runners. Minns et al. reported the prevalence of ECG abnormalities in 87 volunteer runners before and after a half marathon (18). Herm et al. presented the ECG results of 108 athletes during a marathon race with portable ECG recorders(19). Although millions of runners participate

in thousands of marathons every year, few studies with a large sample size have reported the results of ECGs of marathon runners.

Racial and gender differences in cardiovascular risk exist among athletes. The incidence of SCD is higher in black Americans compared with white Americans(20). Moreover, abnormal T wave inversion (TWI) is more frequent in black(12%) than in white competitive athletes(< 4%) (21, 22). Thus, determining the prevalence of ECG abnormalities in other ethnicities would be interesting. However, ECG findings in Hispanic and Asian athletes as well as in those with mixed ethnicities are not well reported (23). Therefore, this study aims to the prevalence of normal, borderline and abnormal ECG changes in young Chinese marathon runners, which may serve as a reference for preparticipation screening for marathon events.

## Methods

### Participants

The Hangzhou Marathon, which was first held in 1987, is one of the earliest marathon events for amateur enthusiasts in China. It attracts approximately 20,000 Chinese runners for half and full marathons every year. The participants of this study were 18,826 contestants who participated in the Hangzhou Marathon (half and full categories) in 2015 and 2016. Prior to the marathon, the amateur runners were encouraged to submit their physical examination report (a 12-lead resting ECG was strongly recommended) to the organiser online for preparticipation screening. The inclusion criteria for the participants in the current study included the following: (1) at least 18 years old and no more than 35 years old;(2) a 12-lead ECG report was provided (In China, patients would get an ECG report sheet with 12-lead electrocardiogram after taking an ECG exam in most hospitals) ;(3) the ECG test was conducted in a qualified county-level hospital or higher within 6 months before the marathon; (4) personal information (e.g. gender, age, height and weight) was available; and (5)only the 2016 data were included if a participant participated in the 2015 and 2016 events. A total of 13,079 runners (9,897 men and 3,182 women) were included in the data analysis. All participants read and signed an informed consent form and this study was approved by the Ethics Committee of the First Affiliated Hospital of the Medical School of Zhejiang University.

### Procedures

The data analysis of this study was based on the ECGs submitted by the marathon runners. The ECGs were interpreted by a group of clinical doctors and verified by reviewers with the international recommendation for ECG interpretation in athletes that was released in 2017(24). In cases with inconsistent diagnoses, a third reviewer was responsible for interpreting and making decisions. Personal information, including gender, age, height and weight, was collected from the physical examination reports submitted by the participants.

## Data analysis

The prevalence of normal, borderline and abnormal ECG changes was presented, and chi-square tests were applied to compare prevalence rates between the male and female runners. Using the median running time of the full or half marathons as the cutoff point, the participants were divided into good and poor performance groups. Logistic regression was utilized to determine the odds ratio of acquiring certain ECG abnormalities in runners with good performance in comparison with runners with poor performance. Data analysis was conducted using SPSS 20.0 (SPSS Inc.). Statistical significance was considered at  $p < 0.05$ .

## Results

A total of 13,079 adults, including 4,896 full marathon runners and 8,183 half marathon runners, participated in the current study. 64.6% of the participants were young adults no older than 30 years (Table 1). More than three quarters of the participants were men. Although the study population was composed of marathon runners, more than 20% of the male runners were overweight. In addition, most runners are still entry-level marathon enthusiasts, who had not experienced long-term intensive training. About 75% of runners took more than 4 hours to complete full marathon and nearly 80% runners need over 2 hours to finish half marathon.

