LETTERS TO THE EDITOR

T-wave inversions in elite athletes: the best predictors have yet to be determined

For many years, efforts have been made to elucidate the significance of altered ECG patterns in athletes, enabling to differentiate between physiological adaptations to regular exercise or underlying structural disorders. The study by Papadakis et al. is another interesting investigation focusing on T-wave alterations in the subgroup of adolescent athletes. Although data on prevalence have been published before, the intriguing new aspect is the implementation of cardiac MRI into the screening procedure. With an increasing number of normal cardiac MRIs in athletes presenting with ECG abnormalities, diagnostic reliability and clinical judgement will certainly improve.

Papadakis et al. state that T-wave inversions beyond lead V2 seem to be physiological in the age group younger than 16 years, but fail to see similar findings in older adolescents. In contrast, others have found a higher prevalence in adult athletes, leaving an equivocal gap between 16 and 18 years. ECG repolarization abnormalities are associated with increased cardiac dimensions induced by exercise training. During the late phase of adolescence, the myocardium is particularly adaptive to exercise training and particularly to endurance exercise. Therefore, a lack of significant ECG abnormalities in this particular age group cannot be readily explained. In the English cohort, elite pure endurance athletes are relatively underrepresented (and the age distribution of sport disciplines is not reported), which might be an explanation for the lower prevalence of T-wave inversions in adolescents between 16 and 18 years.

From our database including more than 2000 Caucasian elite athletes from endurance sports (e.g. cross-country skiing) competing on national and international levels, we cannot confirm the results presented. In a selection of athletes with enlarged hearts, in whom cardiac disorders were excluded by clinical assessment, laboratory analysis, echocardiography, and exercise testing, we did observe significant T-wave inversions in almost 13%, and beyond lead V2 in 10%. In accordance with the English cohort, we confirm the results for deep T-wave inversions in lateral or inferior leads, which are of similar rarity in our athlete population. Therefore, future studies on ECG abnormalities should particularly focus on this age group of adolescents having been engaged in competitive endurance sports since childhood. They should be characterized regarding maximum and aerobic exercise capacity in addition to training history and echocardiography in order to yield more precise information on whether T-wave inversions in anterior pre-cordial ECG leads are still physiological or should be further investigated.

Conflicts of interest: none declared.

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T-wave inversions in elite athletes: the best predictors have yet to be determined: reply

The authors would like to thank Pressler et al. for their interest in our study. We concur that the precise determinants for the presence of T-wave inversions in the electrocardiogram of elite athletes have yet to be established, but suspect these can be attributed to multiple factors including athlete demographics, sport discipline, and confounding genetic factors influenced by ethnicity. Although current studies indicate that endurance disciplines may be associated with a higher frequency of T-wave inversions, these results are not universally confirmed.

In our study, 4% of predominantly Caucasian adolescent athletes exhibited T-wave inversions. T-wave inversions in leads V1–V4 were present in 2.5% of our cohort and most T-wave inversions extending beyond lead V2 were observed in adolescents aged <16 years. Only two athletes (0.1%) ≥16 years exhibited such repolarization changes and although we were unable to identify any structural heart disease or the broader phenotype of arrhythmogenic right ventricular cardiomyopathy in these athletes, given the potential implications associated with the disorder we could not consider T-wave inversions beyond V2 to represent a normal variant in athletes aged ≥16 years.

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T-wave inversions in elite athletes: the best predictors have yet to be determined

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Although direct comparison with the Italian studies is difficult given the age range of the populations studied, our results appear to concur with the Italian data. The prevalence of T-wave inversions in an unselected population of amateur athletes was reported to be 2.3%. In a selected group of elite Italian athletes, 2.7% exhibited ‘diffuse, symmetric, marked T-wave inversions’ with only 1.6% of athletes exhibiting T-wave inversions in leads V1–V4. Finally, a study of 3086 athletes exhibiting T-wave inversions in leads V1–V4.3 Finally, a study of 3086 athletes exhibiting T-wave inversions in leads V1–V4. Finally, a study of 3086 athletes exhibiting T-wave inversions in leads V1–V4.

