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ELECTROPHYSIOLOGY

CASE REPORT: CLINICAL CASE

Dynamic T-Wave Inversion

Unraveling an Athlete's Heart Mystery

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ABSTRACT

A 17-year-old athlete was initially diagnosed with presumed hypertrophic cardiomyopathy, marked by deep inferolateral T-wave inversions and mild anteroseptal hypertrophy on electrocardiogram and imaging studies. Remarkably, 6 years later, following detraining, all diagnostic signs completely resolved. This case underscores the significance of vigilant athlete follow-up. (J Am Coll Cardiol Case Rep 2024;29:102186) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

At 17 years old, a competitive White male basketball player presented with a resting electrocardiogram (ECG) indicating left ventricular hypertrophy (LVH) and deep inferolateral T-wave inversions (TWIs) (**Figure 1**), discovered during a routine pre-participation screening. He was asymptomatic, had normal vital signs (blood pressure: 124/71 mm Hg; pulse: 51 beats/min), and his physical examination revealed normal findings, including the absence of murmurs on cardiac auscultation. He had no family history of heart disease or sudden cardiac death (SCD).

LEARNING OBJECTIVES

- To comprehend the clinical importance of deep TWI in the cardiac evaluation of athletes, encompassing potential underlying factors, distinguishing diagnoses, and their consequences for heart health.
- To scrutinize the importance of routine pre-participation cardiac evaluations for athletes, which includes the use of repeated ECGs and additional diagnostic examinations, as well as continuous monitoring and postassessment care to ensure the well-being and safety of athletes.

PAST MEDICAL HISTORY

He had no prior medical history and reported no use of medications or illicit drugs.

DIFFERENTIAL DIAGNOSIS

Hypertrophic cardiomyopathy (HCM) vs physiologic response to exercise were considered.

INVESTIGATIONS

Initial cardiac assessment via transthoracic echocardiography (TTE) showed mild hypertrophy in the basal septum and posterolateral wall, with maximum thicknesses of 13 mm and 12 mm, respectively. Normal systolic and diastolic function and valve anatomy were observed (**Figure 2**).

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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ABBREVIATIONS AND ACRONYMS