Table 1  
Characteristics of the study population

	Men	Women	Total
n	9897 (75.7%)	3182 (24.3%)	13079 (100%)
Full marathon	4102 (83.8%)	794 (16.2%)	4896(100%)
Half marathon	5795(70.8%)	2388 (29.2%)	8183(100%)
Age, years			
Mean ± SD	28.6 ± 4.2	27.9 ± 4.1	28.5 ± 4.2
< 30 years	6,220 (62.8%)	2,232 (70.1%)	8,452 (64.6%)
30–35 years	3,677(37.2%)	950(29.9%)	4,627(35.4%)
Height, cm	173.6 ± 5.2	162.5 ± 4.8	170.6 ± 6.7
Weight, kg	67.9 ± 8.9	54.8 ± 8.6	65.0 ± 10.0
BMI, kg/m <sup>2</sup>	22.4 ± 2.2	20.3 ± 2.2	22.2 ± 2.2
Overweight, n(%)	1853(20.3%)	74 (2.5%)	1927 (16.0%)
Obesity, n(%)	94 (1.0%)	25 (0.7%)	114 (0.9%)
Finishing time			
Full marathon	4h22min (42 min)	4h47min (39 min)	4h26min (42 min)
< 3 hours	25 (0.6%)	2 (0.3%)	27 (0.6%)
3–4 hours	1120 (27.3%)	67 (8.4%)	1187 (24.2%)
4–5 hours	1955 (47.7%)	361 (45.5%)	2316 (47.3%)
> 5 hours	1002 (24.4%)	364 (45.8%)	1366 (27.9%)
Half marathon	2h10min(20 min)	2h22min (17 min)	2h14min (20 min)
< 2 hours	1604 (27.7%)	152 (6.4%)	1756 (21.5%)
2–3 hours	4143 (71.5%)	2187 (91.6%)	6330 (77.4%)
> 3 hours	48 (0.7%)	49 (2.0%)	97 (1.2%)
Note: overweight: BMI ≥ 24 kg/m <sup>2</sup> and < 28 kg/m <sup>2</sup> ; obesity: BMI ≥ 28 kg/m <sup>2</sup>			

The prevalence of training-related changes according to the 2017 international recommendation for ECG interpretation is summarised in Table 2. Sinus bradycardia and sinus arrhythmia were found in approximately 14.67% and 8.09% of the participants, respectively. The prevalence of left ventricular high voltage was 3.12%, and the male runners exhibited a significantly higher incidence (4.04%) compared

with the female runners (0.25%). 1.25% of runners were found to have early repolarisation. No more than 1% of the runners demonstrated first-degree atrioventricular block (AVB), Mobitz type 1 (Wenckebach) second-degree AVB, ectopic atrial or junctional rhythm and incomplete right bundle branch block (RBBB). It is noteworthy that, the prevalence of sinus bradycardia and sinus arrhythmia in normal weight runners are 15.8% and 6.0% respectively, which are significantly higher than the prevalence in overweight runners (14.3% and 4.0%). The results of logistic regression showed that the good-performance group showed higher rates for sinus bradycardia, left ventricular high voltage, right ventricular high voltage, and AVB after the age, gender, and weight status were adjusted in the models (Table 3).

Table 2  
Prevalence of training related ECG changes in the male and female marathon runners

	Men (n = 9897)		Women (n = 3182)		Total (n = 13079)		P*
	n	%	n	%	n	%	
Sinus bradycardia	1544	15.60%	375	11.79%	1919	14.67%	< 0.01
Sinus arrhythmia	790	7.98%	268	8.42%	1058	8.09%	> 0.05
Left ventricular high voltage	400	4.04%	8	0.25%	408	3.12%	< 0.01
Right ventricular high voltage	9	0.09%	0	0.00%	9	0.07%	> 0.05
Early Repolarization/ ST segment elevation	130	1.31%	33	1.04%	163	1.25%	> 0.05
1° AVB	39	0.39%	4	0.13%	43	0.33%	< 0.01
Mobitz type 1 (Wenckebach) 2° AVB	1	0.01%		0.00%	1	0.01%	
Ectopic atrial or junctional rhythm	5	0.05%	1	0.03%	6	0.05%	> 0.05
Incomplete RBBB	118	1.19%	9	0.28%	127	0.97%	< 0.01
Any of the above findings	2071	20.93%	546	17.16%		20.01%	< 0.01
Note: *: <i>p</i> value of chi-square test between men and women							
AVB: atrioventricular block; RBBB: right bundle branch block							
Some participants had to have more than one ECG abnormality							

Table 3  
Odds Ratios of having ECG findings in marathon runners with good performance as compared with the runners with poor performance

	<b>OR</b>	<b>95% confidence interval</b>
Normal ECG	1.346	1.261–1.438
Sinus bradycardia	1.518	1.409–1.636
Sinus arrhythmia	1.010	0.899–1.135
left ventricular high voltage	1.436	1.233–1.672
1° AVB	1.702	1.034–2.804
Incomplete RBBB	0.803	0.606–1.065
right axis deviation	0.917	0.717–1.174
left axis deviation	0.869	0.611–1.236
Note: Age, gender, weight status were adjusted in the logistic regression model.		
AVB: Atrioventricular block; RBBB: Right bundle branch block		

The prevalence of borderline ECG findings is showed in Table 4. The incidence of right axis deviation in the marathon runners was 1.78%, which was slightly higher than the incidence of left axis deviation (0.88%). 0.70% and 0.54% runners were found to have left and right atrial enlargement respectively. A total of 18 men and only 1 woman were found to have complete RBBB.

