Evaluation of violin bow vibrations using a quantitative Salchow test

Nathan Zhang ‘25, William Qi ‘25, and Christopher Fang-Yen*

Department of Bioengineering, School of Engineering and Applied Science, University of Pennsylvania

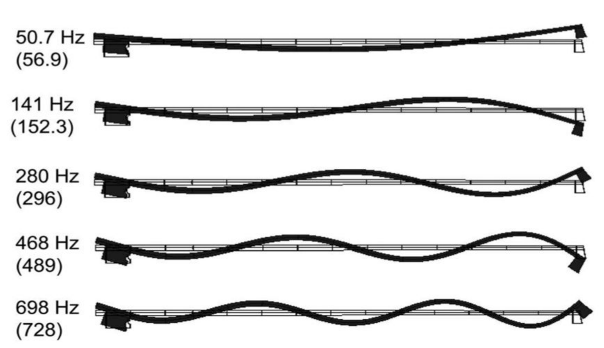
nszhang@sas.upenn.edu; willqi@seas.upenn.edu; fangyen@seas.upenn.edu

Introduction

- During playing of a bowed string instrument, the rosin-coated bow hair is drawn against the string, causing the string to repeatedly stick to and be suddenly released by the hair, a phenomenon known as stick-slip oscillation.
- It is widely accepted among players that different bows have different tonal properties.
- Despite nearly a century of study, how the different tonal qualities of violin bows are related to their physical properties is poorly understood.
- A test that violin players can perform to assess the characteristics of a violin bow is called the Salchow test.
- The Salchow test involves holding the bow at the frog in one hand and tapping the bow hair on the knuckle of the other hand, feeling the resulting vibrations in the bow using the bow hand.
- **We built a device for performing a quantitative version of the Salchow test.**
- We examined the pattern of vibrations and how they depend on the velocity of the bow, the location of the tap on the bow, and how they vary with different bows.

