SECTION 15

Special Considerations: Age, Race, Gender, and Athletes

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Sanjay Sharma, BSc (Hons), MD

CASE
15.1

Patient History

This ECG (**Figure 15.1.1**) was obtained from an asymptomatic cyclist. What further investigation is required?

Figure 15.1.1

Question

This athlete's ECG shows a junctional rhythm with a narrow QRS. What would you do next?

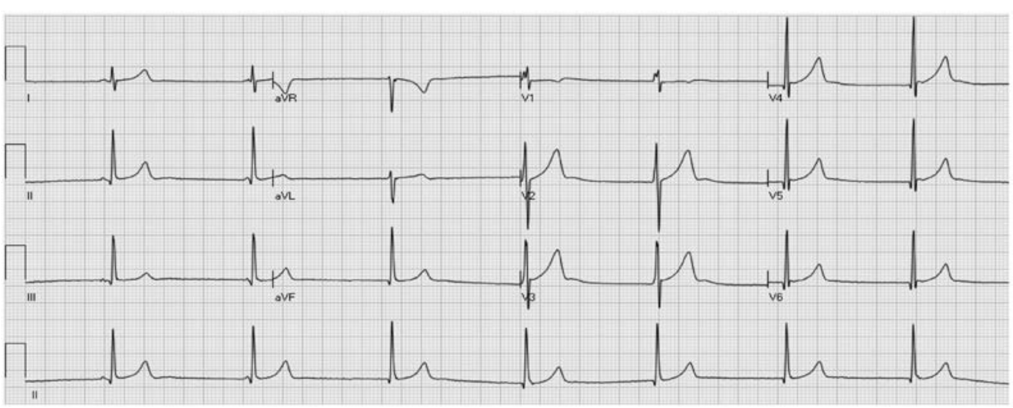

Figure 15.1.2

Discussion

It has been well established that the ECG in the athletically trained heart can exhibit features of high vagal tone. Sinus bradycardia as low as 30 bpm and a PR interval of up to 400 ms are commonplace and do not require further evaluation. Exercise testing is useful to demonstrate chronotropic competence and PR shortening under these circumstances.

Although less frequent, Mobitz I second-degree atrioventricular (AV) block (Wenckebach) and junctional rhythms are also recognized within the physiological spectrum in the asymptomatic athlete (2.4% and 0.3%, respectively). The ECG in **Figure 15.1.1** shows Mobitz I second-degree AV block (Wenckebach) and as such, no further investigation is required. Likewise, **Figure 15.1.2** shows a junctional rhythm and in an asymptomatic athlete does not require any further management. However, higher degrees of AV block, including Mobitz II and complete heart block, are an exceptionally rare physiological finding and should always be investigated further with echocardiography, exercise tolerance testing, ambulatory ECG monitoring, and possibly cardiac magnetic resonance imaging (MRI).

An interesting finding in athletes, not to be confused with complete heart block, is *AV mismatch*, in which the AV node discharges and captures the ventricle faster than the sinoatrial node as a consequence of high vagal tone, with resulting AV dissociation.

References

1. Sharma S, Whyte G, Elliott P, et al. Electrocardiographic changes in 1000 highly trained junior elite athletes. *Br J Sports Med.* 1999;33(5):319–324.
2. Papadakis M, Basavarajaiah S, Rawlins J, et al. Prevalence and significance of T-wave inversions in predominantly Caucasian adolescent athletes. *Eur Heart J*. 2009;30(14):1728–1735.
3. Sharma S, Drezner JA, Baggish A, et al. International recommendations for electrocardiographic interpretation in athletes. *J Am Coll Cardiol*. 2017;69(8):1057–1075.

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CASE 15.2

Patient History

An African-American male soccer player has experienced transient dizziness on two occasions after a strenuous game. He has never lost consciousness. There is no relevant family history. Physical examination and echocardiography were normal.

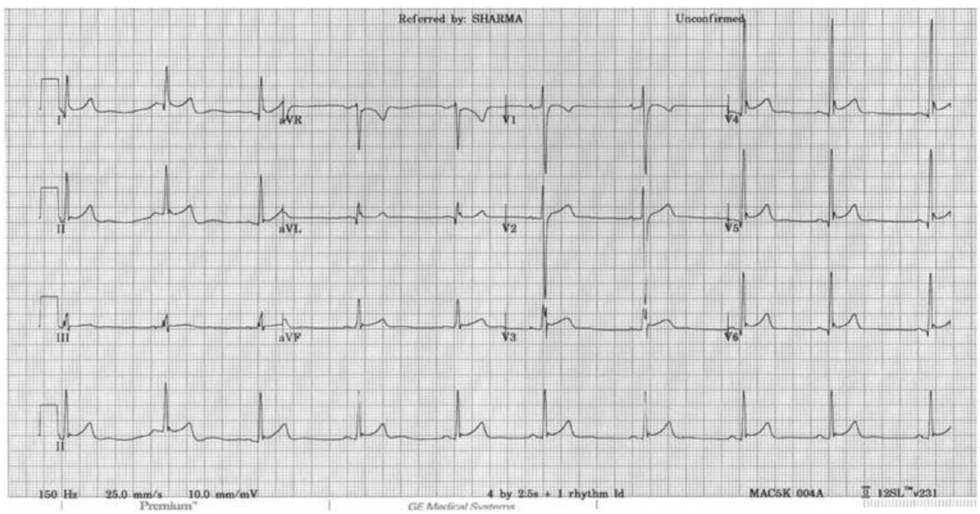

Figure 15.2.1

Question

Is this ECG (**Figure 15.2.1**) normal in the clinical context?

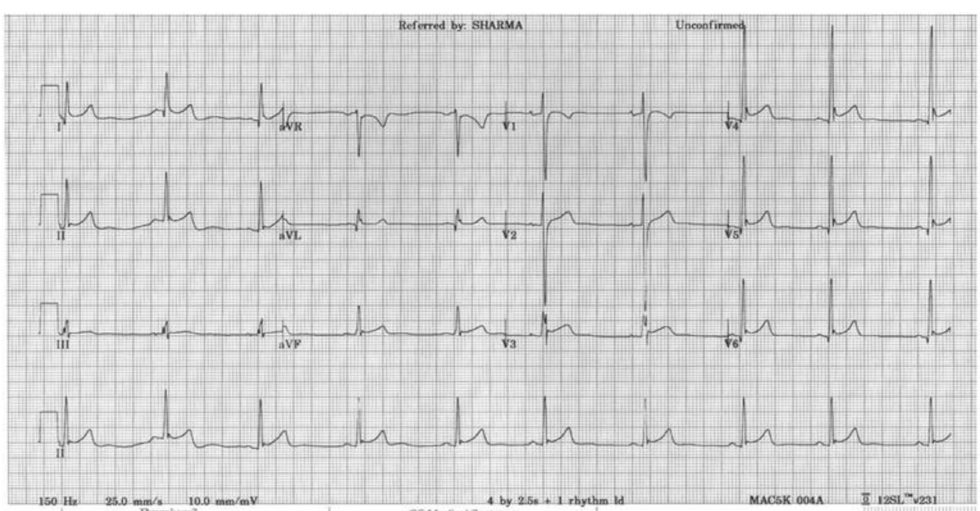

Figure 15.2.2 ECG consistent with early repolarization pattern (ERP). Findings include J-point elevation and notched J waves in leads V_3–V_6, I, and II.

Discussion

The ECG in **Figure 15.2.2** demonstrates the early repolarization pattern (ERP), which is defined as elevation of the QRS-ST junction (J-point) of >0.1 mV, notching of the J-point or slurring of the terminal QRS, with or without ST-segment elevation. The ERP is recognized in 23–44% of athletes, with a predominance in black males (63–91%). **Figure 15.2.3** shows examples of commonly seen ERPs in black athletes. Some small studies including both athletes and nonathletes demonstrated a significantly higher prevalence of ERPs, specifically in the inferior-lateral leads, among patients with idiopathic ventricular fibrillation (VF). However, studies to date have failed to demonstrate any prognostic implication of ERP in athletes, and until studies suggest otherwise, in isolation it should be considered a normal variant in this cohort.

