From Population ECGs to Sports Screening: Transfer Learning for AI-Assisted Pre-Participation Cardiac Evaluation

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Context: Pre-participation cardiovascular screening (PPS) is essential for preventing sudden cardiac death in competitive athletes, yet stress ECG interpretation requires expertise and resources. Deep learning (DL) models have shown promise for automated ECG analysis, but their performance is typically constrained by small, task-specific datasets. We aimed to evaluate whether transfer learning from a large, publicly available ECG database could improve the diagnostic performance of a DL model for automated PPS classification.

Methods: A multimodal ResNet-Attention architecture integrating dual-branch on 10 seconds 12-lead ECG with tabular clinical data (age, sex, sport type) fusion was first pre-trained on PTB-XL ($\sim$ 21,500 ECGs, binary normal vs. abnormal classification), then fine-tuned on a prospective cohort of 526 competitive athletes (32% positive PPS, i.e., requiring further cardiac evaluation) from a single centre. An ablation study systematically compared 30 configurations across four pre-training conditions (0, i.e.scratch, 10, 25, and 50 epochs on PTB-XL), three warm-up durations during which the backbone was kept frozen (0, 5, and 10 epochs), and three learning rate pairs. Performance was assessed by stratified 10-fold cross-validation; statistical significance was tested using Wilcoxon tests with Bonferroni correction.

Results: Pre-training on PTB-XL consistently improved performance over training from scratch across all metrics. The best configuration (25 pre- training epochs, 10 frozen warm-up epochs) achieved AUC 0.73 ± 0.05, F1 0.71 ± 0.08, sensitivity 0.66 ± 0.13, and specificity 0.64 ± 0.13, compared to the best scratch baseline (AUC 0.68 ± 0.09, F1 0.56 ± 0.27). Despite consistent absolute gains (ΔAUC $= 0.05$, ΔF1 $= 0.15$), differences between conditions did not reach statistical significance.

Conclusions: Transfer learning from PTB-XL to sport-specific PPS classification is feasible and yields consistent performance improvements over training from scratch. External validation in larger, multicentre cohorts is required to confirm generalisability and clinical utility.