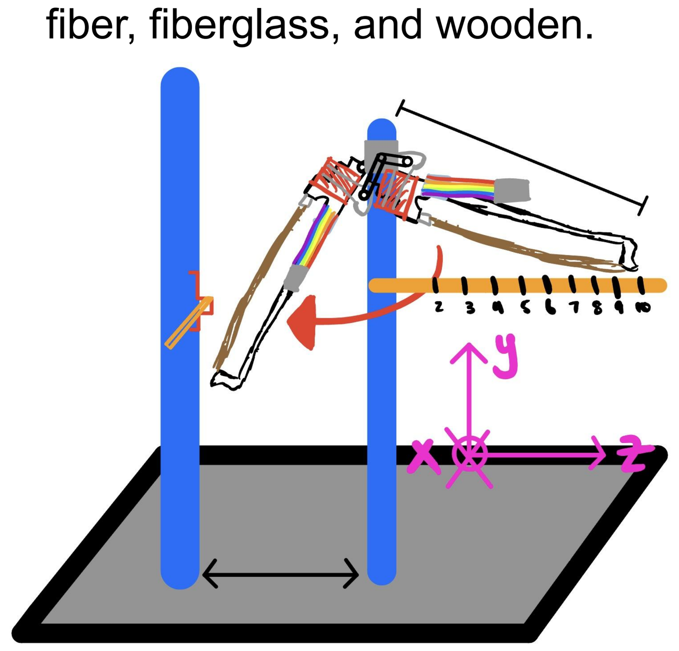
Hypothesis

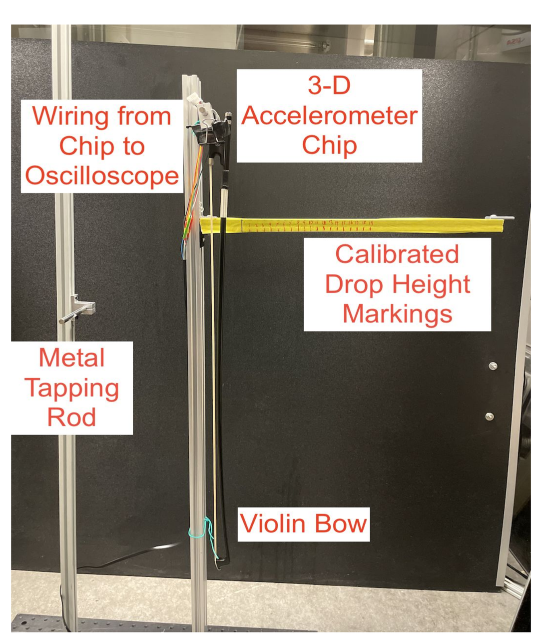
- The Salchow test excites the first lateral bending mode of the bow.
- Different bows have different decay lifetimes of vibration.



Methods

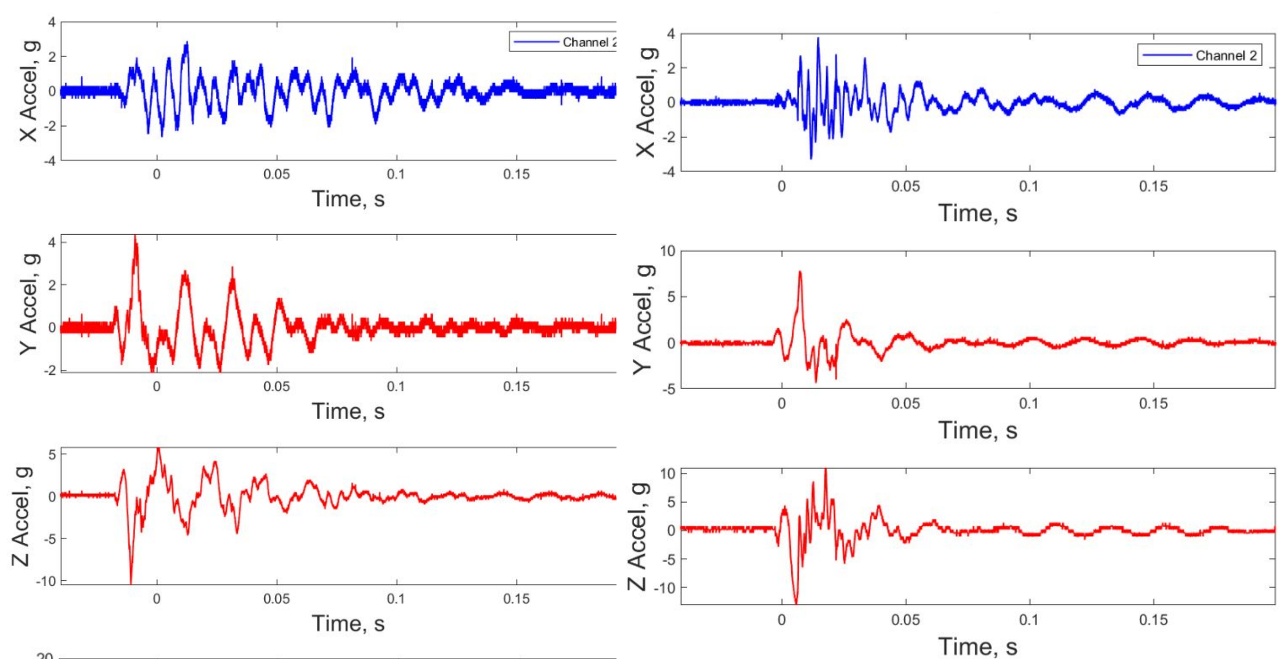
- We built a rig in which the bow hangs by the frog and is allowed to swing by gravity and bump into a fixed rod.
- The violin bow was held vertically by the frog with a binder clip.
- A 3-D accelerometer chip was mounted onto the bow near the frog with Sugru to detect the bow vibration.
- Wires soldered onto the chip were connected to a DS1054Z Rigol oscilloscope, which was then connected to a PC via ethernet for MATLAB analysis.
- Three different violin bows were used in the analysis: carbon fiber, fiberglass, and wooden.