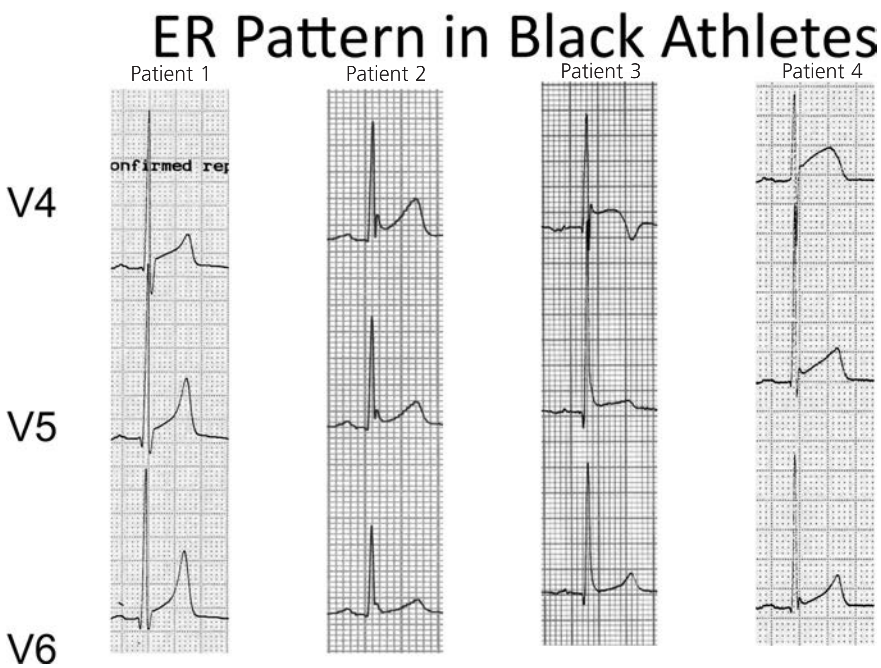

Figure 15.2.3 All four tracings would be considered normal in an otherwise asymptomatic athlete. As mentioned earlier, black athletes are among those most commonly manifesting the ERP, with it being present in more than two-thirds. This can be seen as J-point elevation in isolation, as in all four patients, or in association with notched J waves (patients 2 and 4) or slurring of the terminal QRS (patient 3).

References

1. Sheikh N, Papadakis M, Carre F, et al. Cardiac adaptation to exercise in adolescent athletes of African ethnicity: An emergent elite athletic population. *Br J Sports Med.* 2013;47(9):585–592.
2. Papadakis M, Carre F, Kervio G, et al. The prevalence, distribution, and clinical outcomes of electrocardiographic repolarization patterns in male athletes of African/Afro-Caribbean origin. *Eur Heart J.* 2011;32(18):2304–2313.
3. Noseworthy PA, Weiner R, Kim J, et al. Early repolarization pattern in competitive athletes: Clinical correlates and the effects of exercise training. *Circ Arrhythm Electrophysiol*. 2011;4:432–440.
4. Haissaguerre M, Dervel N, Sacher F, et al. Sudden cardiac arrest associated with early repolarization. *N Engl J Med.* 2008;358:2016–2023.
5. Tikkanen J, Anttonen O, Junttila J, et al. Long-term outcome associated with early repolarization on electrocardiography. *N Engl J Med.* 2009;361:2529–2537.

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CASE 15.3

Patient History

This ECG (**Figure 15.3.1**) was obtained from an asymptomatic 23-year-old rower. Physical examination was normal, with a blood pressure of 110/70 mmHg.

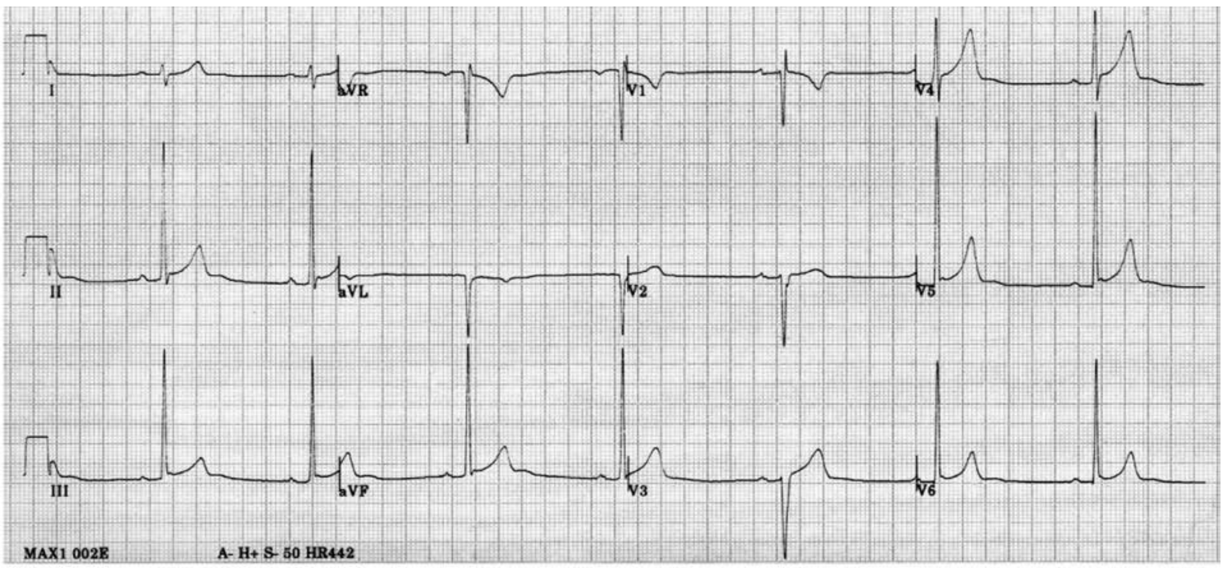

Figure 15.3.1

Question

Is any further investigation required?

Discussion

According to the latest international recommendations, the ECG changes seen in **Figure 15.3.2**, including right axis deviation, incomplete right bundle branch block (RBBB), left ventricular hypertrophy (LVH), sinus bradycardia, and early repolarization pattern (ERP), are all features of athletic adaptation, and therefore this individual does not require further investigation.

Isolated voltage criteria for LVH is seen in up to 50% of ECGs in athletes, most often in young, slender, black males, and does not necessarily correlate with the presence of increased LV wall thickness. It is defined as: S-V_1 + R-$V_{5/6}$ >35 mm. LVH is a common ECG manifestation of hypertrophic cardiomyopathy (HCM) but is very rarely found in isolation (2%) and usually associated with T-wave inversion, ST depression, and pathological Q waves. Therefore, isolated LVH is considered a normal variant in the asymptomatic athlete.

Reported in up to 60% of athletes, incomplete RBBB is a feature of physiological athletic adaptation.