ARVC = arrhythmogenic right ventricular cardiomyopathy

CMR = cardiac magnetic resonance

ECG = electrocardiogram

HCM = hypertrophic cardiomyopathy

LA = left atrium

LGE = late gadolinium enhancement

LV = left ventricular

LVH = left ventricular hypertrophy

SCD = sudden cardiac death

TTE = transthoracic echocardiography

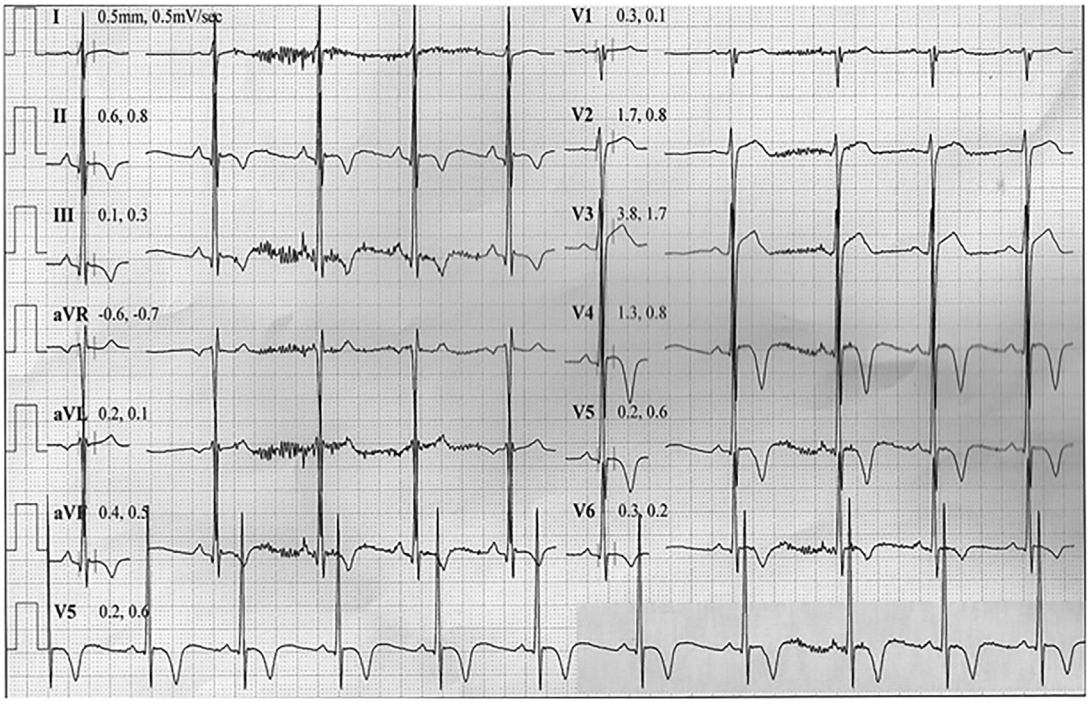
TWI = T-wave inversion

Stress echocardiography during high exertion (19 METs) revealed no blood pressure abnormalities, arrhythmias, or left ventricular outflow tract obstruction. Cardiac magnetic resonance (CMR) confirmed mild septal and posterolateral wall hypertrophy (12 mm) and increased LV mass (202 g). Chamber dimensions and function were normal, with mild left atrium (LA) enlargement (26 cm^2), and no late gadolinium enhancement (LGE) was observed. Given that initial findings indicated mild HCM, genetic panel testing was performed, which did not reveal any pathogenic or likely pathogenic variants (Supplemental Figure 1). Screening of first-degree relatives showed normal results (Supplemental Figure 2). However, a few months later, the patient's younger brother, who was experiencing exercise-related muscle cramps and elevated creatine phosphokinase levels, underwent genetic testing, which identified a COL6A variant of uncertain significance but no likely pathogenic variants. After an 8-week deconditioning period, TWI completely resolved, QRS complex voltage regressed to borderline values (Figure 3), and LVH reduced to maximum wall thickness of 10 mm (Table 1).

MANAGEMENT

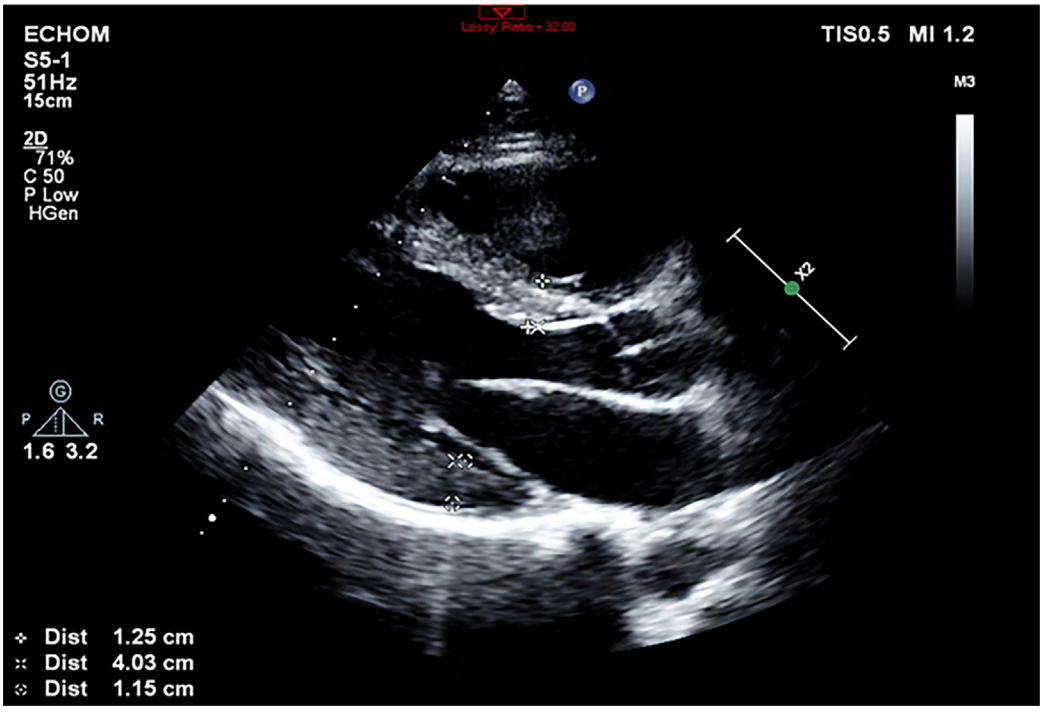
Initial ECG hinted at HCM, but with mild LVH (<15 mm), no family history of cardiomyopathy or SCD, and negative genetic markers, a definite HCM diagnosis remained uncertain. The complexity arose from the potential for ECG changes to precede structural HCM changes. Nevertheless, the reversibility of repolarization changes after brief deconditioning supported a diagnosis of athlete's heart. Despite state restrictions on competitive sports for individuals with HCM or suspected cases, we collectively agreed to allow ongoing high-intensity activity with vigilant clinical supervision,

