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Kinematics of the bow arm of violinists: effect of tempo, string played and play style and their interactions

Benjamin Michaud^{1,*}, Mickaël Begon¹, Sonia Duprey²

¹ S2M, Département de kinésiologie, Université de Montréal, 1700, rue Jacques Tétréault, Laval, QC H7N 0B6, Canada

² Univ Lyon, Université Claude Bernard Lyon 1, IFSTTAR, LBMC UMR_T9406, F69622, Lyon, France

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Introduction

Bowed string musicians are especially at risk of upper limb injuries (Cayea and Manchester, 1998). While a few risk factors were identified, no causal relations could be found (Baadjou et al., 2016), highlighting the need for biomechanical investigations. Among the music parameters impacting violinists' biomechanics, the tempo, string played and play style have been investigated (Visentin and Shan, 2003; Berque and Gray, 2002). However, interactions between these parameters are not clear. Their knowledge could help defining relevant experimental research plans. The objective was to assess the interactions of the tempo, string played and play style on the bow arm biomechanics.

Materials

Nine expert violinists participated in this study after giving their informed consent (ethics 17-018-CERES-D, UdeM). The violinists were equipped with skin markers on the pelvis, thorax and right upper limb. They had to play six times a piece of music including variations: the same theme was played on the low [G-D] and high [A-E] strings, at tempo 60 and 120, playing *spiccato* and *legato*. Marker trajectories were collected at 100 Hz using a Vicon™ optoelectronic system (Oxford Metrics Ltd. Oxford, UK) during the performances.

The joint kinematics was reconstructed with a Kalman filter using a closed-loop chain including a spherical pelvithoracic joint, a two rotational degrees of freedom (DoF) sternoclavicular joint, a spherical acromioclavicular joint, a scapula-thoracic pseudo-joint defined as a point-to-ellipsoid soft constraint (ellipsoid built as *ScapThoEllips* in Michaud et al. (2017)), a spherical glenohumeral joint, a two rotational DoF at the elbow and a two rotational DoF joint at the wrist. Non-parametric three-ways 1d ANOVA (spm1d toolbox) with repeated measures were performed to analyse the interactions and effect of the tempo, string played and play style on the thoracohumeral angles.

Results

TH plane of elevation: the tempo and of the string played interacted with the play style when playing *spiccato*.

TH negative elevation: the tempo interacted with the play style which in turn interacted with the string played.

TH axial rotation: the tempo interacted with the play style when playing *spiccato* at tempo 60.

Conclusion

Statistics showed strong interactions between the three parameters - tempo, string played and play style – on the thoracohumeral angles of the violinists' bow arms. Thus, care should

be taken when designing experimental research plans and when interpreting results: these parameters should advantageously be mixed in the music excerpt to be played.

References

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