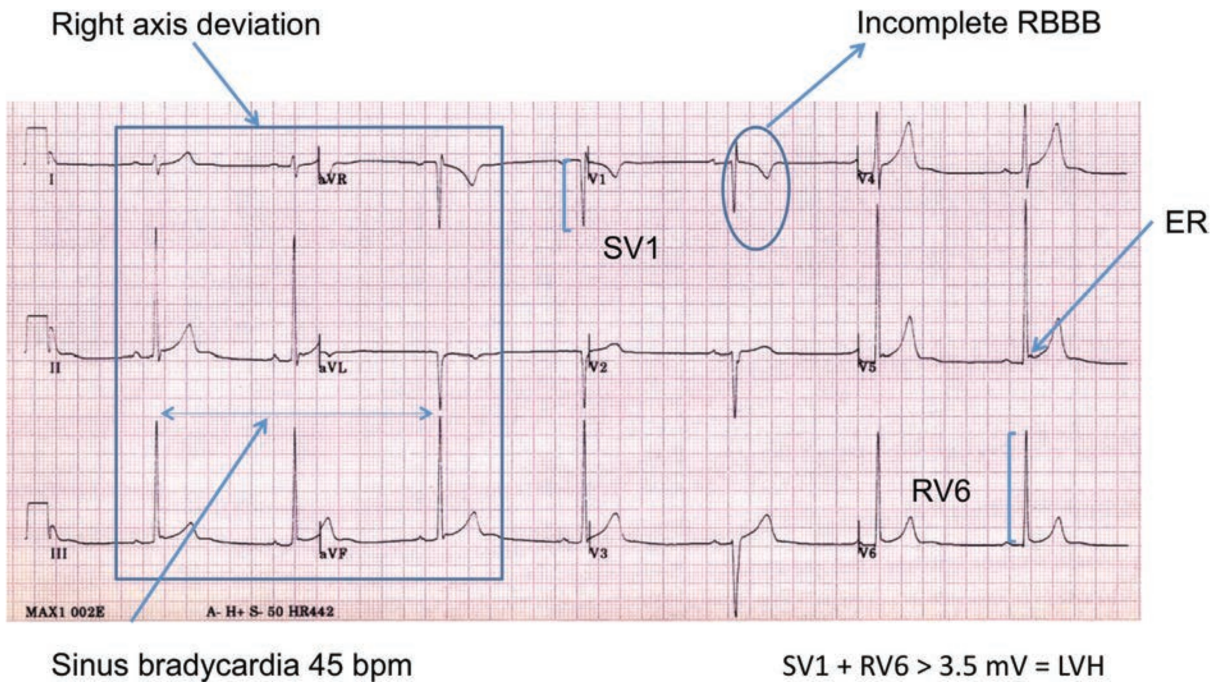

Figure 15.3.2 ECG showing right axis deviation, incomplete RBBB, LVH, early repolarization, and sinus bradycardia.

Isolated right axis deviation, defined as an axis >120 degrees, is considered a normal finding in athletes; however, when seen in association with criteria for atrial enlargement or complete RBBB, further investigation is recommended.

References

1. Pelliccia A, Maron BJ, Culasso F, et al. Clinical significance of abnormal electrocardiographic patterns in trained athletes. *Circulation*. 2000;102(3):278–284.
2. Gati S, Sheikh N, Ghani S, et al. Should axis deviation or atrial enlargement be categorised as abnormal in young athletes? The athlete's electrocardiogram: Time for re-appraisal of markers of pathology. *Eur Heart J.* 2013;34(47):3641–3648.

CASE

15.4

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Patient History

An ECG was obtained from an asymptomatic 15-year-old tennis player (**Figure 15.4.1**). Echocardiography is normal.

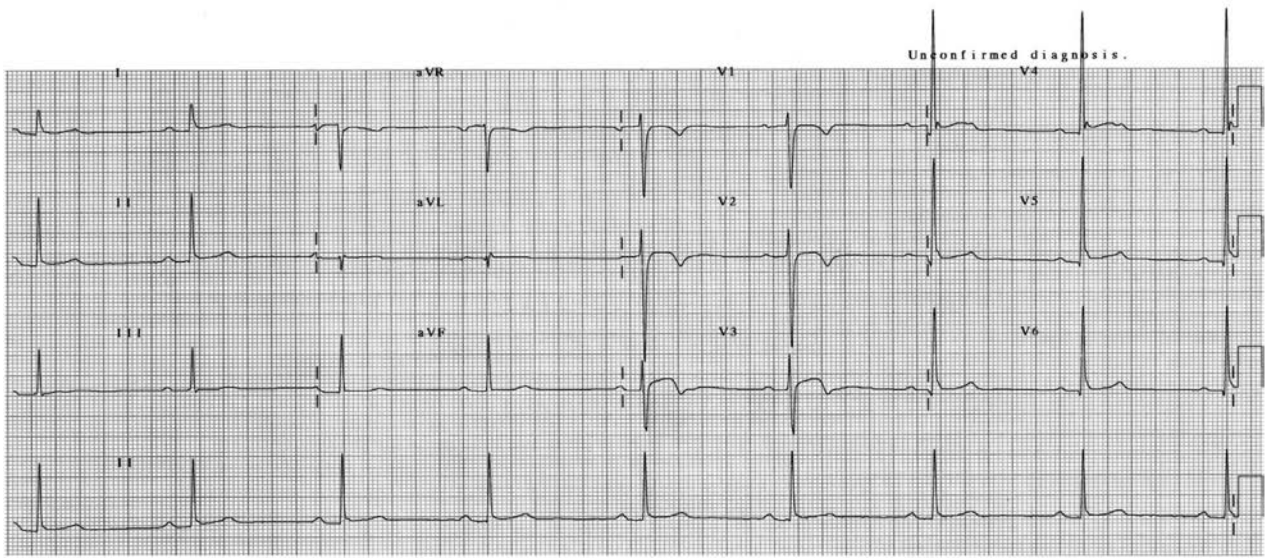

Figure 15.4.1

Question

Would you perform any further investigations at this time?

Discussion

This 15-year-old athlete has an ECG consistent with a benign juvenile ECG pattern with T-wave inversion in V_1 and V_2 and a biphasic T wave in V_3. In the under-16 age group, up to 4% of athletes will have T-wave inversion (TWI) extending beyond V_2. In isolation, in an asymptomatic athlete, this does not require further evaluation; however, a repeat ECG once over the age of 16 is recommended to ensure resolution of the changes. A persistence of TWI beyond V_2 in persons over age 16 is rare (<0.2% beyond V_2) and should be further investigated. If the ECG in **Figure 15.4.2** demonstrated deep T-wave inversion, a much rarer feature in those under age 16 (0.8%), again, further investigation with the minimum of an echocardiogram would be indicated.

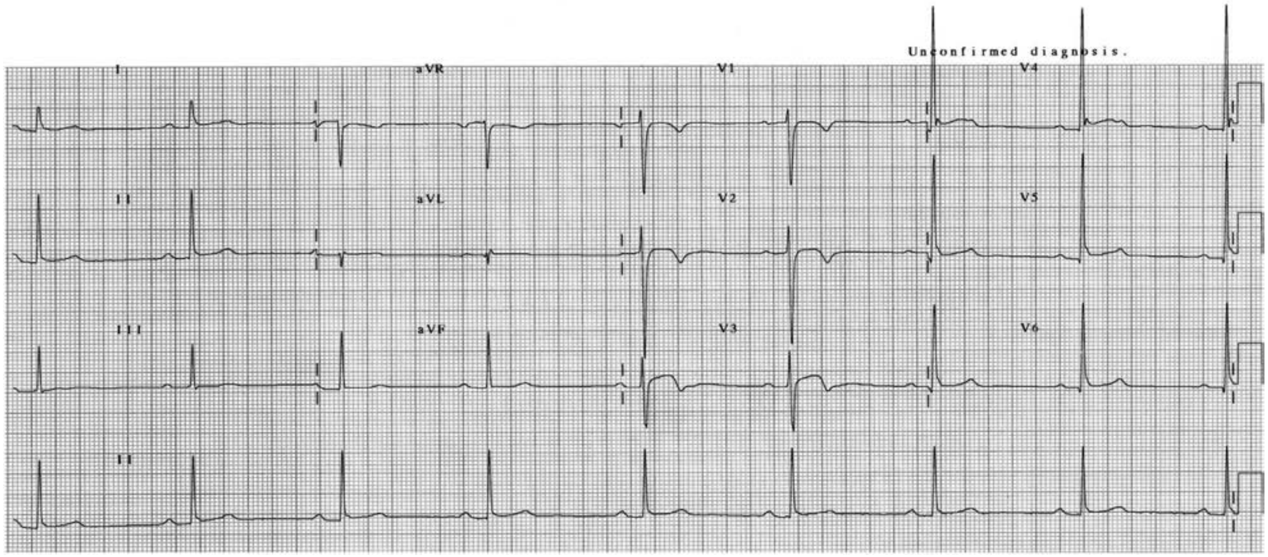

Figure 15.4.2 ECG showing J-point elevation in V_2 and V_3 with convex ST-segment elevation followed by minor T-wave inversion (TWI), consistent with a juvenile ECG pattern.