Pressler et al. report a higher prevalence of T-wave inversions beyond lead V2 (10%) in their cohort of elite Caucasian athletes. However, the reader should exercise caution when interpreting these results. Although under-representation of endurance athletes in the UK and Italian cohorts may provide a potential explanation, other important selection biases should be considered. The German group estimated the prevalence of T-wave inversions in athletes specifically with enlarged hearts on echocardiography who could be regarded to represent athletes exhibiting extreme physiological adaptation. Furthermore, the age range of the cohort is not reported which can be a major determinant since in the Italian study almost 10% of young (<14 years), pre-pubertal athletes exhibited T-wave inversions in leads V1–V4 compared with only 1.4% in athletes aged ≥14 years.

Although further studies with clear characterization of the age group and sporting disciplines would be a useful addition, particular emphasis should be placed on unexplored areas such as the effect of ethnicity on electrocardiographic changes in the adolescent group. Most importantly, however, longitudinal follow-up studies are necessary in order to assess the progression of T-wave inversions as the athletes mature as well as the long-term outcomes in athletes with persistence of T-wave inversions beyond V2 into adulthood.

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Occurrence of late gadolinium enhancement in ventricular ballooning or Tako-Tsubo syndrome: increased wall stress should not be overlooked

With great interest, we read the article by Rolf et al.1 The histological basis of late gadolinium enhancement (LGE) in magnetic resonance imaging (MRI) was examined in 15 patients with transient ventricular ballooning or the so-called Tako-Tsubo syndrome. While all patients exhibited increased collagen-1 in endomyocardial biopsies, it was higher in five patients who showed LGE. After 14 days, LGE and collagen-1 normalized. Since focal LGE pattern did not match the areas of increased collagen that were diffusely spread over the left ventricle, collagen-1 alone cannot explain the occurrence of LGE.

We agree that an increase of the interstitial space associated with fibrosis can contribute to LGE. However, normalization of a transient fibrosis within the short follow-up would require a remarkable turnover rate. Collagen is a ‘dynamic protein’ and collagen turnover appears to be inhomogeneous.3 Most recently synthesized collagens were more prone to be degraded than those where cross-linkage and fibril formation were ongoing. Nonetheless, clinical follow up examinations regarding treatment effects on fibrosis were conducted only after several months.4

Therefore, a role of an increased left ventricular (LV) wall stress should not be dismissed when examining LGE. Left ventricular wall stress depends on LV volume, myocardial mass, and the pressure gradient on the wall.5,6 Following the law of Laplace, an increase of the LV radius leads to an increase of wall stress by square. Ventricular dilatation that is evident in the acute stage of ballooning necessarily leads to increased distending forces on the ventricular wall raising wall stress. Recovery from ballooning is expected to normalize wall stress. In accordance, ballooning and its recovery is commonly characterized by a transient rise of serum BNP that is released in parallel to raised wall stress and cardiomyocyte stretch.5,7 A high wall stress is expected to enhance capillary leakage, thus favouring emission of contrast agent from the vasculature into the interstitial space.8 Also, redistribution into the vasculature can be impaired, which prolongs its venous clearance. Altogether, the amount of tissue with contrast medium would be increased, which can be detected by delayed MR image acquisition.

Recently, we observed the occurrence of LGE in several hundreds of patients with suspected cardiomyopathy. Late gadolinium enhancement pattern was clearly associated with increased LV wall stress and mass. An increased MRI-based ventricular wall stress appears to be a previously unrecognized major determinant of LGE. Conversely, normal wall stress has a favourable negative predictive value for the absence of LGE. Of note, we assessed LV wall stress in four females with Tako-Tsubo syndrome. Late gadolinium enhancement pattern occurred only in one patient with markedly increased end-diastolic (8.0 vs. 5.2 ± 2.2 kPa, normal ≤4 kPa) and end-systolic wall stresses (26.9 vs. 14.3 ± 5.6 kPa, normal ≤18 kPa) compared with the remaining three (unpublished). Work is in progress to consider wall stress-associated LGE as a potential prognostic determinant of heart failure and severe arrhythmias including sudden cardiac death.