

Machine learning for recognition of athlete's heart using 3D volumetric and motion analysis of the right ventricle

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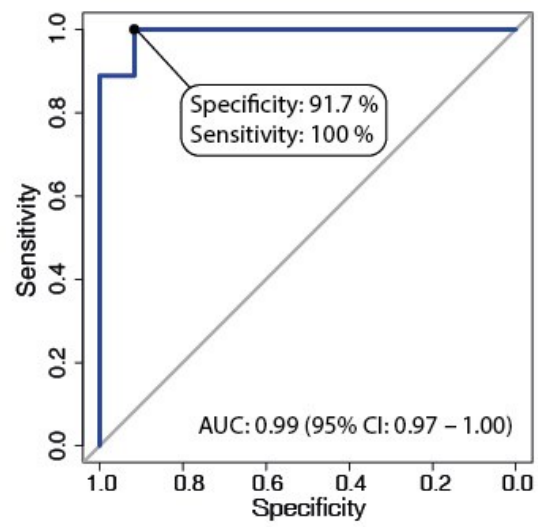
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Background: Repetitive vigorous physical exercise induces significant changes in myocardial structure and function in all four cardiac chambers. However, less is known about the adaptation of the right ventricle (RV) and conventional echocardiographic parameters fail to represent a universal marker of athlete's heart. We hypothesized that machine learning would be able to discriminate athlete's heart using 3D structural and functional parameters of the RV.

Methods: Sixty water polo athletes (19±4 years, 30 females, 30 males, average of 17 hours of training/week) and 40 age and gender matched untrained, healthy controls were enrolled. Detailed medical history and training regime were obtained followed by 3D echocardiography. After reconstruction of the 3D model of the RV, motion components were decomposed along the three anatomically relevant axes. The study population was randomly split to training and testing cohort (70:30) and a random forest ensemble classifier with 10-fold cross-validation was trained on the training dataset. The model with the highest accuracy was applied on the testing cohort to predict whether the given subject is an athlete. To visualize the continuum of RV morphological and functional remodeling, a network was created by connecting each subject to its four nearest neighbor based on the Jaccard distance of the RV variables used in the random forest algorithm.

Results: Left ventricular (LV) and RV end-diastolic volumes were higher in athletes (athletes vs control, LV end-diastolic volume: 176±36 vs 116±19mL, RV end-diastolic volume: 174±37 vs 112±17mL, both p<0.001), along with increased LV mass (194±44 vs 113±22g, p<0.001). Both LV and RV ejection fraction (EF) were lower compared to non-trained individuals (LV EF: 57±5 vs 62±3%, RV EF: 56±4 vs 61±5, both p<0.001). In athletes, a functional shift was observed in the dominance of longitudinal versus radial motion to global RV function, as longitudinal EF/total EF ratio was higher (0.50±0.07 vs 0.43±0.07, p<0.001), whereas radial EF/total EF was lower (0.33±0.08 vs 0.45±0.08, p<0.001) compared to controls. Using the composite of RV end-diastolic-volume, RV ejection fraction, longitudinal EF/total EF ratio and radial EF/total EF ratio, the area under the receiver-operating characteristic curve for the identification of athlete's heart was 0.99 (95% Confidence Interval: 0.97 – 1.00) (Fig A). The separation between athletes' and controls' RVs could be clearly observed on the similarity network as well (Fig B).

Conclusion: The exercise-induced adaptive remodeling also includes a functional shift between the different motion components of the RV. Harnessing the indices of the altered RV mechanics with machine learning algorithms provides a highly accurate identification of athlete's heart. Recognition of such patterns may enable a better understanding of exercise physiology and potentially the diagnosis of underlying pathological conditions.

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