References

1. Papadakis M, Basavarajaiah S, Rawlins J, et al. Prevalence and significance of T-wave inversions in predominantly caucasian adolescent athletes. *Eur Heart J.* 2009;30(14):1728–1735.
2. Migliore F, Zorzi A, Michieli P, et al. Prevalence of cardiomyopathy in Italian asymptomatic children with electrocardiographic T-wave inversion at preparticipation screening. *Circulation*. 2012;125(3):529–538.
3. Calo L, Sperandii F, Martino A, et al. Echocardiographic findings in 2261 peri-pubertal athletes with or without inverted T waves at electrocardiogram. *Heart.* 2015;101:193–200.

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CASE 15.5

Patient History

An ECG (**Figure 15.5.1**) was obtained from a 26-year-old asymptomatic black professional soccer player.

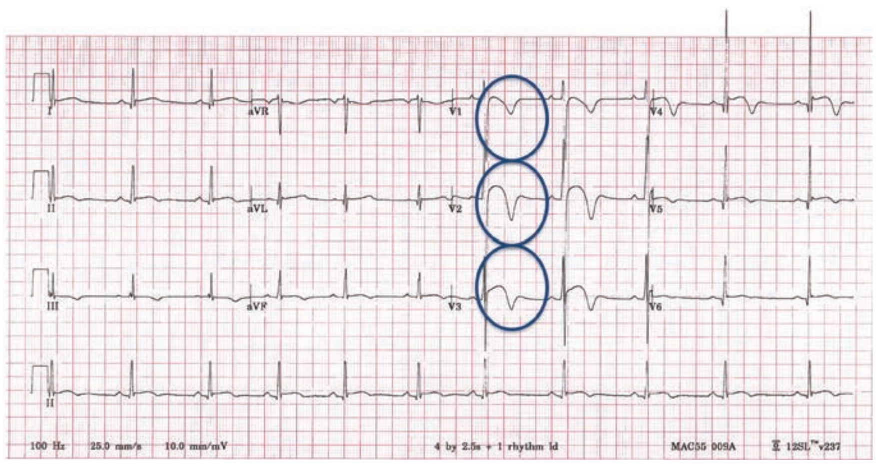

Figure 15.5.1

Question

Is the ECG normal or abnormal?

Discussion

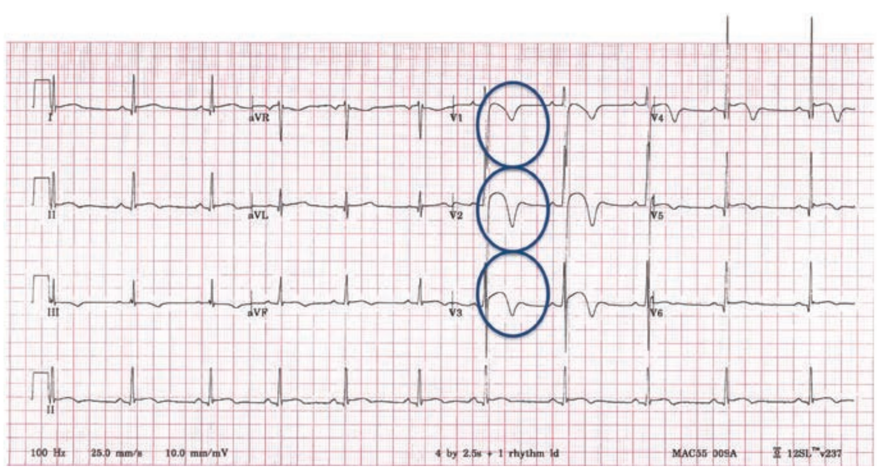

Figure 15.5.2 ECG showing J-point elevation and convex ST-segment elevation with T-wave inversion in V_1–V_4, consistent with physiological changes in a black athlete.

This ECG is consistent with an exercise-related early repolarization pattern (ERP) in an adult black athlete (**Figure 15.5.2**). This is a common manifestation in this cohort and is defined as J-point elevation with convex ST segments in V_1–V_4, followed by inverted T waves. Further examples of the ERP are shown in **Figure 15.5.3**. These findings in isolation do not warrant any further investigation.

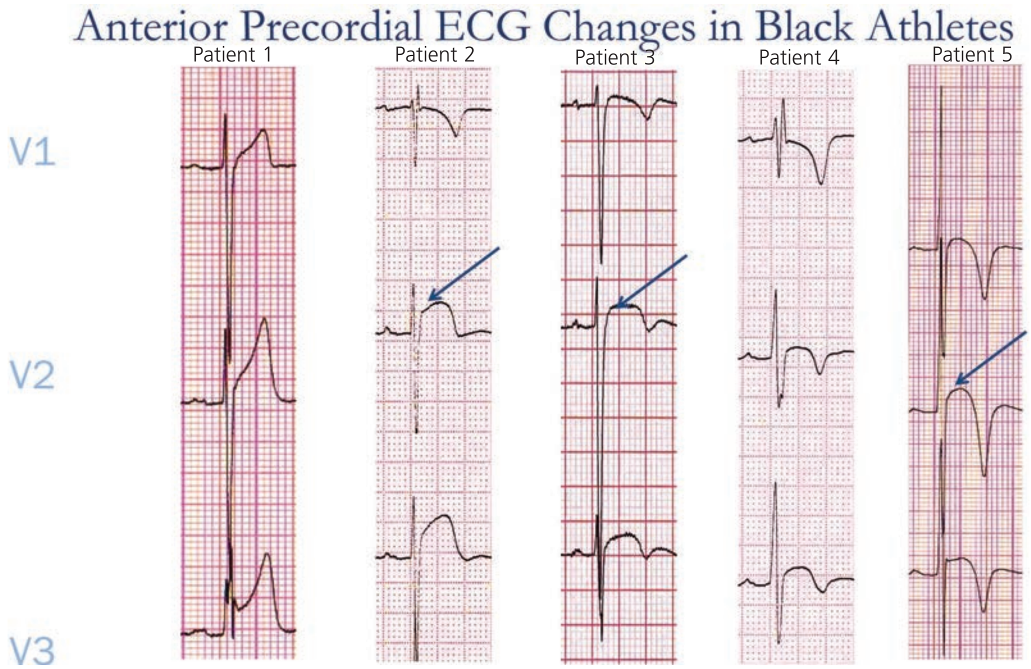

Figure 15.5.3 Patient 1: Anterior J-point elevation with concave ST-segment elevation. Patient 2: rSR′ in V_1 with anterior J-point elevation and convex ST segment elevation. Patient 3: Anterior J-point elevation with convex ST-segment elevation followed by biphasic T waves. Patient 4: rSR′ in V_1 with anterior J-point elevation and T-wave inversion. Patient 5: Anterior J-point elevation with convex ST segments and deep T-wave inversion. All of these anterior lead ECG traces represent a variant of the ERP, which is a normal finding in an otherwise asymptomatic black athlete.

The ERP usually regresses with detraining, which can be useful in cases where the differentiation of adaptive from pathological changes is unclear. An example of such regression is shown in **Figure 15.5.4**.

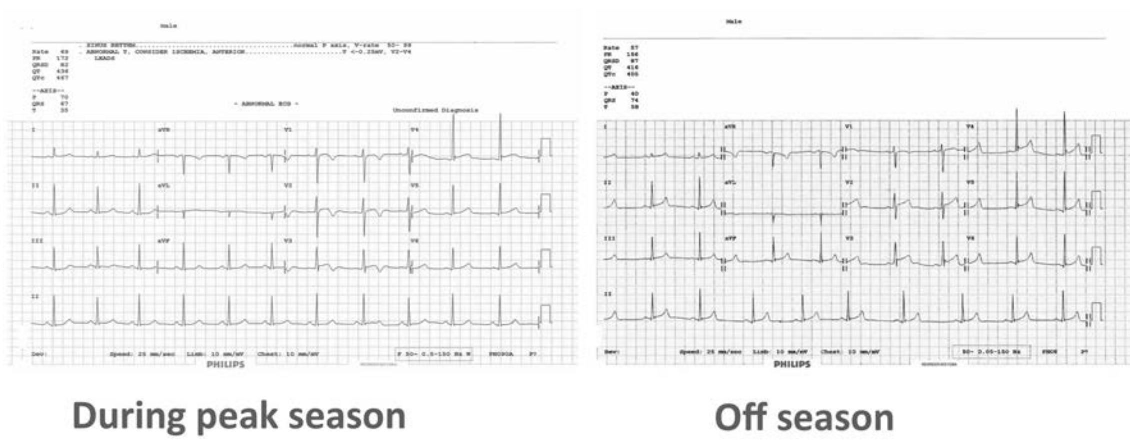

Figure 15.5.4 ECGs taken during peak season and off-season in a black athlete.

