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Bow influence on violinist gestures: upper arm angles and shoulder muscle activity

S. Duprey¹

B. Michaud²

E. Gagne³

M. Begon²

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

² Laboratoire de simulation et de modélisation du mouvement, École de Kinésiologie et des Sciences de l'Activité Physique, Faculté de Médecine, Université de Montréal, Canada

³ Wilder & Davis, Montréal, Canada
sonia.duprey@univ-lyon1.fr

ABSTRACT

Understanding the effect of bow parameters on the violinist biomechanics could help quantifying understand why a violinist will prefer a given bow over another.

A violin bow was modified by adding masses (0, 1 and 2 g) at the tip and frog and by changing its camber (3 curvatures), leading to 18 bow configurations. Ten violin players were equipped with reflective markers on the right upper limb and electromyographic electrodes on the shoulder muscles, to record their kinematics and muscle activities. The participants played the same score with the 18 bow configurations, in a random order.

Inter-violinist variability in kinematics and muscle pattern was high. However, whatever the bow, all violinists but one adopted the very same strategy. This participant adopted two kinematic strategies according to the played camber.

As a conclusion, violinists appear as kinematic experts able to reproduce very similar kinematic patterns with different bows. Modifying their kinematic and muscular recruitment patterns was generally not a strategy. Perspectives will be to analyze the acoustic performance (experts' assessment and audio-descriptors in relation with violinists' bow appreciations) and to enlarge the sample of violinists to broaden the present conclusions.

1. INTRODUCTION

Some bow makers hypothesize that muscle recruitment could depend on the bow: a bow with ideal physical characteristics (camber, weight distribution, etc.) would allow maximum muscle relaxation and thus the production of a sound with better musical characteristics [1]. In their review on studies involving bow string musicians, in 2013, Kelleher et al. [2] point out that quantitative biomechanical studies are increasingly frequent. They reported seven biomechanical studies focusing on the bow motion [3]–[9], however none of these studies documented the influence of the bow on the violinist right arm biomechanics. The aim of the present work is to study whether bow parameters influence the violinist biomechanics or not.

2. MATERIAL & METHODS

Ten expert violinists, 9 women, 1 man (27.7 ± 7.6 years old), without any upper limb musculoskeletal disorders were recruited. The protocol was approved by the ethics committee of the University of Montreal (17-018-CERES-D).

A single bow, made of Pernambuco, was modified by changing its camber (three cambers), and by adding combinations of 0, 1 or 2 g masses at the tip and/or 0 or 2 g at the frog (six combinations of mass additions). The violinists played the same music score with each of these 18 bow configurations. The musical piece consisted of three sections, corresponding to three octaves. Each of these sections was played with two types of articulation: *spiccato* and *legato* and at two *tempi* (60 and 120 bpm).

2.1 Data collection

Reflective markers were put on the skin of the participants to record their kinematics using a Vicon optoelectronic system (Oxford Metrics Ltd. Oxford, UK), (Fig. 1, left). To measure the electromyographic activity (EMG) of the right upper limb muscles, surface electrodes or intra-muscular needles were used with a wireless EMG device (Trigno, Delsys Inc., Boston, MA) (Fig. 1, right).



Figure 1. A participant equipped with reflective markers (highlighted in red) and EMG electrodes. Left: anterior view; right: posterior view.

2.2 Data treatment and analysis

The joint kinematics was reconstructed using an extended Kalman filter [10]. The EMG data were filtered using a zero-lag 4th-order Butterworth band-pass filter between 20 and 400 Hz. EMG envelopes were obtained using a 250 ms sliding window root mean square (RMS) envelop.

EMG data were normalized according to maximal voluntary contraction (MVC).

The inter and intra-subject variabilities were calculated for EMG data and joint angles. The intra-subject variability was calculated as the standard deviation of the 18 repeated performances, averaged over the frames and over the subjects. The inter-subject variability was calculated as the standard deviation of the performances of the nine subjects, averaged over the frames and over the 18 bow configurations.

3. RESULTS

The intra-subject variabilities were mostly lower than 6° for the upper limb angles (Fig. 2) and lower than 3% MVC. The inter-subject variability was up to about 16.5° (Fig. 3) for the upper limb angles and 11.2% MVC for EMG. The mean muscular activations were generally lower than 10% MVC.

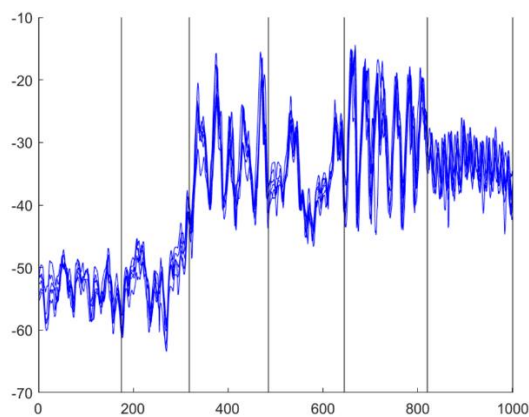


Figure 2. Shoulder (glenohumeral) elevation angles versus time frames for 1 subject playing six different bow configurations.

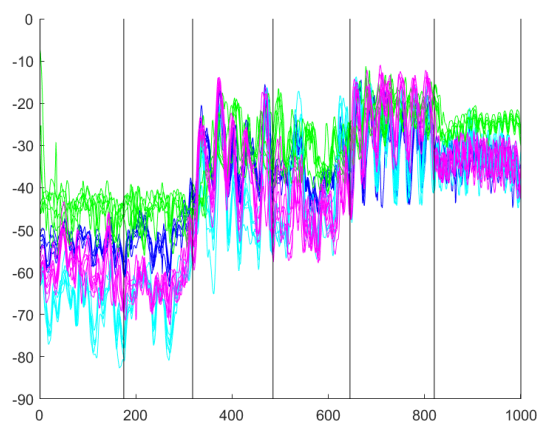


Figure 3. Time histories of shoulder (glenohumeral) elevation angles for four subjects (each color indicating a different subject) playing six bow configurations.

4. DISCUSSION

The large inter-individual variability in the upper limb angles is consistent with the findings of Yagisan et al. (2009) [9] and highlights that several strategies can be adopted by different violinists for the same piece. The low intra-subject variability indicates that most violinists used a single kinematic strategy even when bow changes in inertia. This absence or variability can be explained by different causes. First, in early training (childhood), teachers support a unique kinematic strategy to rapidly improve the quality of play [11]. Secondly, low intra-subject variability may ensure sound's reproducibility. As for muscle recruitment, multiple muscle patterns (i.e. muscle redundancy) are possible for a given kinematic task [12]. Our results show however that the violinists do not take advantage of the muscle redundancy. Indeed, a low intra-subject variability in muscle activations was observed while playing with different bow configurations. A bow with higher inertia should logically necessitate higher muscle activations. However, the added masses of several grams (while the arm is about 3 kg) were obviously too low to generate changes in EMG patterns, even though all participants reported feeling the difference in weight. Thus, to date, it cannot be concluded that using different bow could generate any adaptation in the biomechanics of the right upper limb of violinists.

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