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## Myocardial Fibrosis in Competitive Triathletes Detected by Contrast-Enhanced CMR Correlates With Exercise-Induced Hypertension and Competition History

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**ABSTRACT: Objectives:** This study analyzed the presence of myocardial fibrosis detected by late gadolinium-enhancement (LGE) cardiac magnetic resonance (CMR) in correlation with the performance of competitive triathletes objectified by an exercise test and individual competition history. **Background:** Myocardial fibrosis detected by LGE CMR has been reported to occur in 0% to 50% of asymptomatic athletes. However, the cause and mechanisms of myocardial fibrosis are unclear. **Methods:** Eighty-three asymptomatic triathletes undergoing >10 training h per week ( $43 \pm 10$  years of age; 65% male) and 36 sedentary controls were studied by using LGE and extracellular volume (ECV) CMR. Parameters of physical fitness were measured by spiroergometry. Triathletes reported their lifetime competition results. **Results:** LGE CMR revealed focal nonischemic myocardial fibrosis in 9 of 54 (17%) male triathletes (LGE+) but in none of the female triathletes ( $p < 0.05$ ). LGE+ triathletes had higher peak exercise systolic blood pressure ( $213 \pm 24$  mm Hg) than LGE- triathletes ( $194 \pm 26$  mm Hg;  $p < 0.05$ ). Furthermore, left ventricular mass index was higher in LGE+ triathletes ( $93 \pm 7$  g/m<sup>2</sup>) than in LGE- triathletes ( $84 \pm 11$  g/m<sup>2</sup>;  $p < 0.05$ ). ECV in LGE- myocardium was higher in LGE+ triathletes ( $26.3 \pm 1.8\%$ ) than in LGE- triathletes ( $24.4 \pm 2.2\%$ ;  $p < 0.05$ ). LGE+ triathletes completed longer cumulative distances in swimming and cycling races and participated more often in middle and Iron Man distances than LGE- triathletes. A cycling race distance of >1,880 km completed during competition had the highest accuracy to predict LGE, with an area under the curve value of 0.876 ( $p < 0.0001$ ), resulting in high sensitivity (89%) and specificity (79%). Multivariate analysis identified peak exercise systolic blood pressure ( $p < 0.05$ ) and the swimming race distance ( $p < 0.01$ ) as independent predictors of LGE presence. **Conclusions:** Myocardial fibrosis in asymptomatic triathletes seems to be associated with exercise-induced hypertension and the race distances. There appears to be a safe upper limit, beyond which exercise may result in myocardial fibrosis.

**STATEMENT:** *Regular exercise is widely considered to have beneficial effects on the cardiovascular system and regular activity is recommended for primary and secondary prevention of cardiovascular diseases. In this study we investigated competitive male and female triathletes using Cardiac Magnetic Resonance. Our results indicate that male triathletes face a higher risk of a potentially dangerous heart condition called myocardial fibrosis. The increased risk, which was not evident in female triathletes, is directly associated with the athletes' amount of exercise. Although previous studies have also reported on the presence of myocardial fibrosis*

*in elite athletes this is the first time that this phenomenon has been linked to the lifetime competitive exercise bouts of individual athletes. Further, we detected higher imaging markers of fibrosis in normal appearing heart muscle in male triathletes with focal detectable scars than in triathletes without any visible scars. There are several possible factors that could explain the link between the amount of exercise and the risk of myocardial fibrosis. Higher exercise-induced systolic blood pressure may result in greater myocardial mass and more exercise might expose the athlete to a higher risk of myocarditis, or inflammation of the heart muscle. These factors, in combination with repeatedly increased stress of the left ventricular wall due to exercise, could injure the heart muscle. Other factors may also be responsible for the difference in myocardial fibrosis risk between male and female triathletes including the presence of testosterone. Importantly, we have to perform long-term follow-up studies to see if any cardiac events occur in the triathletes, who had evidence of myocardial fibrosis.*

**BACKGROUND:** This work was performed at the Department of Diagnostic and Interventional Radiology and Nuclear Medicine in the group of Prof. Dr. Gunnar K. Lund, who holds a professorship at UKE. It was part of the research topic of Dr. med. Enver Tahir on competitive athletes using cardiac MRI in the DFG founded research group. Both authors have strong research interests in the field of Cardiac Magnetic Resonance Imaging with a special focus on morphological cardiac adaptations to increased exercise, myocardial edema development following a myocardial ischemia and effects of radiochemotherapy on human myocardium.