The ECG during peak season shows J-point elevation with convex ST segments followed by T-wave inversion in V_1–V_3. In the subsequent ECG off-season, i.e., detrained, although the J-point elevation remains in V_2–V_5, the ST-segment elevation is not concave and the T-wave inversion has resolved.

Other notable features seen in the ECG in **Figure 15.5.4** are a longer PR interval (as a result of high vagal tone) and a longer QTc of 467 ms at peak training. This QTc although acceptable for a male athlete (upper limit of normal ≥470 ms) would be considered prolonged in a sedentary male (cut-off 450 ms) and would require further investigation in a sedentary individual. Similarly, a QTc up to 480 ms is considered normal in female athletes, not requiring further evaluation, in contrast to nonathlete females, where the cut-off is 460 ms.

References

1. Sheikh N, Papadakis M, Carre F, et al. Cardiac adaptation to exercise in adolescent athletes of African ethnicity: An emergent elite athletic population. *Br J Sports Med.* 2013;47(9):585–592.
2. Papadakis M, Carre F, Kervio G, et al. The prevalence, distribution, and clinical outcomes of electrocardiographic repolarization patterns in male athletes of African/Afro-Caribbean origin. *Eur Heart J.* 2011;32(18):2304–2313.
3. Brosnan M, La Gerche A, Kalman J, et al. The Seattle Criteria increase the specificity of preparticipation ECG screening among elite athletes. *Br J Sports Med.* 2014;48(15):1144–1150.

CASE 15.6

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Patient History

An ECG (**Figure 15.6.1**) was obtained from an asymptomatic black athlete. Echocardiography was normal.

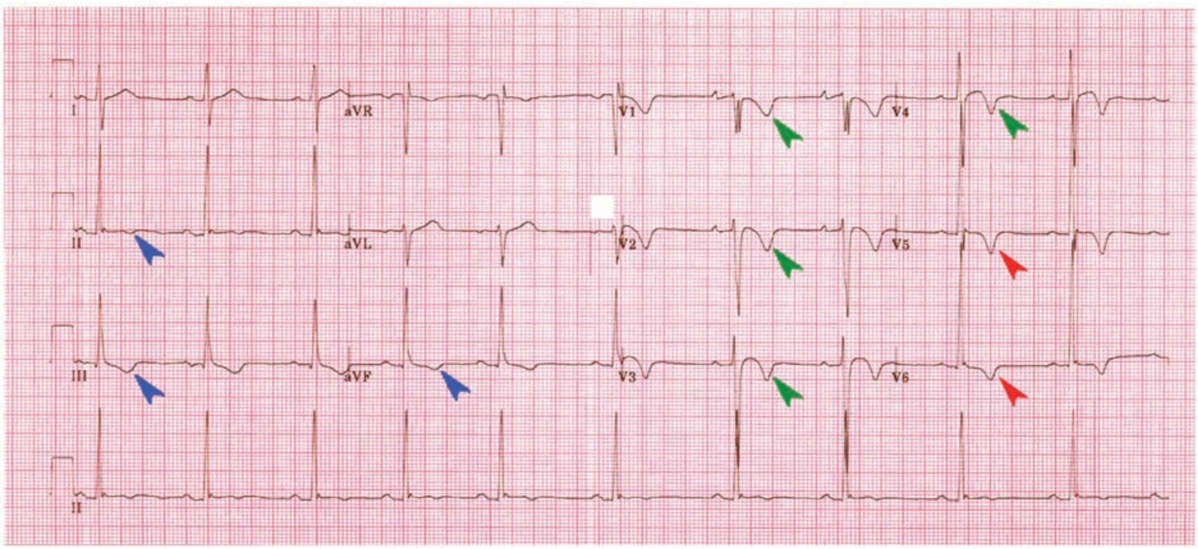

Figure 15.6.1 ECG showing widespread T-wave inversion in the anterior, lateral and inferior leads with J-point elevation and convex ST segments in V_2 and V_3.

Question

Are any further investigations required?

Discussion

T-wave inversion (TWI) is the most common ECG manifestation of cardiomyopathy, found most often in arrhythmogenic right ventricular cardiomyopathy/dysplasia (ARVC/D) and hypertrophic cardiomyopathy (HCM). Differentiating benign from pathological T-wave inversion poses a great challenge, especially among those groups of athletes, e.g., juvenile/black, in whom TWI can be very extensive yet not pathological. Recent research has allowed us to further refine our criteria for this differentiation; however, overlap does remain, and under such circumstances further investigation is warranted. A large study demonstrated significant TWI in 23% of black athletes. Eighty-nine percent of these were anterior (V_1–V_4), with inferior and lateral T-wave inversion being much less common (6% and 4.1%, respectively). Inferior TWI is commonly isolated to leads III and aVF and often benign; in contrast, TWI in the lateral leads is a strong predictor of HCM and warrants a higher index of suspicion.

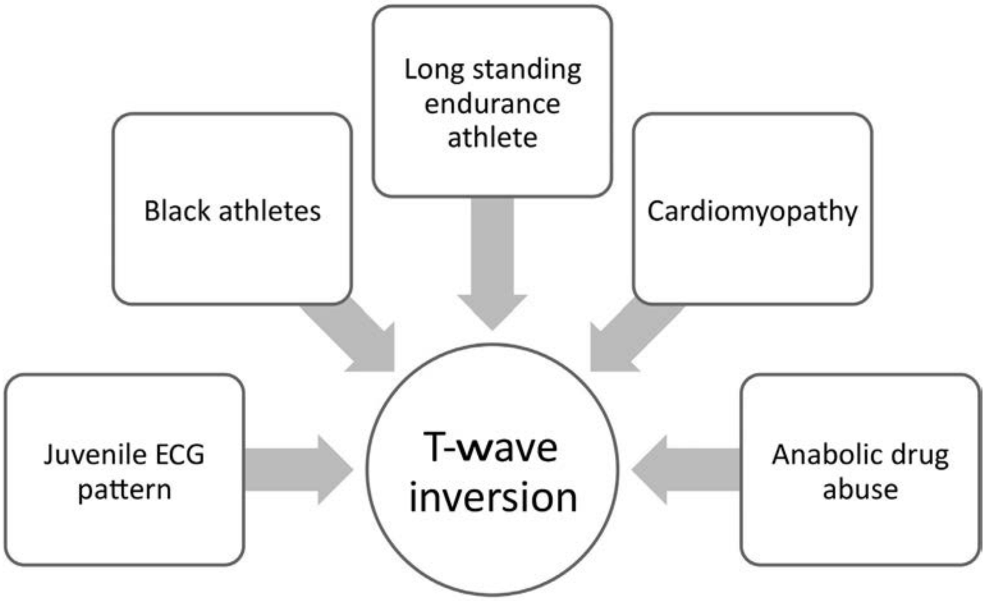

Figure 15.6.2 Image highlighting those common circumstances in which extensive T-wave inversion can manifest.

References

1. Pelliccia A, Di Paolo FM, Quattrini FM, et al. Outcomes in athletes with marked ECG repolarization abnormalities. *N Engl J Med*. 2008;358(2):152–161.
2. Papadakis M, Carre F, Kervio G, et al. The prevalence, distribution, and clinical outcomes of electrocardiographic repolarization patterns in male athletes of African/Afro-Caribbean origin. *Eur Heart J.* 2011;32(18):2304–2313.

CASE 15.7

Gemma Parry-Williams, MBChB, MRCP (UK)
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Patient History

An ECG (**Figure 15.7.1**) was obtained from a 32-year-old white female elite rower.