Table 4  
Prevalence of borderline ECG findings in the male and female marathon runners

	Men (n = 9897)		Women(n = 3182)		Total(n = 13079)		p*
	n	%	n	%	n	%	
Right axis deviation	176	1.78%	28	0.88%	204	1.56%	< 0.01
Left axis deviation	98	0.99%	9	0.28%	107	0.82%	< 0.01
Left atrial enlargement	70	0.71%	22	0.69%	92	0.70%	> 0.05
Right atrial enlargement	55	0.56%	16	0.50%	70	0.54%	> 0.05
Complete RBBB	18	0.18%	1	0.03%	19	0.15%	< 0.05
Any of the above findings	386	3.90%	66	2.07%	452	3.46%	< 0.01
Note: *: <i>p</i> value of chi-square test between men and women							
RBBB: right bundle branch block							

The prevalence of abnormal ECG findings was very low, and none was greater than 1‰ (Table 5). Among the amateur runners, 0.03% (2 men and 2 women) were found to have TWI. That 6 (0.06%) male and 6 (0.19%) female runners were found to have ST segment depression was noteworthy. In addition, several runners were found to have premature ventricular contraction, pathologic Q waves, atrial fibrillation and prolonged QT interval.

Table 5  
Prevalence of abnormal ECG findings in the male and female marathon runners

	Men (n = 9897)		Women (n = 3182)		Total(n = 13079)		P*
	n	%	n	%	n	%	
T wave inversion	2	0.02%	2	0.06%	4	0.03%	> 0.05
ST segment depression	6	0.06%	6	0.19%	12	0.09%	< 0.01
Pathologic Q waves	2	0.02%			2	0.02%	
Premature ventricular contraction	4	0.04%	1	0.03%	5	0.04%	> 0.05
Atrial fibrillation	1	0.01%			1	0.01%	
Prolonged QT interval	1	0.01%			1	0.01%	
Any of the above findings	15	0.15%	7	0.22%	22	0.17%	> 0.05

Note: \*: *p* value of chi-square test between men and women

## Discussion

A marathon is a vigorous long-term exercise that challenges human limits and imposes a heavy cardiac load. In response to prolonged exercise, physiological and anatomical adaptations can develop in healthy marathon runners. In the current study, the prevalence of 'training-related', borderline and abnormal ECG changes in a large sample of amateur marathon runners was reported to serve as a reference for SCD prevention during marathons.

It is noteworthy that the prevalence of some ECG changes in the current study are quite low. Only 0.97% and 0.15% of the runners were found to have incomplete and complete RBBB, respectively, which is obviously lower than the prevalence reported in previous studies (IRBBB: 7–20%, CRBBB: 2–3%) (25–27). The prevalence of AVB in the athletes in this study (0.34%) was also significantly lower than that reported in previous studies (approximately 4.5–7.5%) and similar to that in sedentary healthy adults in other studies (17, 21, 28, 29). Low prevalence were also found in ST segment depression, TWI and pathologic Q waves. TWI was found in 22.9% of 329 adolescent black athletes and in 4.5% of 903 adolescent white athletes (30). Another study using 1,000 athletes showed that the prevalence of TWI was 4% (17). However, in the current study, no more than 0.1% of the amateur marathon runners exhibited ST segment depression, TWI, premature ventricular contraction, pathologic Q waves and prolonged QT interval.

The large difference in prevalence rates can be attributed to multiple reasons, one of which could be participants' training levels. Lots of ECG changes including AVB, RBBB and ST segment elevation are

associated with long-term endurance training (31, 32) and could be influenced by the number of years of training in a respective sport (27). In the current study, most runners are still entry-level marathon enthusiasts. More than 75% of participants took more than 4 hours to complete full marathon and nearly 80% runners need more than 2 hours to finish half marathon. Therefore, most participants in this study are physical active adults and different from professional athletes who receive long-term intensive training. Due to the U-shaped relationship between physical activity and cardiac abnormality morbidity (33), the physical active participants may have significant lower prevalence of abnormal ECG findings than sedentary Chinese adults and professional athletes.