FIGURE 1 Initial Electrocardiogram at Presentation



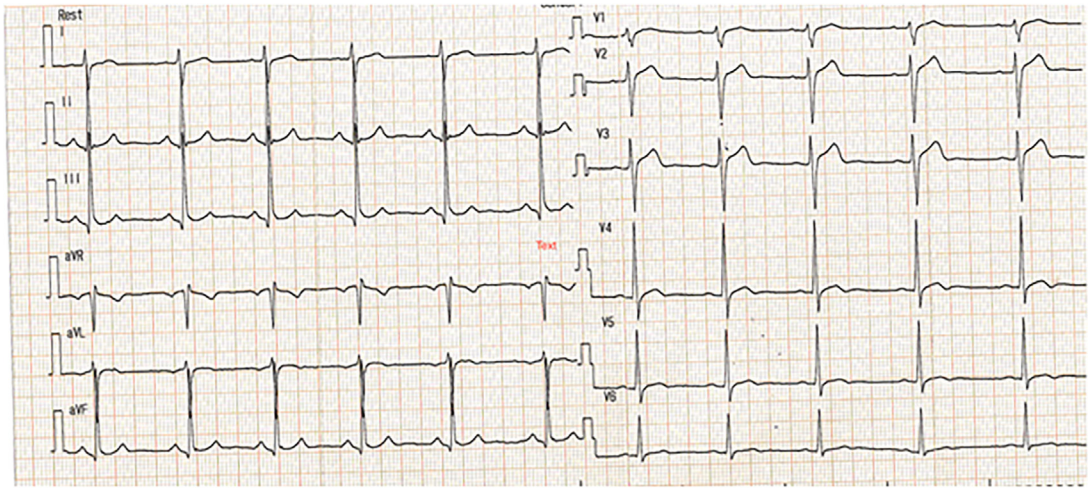
The initial electrocardiogram at presentation highlights left ventricular hypertrophy and pronounced T-wave inversions in leads II, III, AVF, V_4 to V_6.

FIGURE 2 **Baseline Transthoracic Echocardiography Assessment, Parasternal Long-Axis View**



The baseline transthoracic echocardiograph assessment (parasternal long-axis view) demonstrates mild left ventricular hypertrophy in the basal septum (13 mm) and basal posterolateral wall (12 mm).

FIGURE 3 **Electrocardiogram After 8 Weeks of Deconditioning**



An electrocardiogram after 8 weeks of deconditioning shows resolution of T-wave inversion, with QRS complex voltage meeting borderline left ventricular hypertrophy criteria in inferior leads.