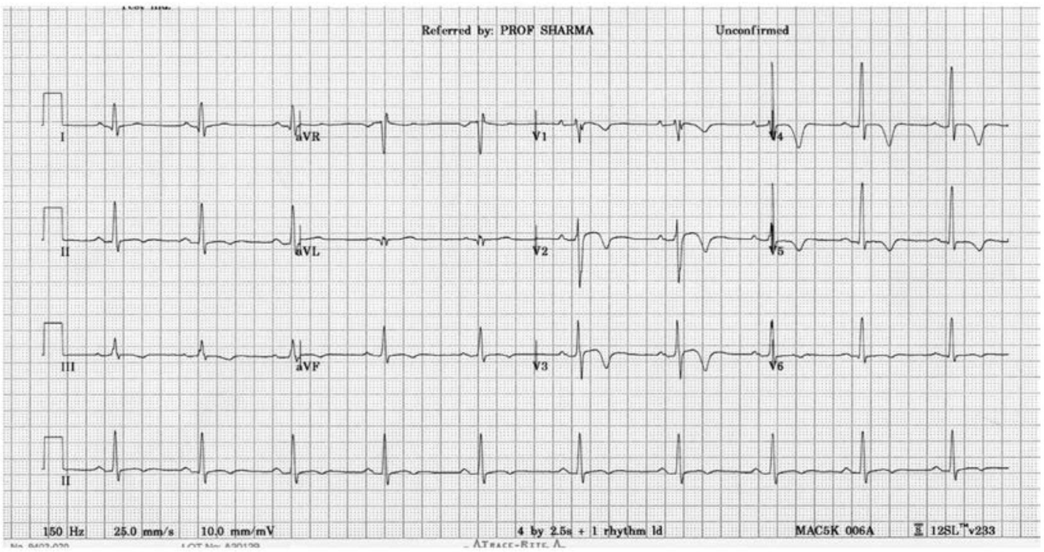

Figure 15.7.1

Question

Is the ECG normal or abnormal?

Discussion

This ECG shows extensive deep T-wave inversion (TWI) from V_1–V_6, II, III, and aVF. There is also J-point elevation with convex ST-segment elevation in V_2 and V_3. This pattern is **not** recognized within the spectrum of ECG changes seen in athletes regardless of age or ethnicity and warrants further investigation. Such investigation should include an echocardiogram, exercise tolerance test, ambulatory cardiac monitor, and cardiac MRI looking for any features of cardiomyopathies such as arrhythmogenic right ventricular cardiomyopathy/dysplasia (ARVC/D) and apical hypertrophic cardiomyopathy (HCM).

In a study of predominantly Caucasian athletes, the prevalence of anterior T-wave inversion extending beyond V_2 in individuals over age 16 was very low (0.1%). Inferior-lateral TWI in this cohort was also rare, seen in 1.5%.

Reference

1. Papadakis M, Basavarajaiah S, Rawlins J, et al. Prevalence and significance of T-wave inversions in predominantly Caucasian adolescent athletes. *Eur Heart J.* 2009;30(14):1728–1735.

CASE
15.8

Gemma Parry-Williams, MBChB, MRCP (UK)
Sanjay Sharma, BSc (Hons), MD

Patient History

Below are a selection of ECGs taken in asymptomatic professional athletes between the ages of 14 and 35.

Question

Which of these patients requires further investigation based on their ECG findings?

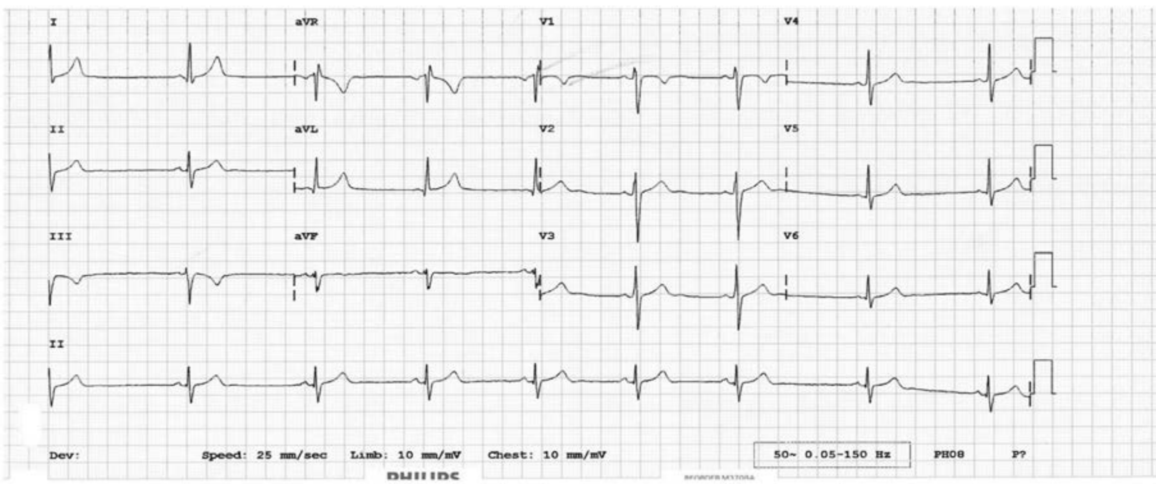

Figure 15.8.1 ECG showing left axis deviation in an athlete.

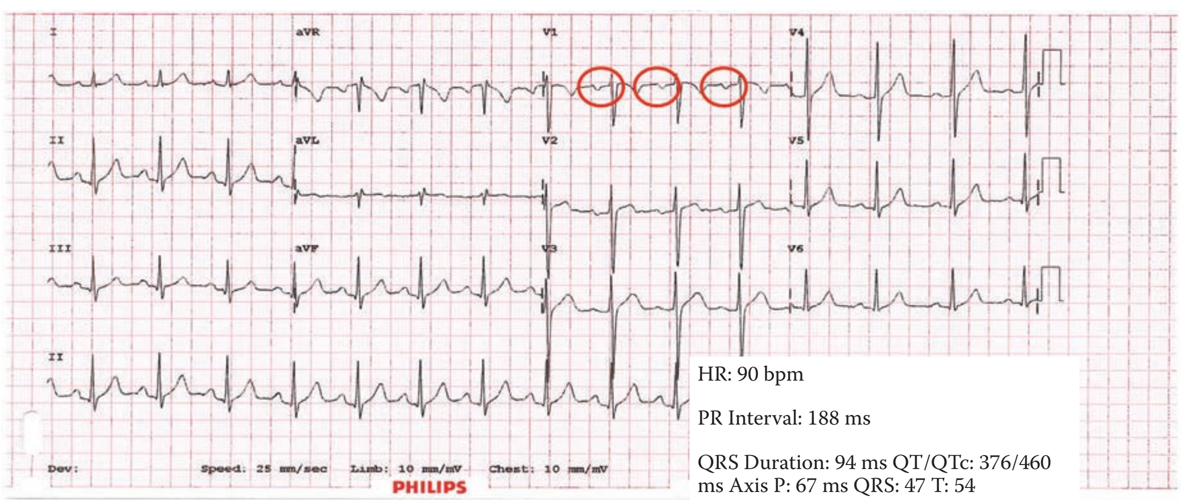

Figure 15.8.2 ECG demonstrating evidence of left atrial enlargement in lead V_1 in an athlete.

Figure 15.8.3 Focus on lead V_1 showing biphasic P wave with negative portion ≥1 mm in depth and ≥40 ms duration, consistent with criteria for left atrial enlargement.

