T-Wave Time-Warping Morphology Analysis During Music Performance

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Aims: Music engagement modulates the autonomic nervous system. Its effect on heart rate variability (HRV) has been documented, but its impact on ventricular repolarisation remains unexplored. Here, we applied time-warping analysis to characterise T-wave morphology changes in musicians across different performance action categories during live ensemble playing and investigate whether the observed changes reflect intrinsic repolarisation modulation beyond heart rate adaptation.

Methods: ECG signals were collected whilst a professional ensemble (violin, cello, piano) performed Schubert's Trio Op.100, Andante con moto, nine times during in-lab rehearsals, with pre-performance baseline and post-performance recovery. The musicians provided annotations of their performance action categories. For each session and category, mean warped T-waves were computed and four morphological markers extracted by comparing each category with the baseline template: temporal (d_w) and amplitude (d_a) differences, and their nonlinear components d_w^{NL} and d_a^{NL}. Repeated measures ANOVA with Greenhouse-Geisser correction and linear mixed-effects (LMM) models were applied. Repeated measures correlation assessed the association between T-wave markers and ΔRR.

Results: All four markers were significant in the pianist ($p < 0.05$), while only d_w ($p = 0.021$) and d_a ($p = 0.045$) reached significance in the cellist, with musically intense categories such as Climax showing larger differences. The violinist's data was not usable due to noise. After controlling for RR in LMM, d_a remained significant in both musicians (both $p < 0.01$) and d_a^{NL} ($p < 0.001$) in the pianist. In contrast, d_w became non-significant in both musicians. Repeated measures correlation confirmed a strong d_w–ΔRR association.

Conclusion: Significant T-wave morphology differences were observed across musical action categories during performance. Amplitude-domain changes persisted after controlling for heart rate, while overall temporal changes were primarily heart-rate driven, suggesting that music performance modulates ventricular repolarisation dispersion beyond heart-rate adaptation. This work provides a framework for analysing ventricular repolarisation during active music engagement.