TABLE 1 TTE Studies Presented From the Initial Diagnosis Through the Final Evaluation

TTE	LVEF, %	LV EDD/ESD, mm	IVS, mm	PW, mm	LA Area, cm^2	E/A	E′, cm/s
Baseline September 2016	60	38/23	13	12	19		
8 weeks postdetraining February 2017	65		9	10			
Follow-up December 2017	60		11	10			
Follow-up August 2019	65	40/25	12	12	17	1.7	
Follow-up March 2020	65	43/29	12	11			12
Follow-up October 2021	65	49/28	13	11	19		
7 months postdetraining August 2022	65	42/23	12	11	16	1.7	16

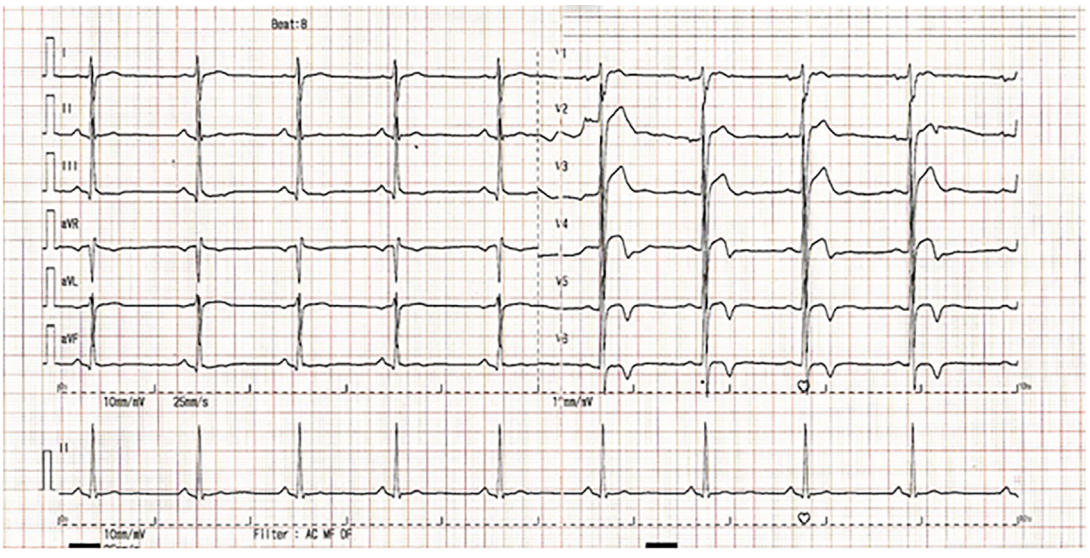
E′ = tissue velocity; E/A = mitral annular velocities ratio; EDD = end-diastolic diameter; ESD = end-systolic diameter; IVS = interventricular septum; LA = left atrium; LV = left ventricular; LVEF = left ventricular ejection fraction; PW = posterior wall; TTE = transthoracic echocardiography.

excluding participation in competitions, because of the patient's low-risk profile.

DISCUSSION

TWI in athletes refers to the presence of a negative T-wave with a depth of at least 1 mm in more than 2 contiguous leads, excluding leads aVR, III, and V_1.[1] This phenomenon is observed at a similar rate in both highly trained and amateur athletes (2.7% vs 2.3%, respectively)[2] but is more prevalent in Black athletes compared to their White counterparts (22.8% vs 3.7%, respectively).[3] The occurrence of TWI in young, apparently healthy athletes presents a significant challenge for sports cardiologists because it can either signify a normal cardiac adaptation, such as chamber enlargement, or raise concerns about underlying cardiac conditions, notably HCM or arrhythmogenic right ventricular cardiomyopathy (ARVC).[4] Assessing TWI in athletes requires careful consideration of its location, the athlete's personal and family history of heart-related conditions or SCD, the presence of cardiac symptoms, and any relevant clinical findings.[1] Inferolateral TWIs, affecting leads I, II, AVL, AVF, and V_5 to V_6, are less commonly encountered, with a prevalence of 1.5% to 1.8%.[5] However, they often indicate potential underlying cardiomyopathies, necessitating comprehensive evaluation and ongoing clinical monitoring.[1,4,6] Pelliccia et al[4] and other studies[5] have shed light on the connection between TWI and cardiomyopathies in athletes. In their research,[4] 81 highly trained athletes with widespread deep TWI patterns initially showed

FIGURE 4 Electrocardiogram Upon Resumption of High-Intensity Activity



An electrocardiogram upon resumption of high-intensity activity reveals the reappearance of left ventricular hypertrophy and T-wave inversion in III and AVF along with ST-segment elevation and T-wave inversion in V_4 to V_6.