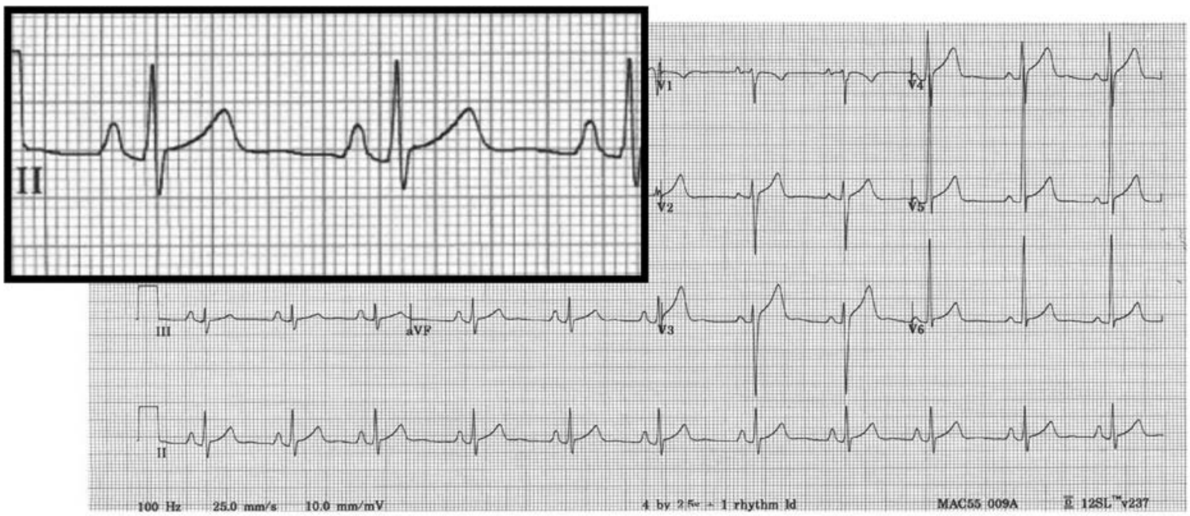

Figure 15.8.4 ECG showing P wave ≥2.5 mm in leads II and aVF consistent with criteria for right atrial enlargement in an athlete.

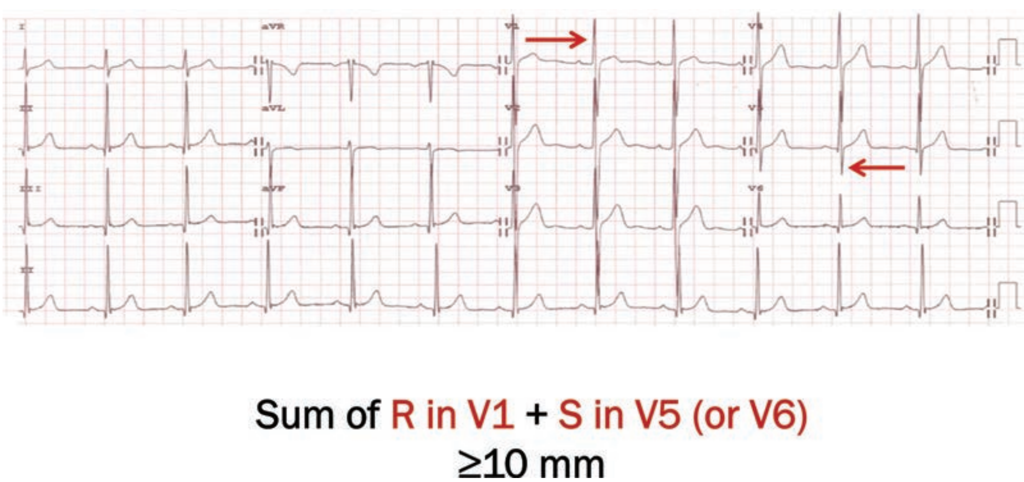

Figure 15.8.5 ECG showing tall R wave in V_1 and a deep S wave in V_6, and the sum of their voltages is ≥10 mm, in keeping with voltage criteria for right ventricular hypertrophy in an athlete.

Discussion

These ECGs demonstrate atrial enlargement, left axis deviation, and right ventricular hypertrophy (RVH), respectively, which in isolation are normal findings in an athlete and require no further investigation. Data to support this comes from studies of athletes with isolated atrial enlargement and axis deviation in whom echocardiography failed to demonstrate any significant pathology. Similarly, in athletes with RVH by voltage criteria whose hearts were characterized structurally using both echocardiography and cardiac magnetic resonance imaging, no pathology was identified.

References

1. Gati S, Sheikh N, Ghani S, et al. Should axis deviation or atrial enlargement be categorised as abnormal in young athletes? The athlete's electrocardiogram: time for re-appraisal of markers of pathology. *Eur Heart J.* 2013;34(47):3641–3648.
2. Zaidi A, Sheikh N, Jongman JK, et al. Clinical differentiation between physiological remodeling and arrhythmogenic right ventricular cardiomyopathy in athletes with marked electrocardiographic repolarization anomalies. *J Am Coll Cardiol.* 2015;65(25):2702–2711.

CASE
15.9

Gemma Parry-Williams, MBChB, MRCP (UK)
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Patient History

A 30-year-old female cyclist had a routine ECG (**Figure 15.9.1**).

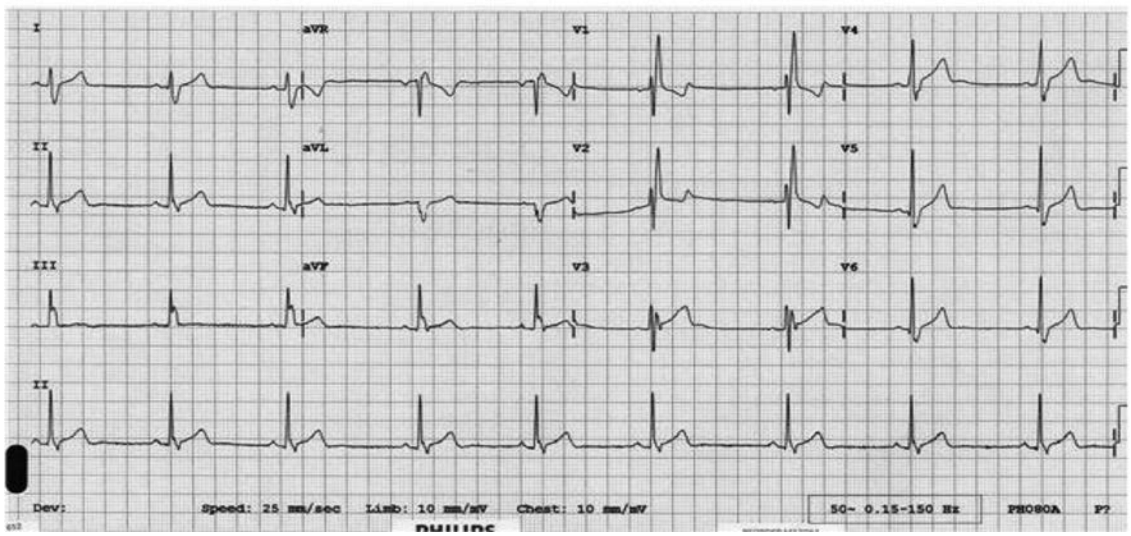

Figure 15.9.1 ECG showing complete right bundle branch block (RBBB).

Question

Are any further investigations required?

Discussion

Complete right bundle branch block (RBBB) is a relatively common finding in athletes (0.5–2.5%); however, its significance is uncertain. It is believed to be secondary to conduction delay as a consequence of increased right ventricle (RV) cavity size. One study demonstrated that athletes with a RBBB were more likely to have a bigger RV and lower RV ejection fraction. In isolation, it does not necessitate further investigation in athletes.

Reference

1. Kim JH, Noseworthy PA, McCarty D, et al. Significance of electrocardiographic right bundle branch block in trained athletes. *Am J Cardiol*. 2011;107(7):1083–1089.

CASE 15.10

Gemma Parry-Williams, MBChB, MRCP (UK)
Sanjay Sharma, BSc (Hons), MD

Patient History

An asymptomatic 21-year-old professional football player underwent pre-participation screening. **Figure 15.10.1** is his ECG.