Numerous studies indicated that ECG abnormalities vary across ethnicity and these variations may have implications for further diagnostic testing(34, 35). Electrocardiographic repolarisation changes and echocardiographic left ventricular hypertrophy have been demonstrated to be more common in black athletes (22, 36). However, most of these studies are based on black and white athletes, and limited data on ECG data of Chinese athletes were reported. The prevalence of TWI reported by Feng et al. was 1.7% in young Chinese athlete and none of the college students was found to have TWI(37). While 4.5% of West-Asian young athletes and 15.9% of black athletes were found to have TWI (38). Another study reported the prevalence of ECG abnormalities in South-East Asians, which also showed that Chinese have lower prevalence of T wave abnormalities than South Asians (39). Moreover, pathologic Q waves may also be infrequently in Chinese. Ng et al reported that only 20 out of 18476 young male military conscripts had abnormal Q wave (39). Another study demonstrated that the prevalence pathologic Q waves was 1.8% in ordinary Chinese (35–54 years old) which was also significantly lower than the data in the U.S. (40). These research evidences suggested Chinese populations may have a relatively low prevalence of ECG abnormalities.

In addition, possibility of selection bias may also be an important reason for the low prevalence of ECG abnormalities found in this study. The data of this study came from the self-submitted ECG report by the marathon runners. Therefore, the prevalence of ECG abnormalities could be underestimated, as some marathon runners maybe not willing to submit their ECG report if they had serious cardiac problems.

It is noteworthy that the prevalence of most normal and borderline ECG in the current study are similar to the data in previous studies. Left and right axes deviation is classified by the new criteria as a borderline training-related ECG change. Gati et al. reported that the prevalence of left and right axes deviation in 2,533 athletes was 1.46% and 1.11%, respectively (41). In the current study, 1.56% and 0.82% of the marathon runners were found to have right and left axes deviation respectively, which is similar to the results reported by Gati et al. Furthermore, the data suggested that no significant differences existed in the incidence of left and right axes deviation between amateur marathon runners and sedentary healthy adults (28, 29, 42). The data of the current study confirmed that long-term marathon training can cause physiological changes in the heart of runners, which was reflected in ECG training-related changes. Sinus bradycardia and sinus arrhythmia, which are associated with increased vagal tone, as well as training-related ECG changes are common in long-distance runners (43). The prevalence of sinus bradycardia in sedentary healthy Chinese adults is 5.99–10.51%(29, 44), which was lower than that in the marathon

runners in this study (14.67%). The prevalence of sinus arrhythmia in the participants was 8.09%, which is similar to that in sedentary healthy adults (5.38–8.14%) (29, 44).

Several limitations should be acknowledged when the results are interpreted. Firstly, the prevalence of ECG abnormalities could be underestimated due to the self-submitted ECG data. The results from this population could be translated to others with extreme caution. Secondly, all the participants of this study were Chinese. As ethnicity is an important determinant of cardiac adaptation to exercise (30, 45), the results may not be generalised to other ethnicities. Thirdly, further cardiovascular examinations were not conducted in participants with positive ECG results so the true disease rate is unclear. The strengths of this study include the large sample size and the special study population. Despite these limitations, this study is beneficial in understanding the cardiac status of amateur marathon runners, the influence of prolonged marathon training on the heart and the prevention of SCD during marathon events.

## **Conclusion**

Training-related ECG changes, including sinus bradycardia, sinus arrhythmia and left ventricular high voltage, were common in the amateur marathon runners. In addition, left and right axes deviation as well as atrial enlargement were common borderline ECG changes. Most abnormal ECG changes, including ST segment depression, TWI, premature ventricular contraction, pathologic Q waves and prolonged QT interval, were infrequently found in the amateur marathon runners.

## **Declarations**

### **Ethics approval and consent to participate**

All participants read and signed an informed consent form and this study was approved by the Ethics Committee of the First Affiliated Hospital of the Medical School of Zhejiang University.

### **Consent for publication**

Not applicable.

### **Availability of data and materials**

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request

### **Competing interests**

None declared.

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### Authors' contributions

XW and TSX conceived and designed the study. YMH, THS and YLG collected data and conducted the data analysis. XW, YMH and TSX wrote the paper. RQD and LX reviewed and edited the manuscript. All authors read and approved the manuscript.

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