TABLE 2 The 4 CMR Studies Conducted Between Initial Diagnosis and Final Evaluation

CMR	LVEF, %	EDVi, mL/m²	ESVi, mL/m²	ED Wall Mass, g/m²	IVS, mm	PW, mm	LA, cm²	LGE
Baseline October 2016	64	90 (68-103)	33 (19-41)	107 (59-93)	12	12	22	–
8 weeks postdetraining September 2017	72	–	–	–	13	12	–	–
Follow-up September 2021	73	83 (49-97)	23 (11-34)	173 (74-110)	13	15	25	–
7 months postdetraining August 2022	67	73 (61-101)	24 (18-35)	156 (74-110)	12	12	26	–

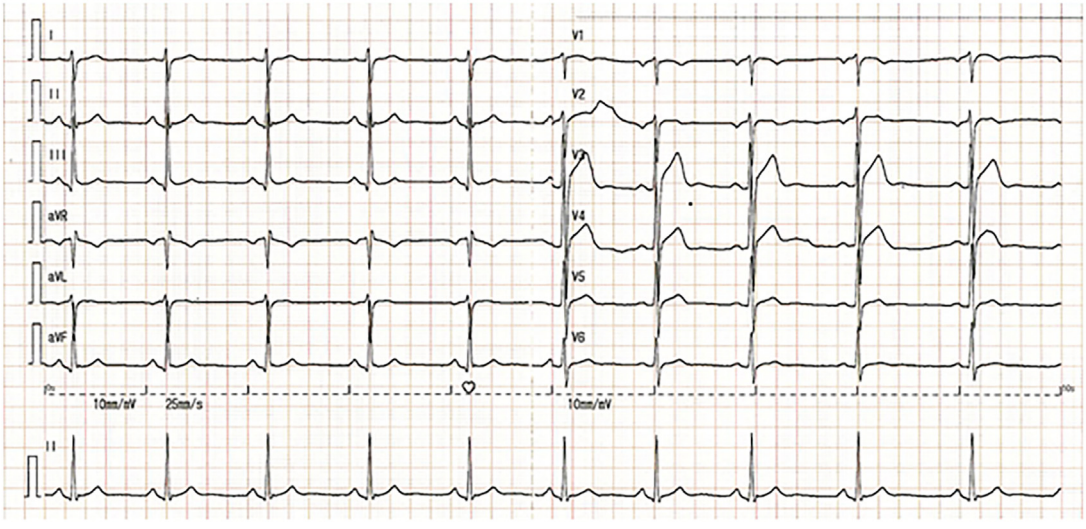
Values in parentheses are normal value ranges.

CMR = cardiac magnetic resonance; ED = end-diastolic; EDVi = end-diastolic volume indexed; ESVi = end-systolic volume indexed; LGE = late gadolinium enhancement; other abbreviations as in Table 1.

no signs of heart disease. However, over 9 years, 6% of them were diagnosed with cardiomyopathies, including HCM, dilated cardiomyopathy, and ARVC, with 2 athletes experiencing major cardiovascular events.