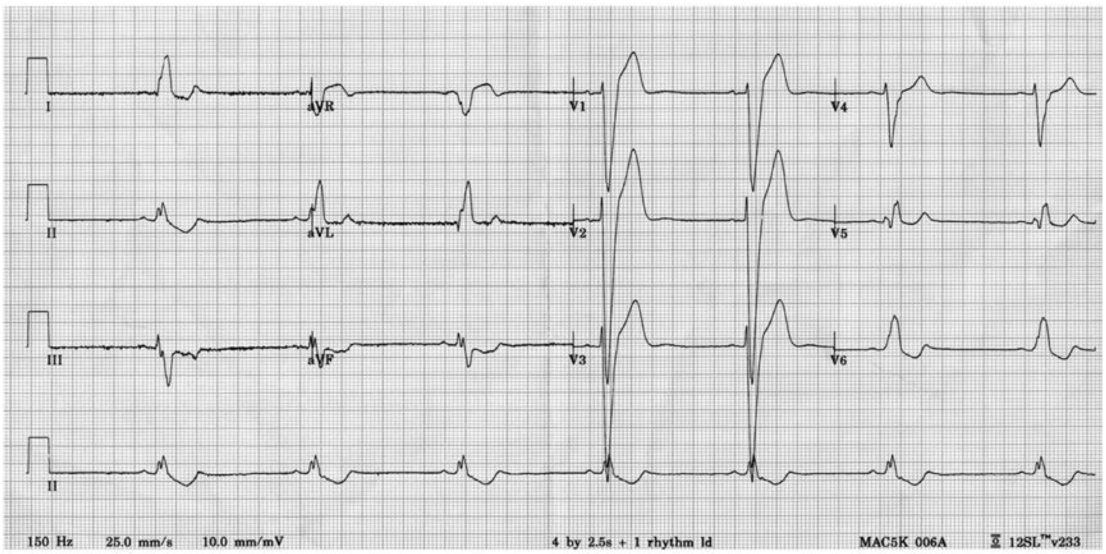

Figure 15.10.1 ECG showing complete left bundle branch block (LBBB).

Question

What investigations would you perform?

Discussion

Left bundle branch block (LBBB) is rare in athletes (<0.1%) but is a well-recognized ECG manifestation of cardiac disease including dilated cardiomyopathy, hypertrophic cardiomyopathy, left ventricular noncompaction (LVNC), sarcoid, and myocarditis and therefore always necessitates further investigation, including echocardiography, cardiac magnetic resonance imaging, and ischemia testing.

Reference

1. Sharma S, Drezner JA, Baggish A, et al. International recommendations for electrocardiographic interpretation in athletes. *J Am Coll Cardiol.* 2017;69(8):1057–1075.

CASE 15.11

Gemma Parry-Williams, MBChB, MRCP (UK)
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Patient History

This is the ECG (**Figure 15.11.1**) of an asymptomatic 24-year-old black basketball player. Echocardiography was normal.

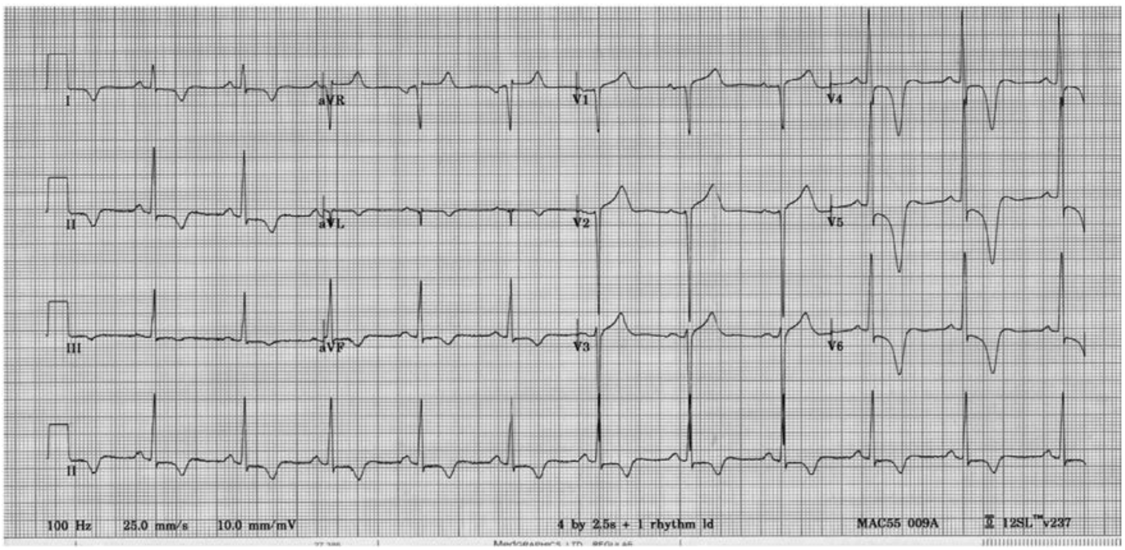

Figure 15.11.1 ECG showing ST depression followed by deep T-wave inversion in the inferior-lateral leads.

Question

Are any further investigations required at this time?

Discussion

This ECG is grossly abnormal and indisputably requires further investigation. It shows ST depression, which is **not** a feature of athletic adaptation, and deep T-wave inversion in the inferior-lateral leads. As mentioned earlier, T-wave inversion in the lateral leads is a strong predictor of hypertrophic cardiomyopathy and the index of suspicion here is even greater, given the presence of left ventricular hypertrophy by voltage criteria. This athlete requires thorough investigation, including echocardiography, cardiac magnetic resonance imaging, exercise testing, and ambulatory cardiac monitoring, and if negative, should be followed up very closely.

Reference

1. Sharma S, Drezner JA, Baggish A, et al. International recommendations for electrocardiographic interpretation in athletes. *J Am Coll Cardiol.* 2017;69(8):1057–1075.

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CASE 15.12

Patient History

An ECG (**Figure 15.12.1**) was obtained from an asymptomatic 21-year-old white swimmer.

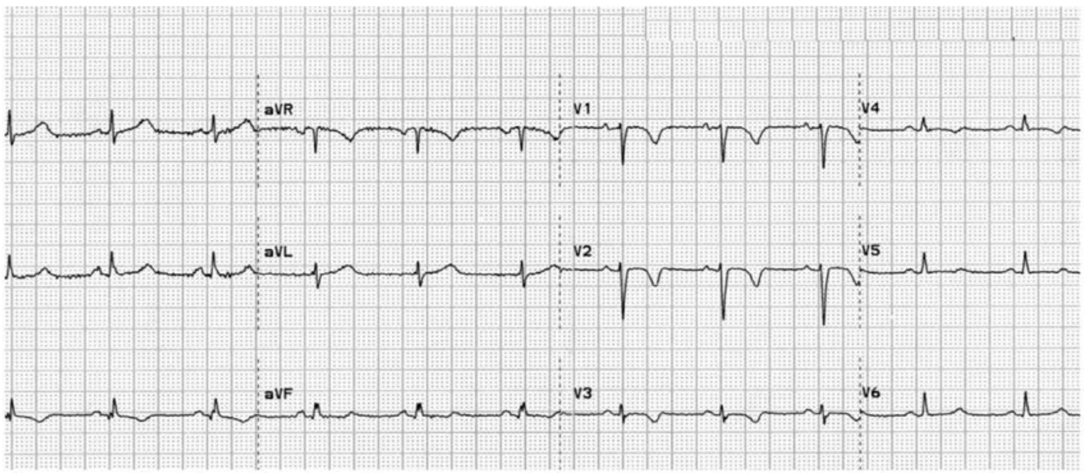

Figure 15.12.1 ECG showing isolated T-wave inversion (TWI) in leads V_1–V_3.

Question

Is this ECG normal?

Discussion

This is an abnormal ECG showing T-wave inversion (TWI) in V_1–V_3 without any J-point or ST-segment elevation. TWI extending beyond V_2 in a white athlete over the age of 16 has a prevalence of only 0.1% and is considered an abnormal finding warranting further investigation. Arrhythmogenic right ventricular cardiomyopathy/dysplasia (ARVC/D) is a condition that commonly presents with anterior T-wave inversion. Apical hypertrophic cardiomyopathy (HCM) presents in this way much more rarely. Investigation should therefore be targeted at identifying the recognized features of these cardiomyopathies. Investigations include echocardiography, cardiac magnetic resonance imaging, exercise testing, 24-hour ambulatory cardiac monitoring, and signal-averaged ECG. Other features that would raise the index of suspicion for ARVC/D include epsilon waves and ectopy originating in the right ventricle. The epsilon wave is a small positive deflection ('blip') buried within the end of the QRS complex. Epsilon waves are highly specific for ARVC/D and a major diagnostic criterion.

Reference

1. Papadakis M, Carre F, Kervio G, et al. The prevalence, distribution, and clinical outcomes of electrocardiographic repolarization patterns in male athletes of African/Afro-Caribbean origin. *Eur Heart J.* 2011;32(18):2304–2313.