Findings that shed new light on the possible pathogenesis of a disease or an adverse effect

Delayed enhancement of the intraventricular septum following an extraordinary endurance exercise

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Summary

Cardiac fatigue and elevations in cardiac biomarkers have been described following prolonged exertion in endurance athletes. We comprehensively evaluated a highly trained 46-year-old man attempting a North American transcontinental run in a record time of 45 consecutive days. After running 1460 km and ascending over 2600 m, the run was ended prematurely on day 17 following a leg injury; in support of the event, the subject cycled an additional 1580 km. Echocardiography and biomarker analysis performed pre-event and while running revealed no decrement in systolic function and undetectable levels of troponin I and T. Post-event cardiac MRI demonstrated the interval appearance of delayed enhancement of gadolinium at the inferior insertion of the right ventricle and in the interventricular septum—a novel finding that may represent subtle inflammation secondary to a combined exercise and altitude effect.

BACKGROUND

Transient drops in contractile function, termed cardiac fatigue,¹ and elevated cardiac biomarkers² have been observed in endurance athletes following prolonged exertion; however, prior studies have focused on shorter events and did not incorporate newer cardiac imaging techniques such as delayed enhancement (DE) by cardiac MRI or strain and strain rate imaging by tissue Doppler echocardiography. Hence, we sought to comprehensively evaluate the cardiac function of an ultra endurance athlete attempting a North American transcontinental run in record time.

CASE PRESENTATION

A highly trained 46-year-old male athlete with no known medical conditions attempted to run from San Francisco, California to New York in a record time of 45 consecutive days.³ The run started as planned; after running 1460 km and ascending over 2600 m the run was ended prematurely on day 17 secondary to severe tendonitis of the right anterior tibialis. In support of the event, after a 3 day rest, the subject cycled an additional 1580 km in 9 days ascending another 1190 m. While running, the subject averaged an 8.7 km/h pace for approximately 12 h/day. After the leg injury, the subject cycled an average of 175 km/day. Caloric intake was estimated at 8000 kCal/day. The subject's weight dropped from 83 to 78 kg from day 1 to day 17. Of note, on day 2 of the run the subject ascended 2500 m.

INVESTIGATIONS

Echocardiography and biomarker analysis were performed at four points in time: 'in-training', months before the event while the subject was running an average of 150 km/week (17 April 2008); 'pre-event', the day before the start of the

run (12 September 2008); 'in-run', on day 15 of the run (27 September 2008); and 'post-event', after cycling for 9 days (13 October 2008). Cardiac MRI with DE of gadolinium was performed in-training and post-event.

OUTCOME AND FOLLOW-UP

Echocardiography revealed no decrement in systolic function from pre-event to in-run testing as demonstrated by left ventricular (LV) ejection fraction (0.57 to 0.67), medial mitral annular peak systolic velocity (6.2 to 8.7 m/s), peak systolic strain (11.3 to 16.3%) and peak systolic strain rate (0.63 to 0.98 1/s). Indices of diastolic function showed little change between pre-event and in-run testing as evidenced by the ratio of early to late mitral inflow (1.4 to 1.3), medial mitral annular early diastolic velocity (−6.6 to −5.2 m/s) and global early diastolic strain rate (0.95 to 0.83 1/s). Using the modified Simpson's method, LV end diastolic volume increased from pre-run to in-run testing (130 to 148 ml). During all four assessments, there were no detectable levels of troponin I (ADVIA Centaur TnI Ultra Immunoassay, Siemens (Tarrytown, NY, USA); lower limits of detection <0.1 ng/ml) or T (Cobas e411 TnT, Roche Diagnostics (Indianapolis, IN, USA); lower limits of detection <0.01 ng/ml). Brain natriuretic peptide (BNP) and pro N-terminal BNP fell within normal limits on all four assessments while serum creatinine varied as follows: pre-event 1.1, in-run 1.5 and post-event 1.2 mg/dl. LV mass as assessed by cardiac MRI was unchanged from in-training to post-event scans (159.7 to 157.4 g). Post-event cardiac MRI demonstrated the interval appearance of DE of gadolinium at the inferior insertion of the right ventricle (RV) and in the interventricular septum (IVS) (figure 1).

Figure 1 Delayed enhancement of myocardium with gadolinium on cardiac MRI. Top row: images from the in-training (17 April 2008) cardiac MR demonstrating trace delayed enhancement of gadolinium at the inferior insertion of the right ventricle at baseline. Bottom row: corresponding images from the post-run (13 October 2008) cardiac MR demonstrating increased delayed enhancement of gadolinium at the inferior insertion of the right ventricle (bottom white arrow) and its interval appearance in the interventricular septum (top white arrow).

DISCUSSION

Cardiac fatigue¹ and elevations in cardiac biomarkers² have been described following prolonged exertion in endurance athletes. Yet, despite our subject's extraordinary effort—running and cycling over 3000 km in 27 days while ascending greater than 3900 m—there were no decrements in systolic function or detectable levels of troponin I or T. Conversely, the observation of DE on cardiac MRI at the inferior insertion of the RV and in the IVS is a novel finding, which may suggest subtle inflammation not reflected in echocardiographic indices or cardiac biomarkers.

DE has not been studied extensively in the athlete's heart. Breuckmann *et al* demonstrated DE in a low percentage (12%) of older male marathoners, although the distribution was consistent with coronary disease in roughly half and the overall prevalence of DE was not clearly greater than age-matched controls.⁴ Scharhag *et al* assessed for DE in a cohort of 20 highly trained athletes following 1-hour and 3-hour runs at 100% and 75% of the ventilatory threshold, respectively. Despite detectable increases of troponin T in seven subjects, there were no instances of DE on any of the 40 scans.⁵ Likewise, Mousavi *et al* studied 14 moderately trained runners participating in the Manitoba Marathon. All runners had detectable increases in troponin T post-marathon; however, DE was not observed on any of the subjects' pre-marathon or post-marathon scans.⁶ DE localising to the insertions of the RV and the IVS has been described in patients with pulmonary hypertension.^{7 8} While there was no evidence of pulmonary hypertension, RV dilation or RV dysfunction on any of our subject's cardiac MRIs or echocardiograms (all performed at rest), increases in pulmonary vascular resistance secondary to the acute rise in altitude coupled with requisite increases in cardiac output may have led to increased RV strain while running and cycling leading to the pattern of DE observed on cardiac MRI.

In conclusion, despite our subject's extraordinary effort, there was no evidence of cardiac fatigue or elevated cardiac biomarkers. However, the observation of DE at the inferior insertion of the RV and in the IVS may represent subtle inflammation secondary to a combined exercise and altitude effect—a finding which warrants further investigation.

Learning points

- In the setting of extraordinary exertion, cardiac fatigue or elevated cardiac biomarkers were not observed.
- The DE on post-exertion cardiac MRI is a novel finding suggesting subtle inflammation not reflected in echocardiographic indices or cardiac biomarkers.
- This distribution of DE has been observed in patients with pulmonary hypertension suggesting altitude-associated right ventricular strain due to increases in pulmonary vascular resistance and cardiac output.

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Competing interests None.

Patient consent Obtained.

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