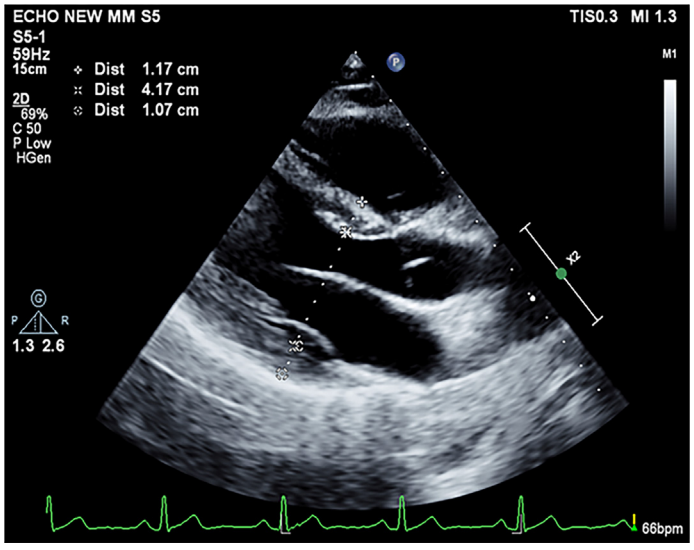
In our patient's case, inferolateral TWI first appeared during late adolescence, accompanied by minor structural changes like mild LVH, increased LV mass, and a dilated LA. Given the absence of familial or genetic evidence, these ECG changes were initially considered part of adaptive cardiac remodeling in an athlete. Their regression after a brief period of deconditioning supported this notion. However, because of the patient's age, the concerning TWI location, and the potential for these changes to precede cardiomyopathy development, a definitive diagnosis was elusive. Our approach involved close monitoring and repeated evaluations. Regarding exercise, we faced a dilemma assessing the risk associated with high-intensity and competitive sports. Based on clinical findings and updated data, we temporarily categorized the patient as having HCM with soft risk markers until a definitive diagnosis was established. Because our state policy forbade competitive sports for athletes with HCM or suspected HCM, we advised against competitive sports.

FIGURE 5 Electrocardiogram After 7 Months of Deconditioning



An electrocardiogram after 7 months of deconditioning exhibits complete resolution of left ventricular hypertrophy and repolarization changes.

FIGURE 6 Postdetraining Transthoracic Echocardiography, Parasternal Long-Axis View



Postdetraining, transthoracic echocardiography (parasternal long-axis view) illustrates left ventricular hypertrophy regression in the basal septum (11 mm) and basal posterolateral wall (10 mm).

However, because of the patient's very low risk profile, a shared decision was made to allow participation in high-intensity activities in controlled settings equipped with defibrillators.

FOLLOW-UP

Upon resuming high-intensity activity, the patient's ECG and structural changes reappeared (Figure 4). Over 6 years, he remained symptom free, with stable ECG, echocardiography, and CMR results (Tables 1 and 2). At age 23 years, following a 7-month leave adhering to exercise restrictions, routine ECG showed the complete resolution of LVH and all repolarization changes (Figure 5). This led to a comprehensive evaluation. TTE revealed mild anterior septum hypertrophy (12 mm) and normal systolic and diastolic function, including global longitudinal strain of -19 (Figure 6). Exercise stress test results were normal, as were findings on CMR, which showed stable mild hypertrophy, increased LV mass, mildly dilated LA (26 cm^2), and no LGE (Figure 7, Table 2). With no LVH progression or new LGE appearance and considering the complete resolution of all ECG changes after extended deconditioning, we concluded that the initial diagnosis was an exaggerated ECG response to exercise. However, given that a negative genetic test result for HCM does not exclude the possibility of diagnosis, we continue his ongoing follow-up care at our sports cardiology clinic to monitor for the potential development of cardiomyopathy later in life.

CONCLUSIONS

Our case underscores the complexity of interpreting TWI in athletes and managing their clinical care. We presented a distinctive scenario in which an athlete exhibited inferolateral TWI, which later resolved following an extended detraining period. This case serves as a compelling example of an exaggerated ECG response to exercise. It highlights the importance of managing such cases by sports cardiologists or dedicated HCM centers, as well as the need for continuous clinical surveillance and reassessment throughout the diagnostic process, especially in areas with prevalent knowledge gaps.

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The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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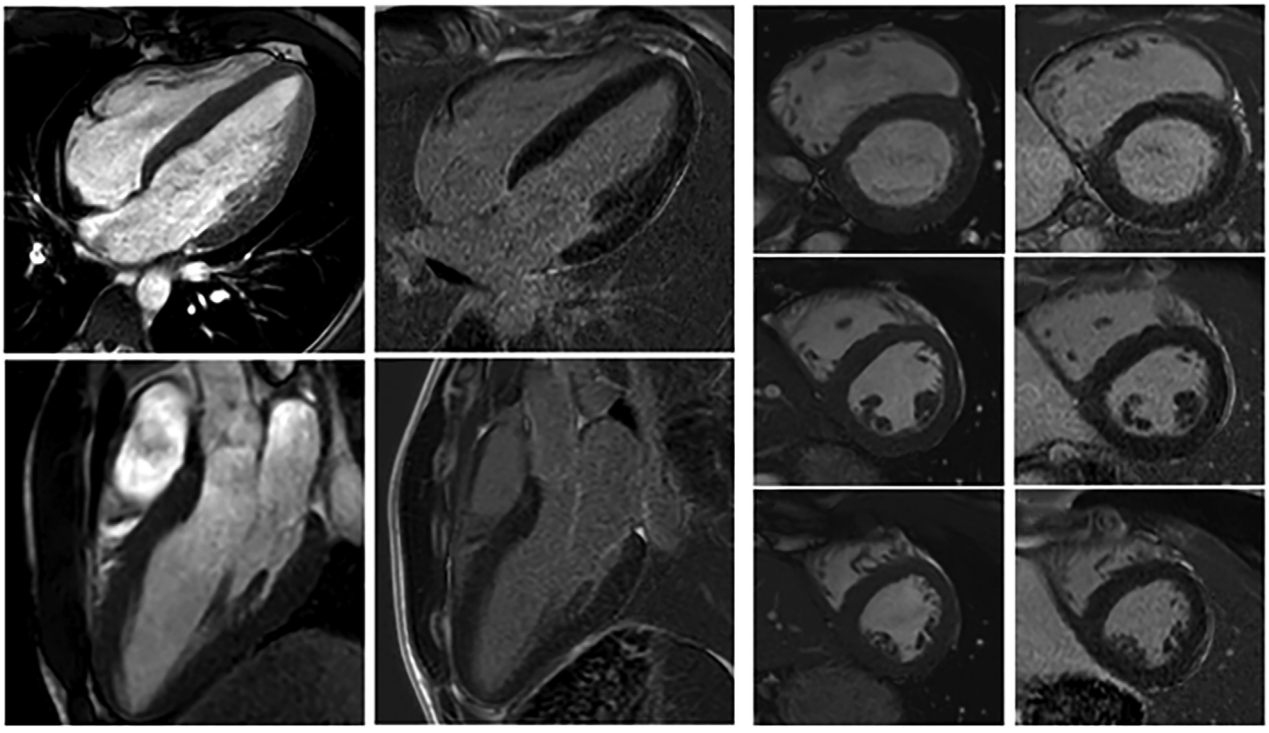
FIGURE 7 **Cardiac Magnetic Resonance Postdetraining**



Cardiac magnetic resonance postdetraining presents cine and late gadolinium enhancement images in various views, indicating mild left ventricular hypertrophy, increased left ventricular mass, mildly dilated left atrium (26 cm^2), and no late gadolinium enhancement.

REFERENCES

1. Sharma S, Drezner JA, Baggish A, et al. International recommendations for electrocardiographic interpretation in athletes. *Eur Heart J*. 2018;39(16):1466-1480.

2. Sheikh N, Papadakis M, Sharma S. Comparison of electrocardiographic criteria for the detection of cardiac abnormalities in elite Black and white Athletes. *Circulation*. 2014;129:1637-1649.

3. Pelliccia A, Maron BJ, Culasso F, et al. Clinical significance of abnormal electrocardiographic patterns in trained athletes. *Circulation*. 2000;102:278-284.

4. Pelliccia A, Di Paolo FM, Quattrini FM, et al. Outcomes in athletes with marked ECG repolarization abnormalities. *N Engl J Med*. 2008;358:152-161.

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

6. Wilson MG, Sharma S, Chalabi H, et al. Significance of deep T-wave inversions in asymptomatic athletes with normal cardiovascular examinations: practical solutions for managing the diagnostic conundrum. *Br J Sports Med*. 2012;46:i51-i58.

KEY WORDS athlete, athlete's heart, cardiomyopathy, left ventricular hypertrophy, T-wave inversions

APPENDIX For supplemental figures, please see the online version of this paper.