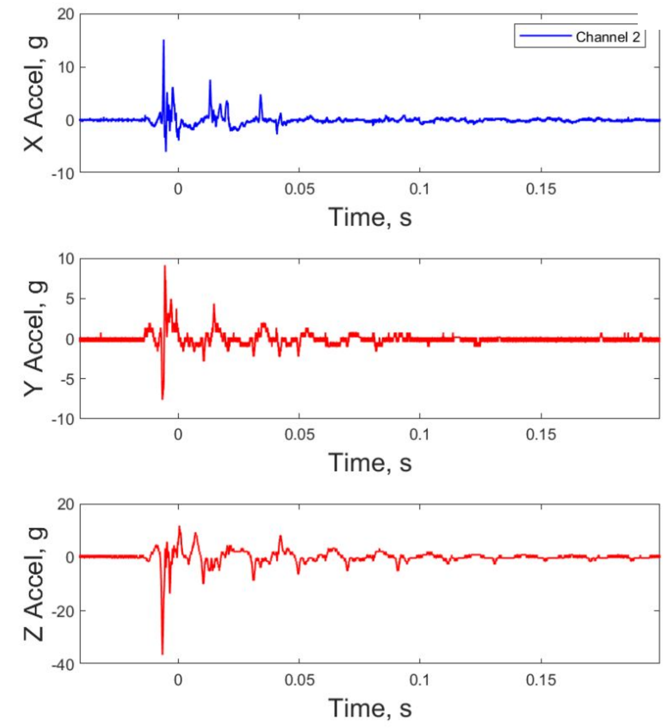




Results

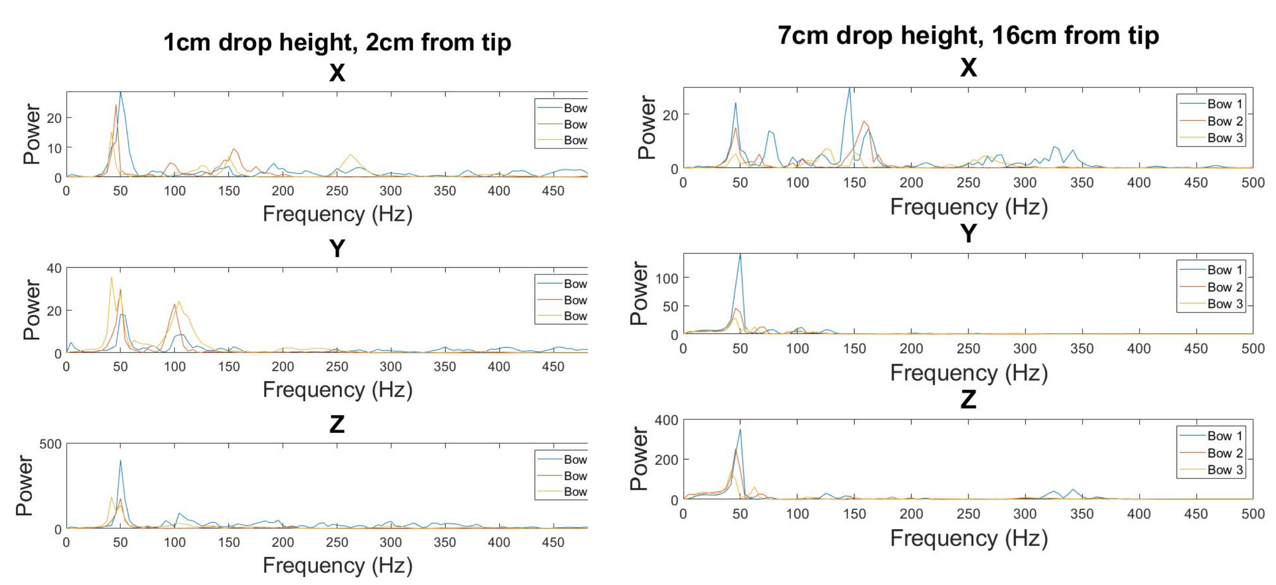
Different bows showed different decay rates

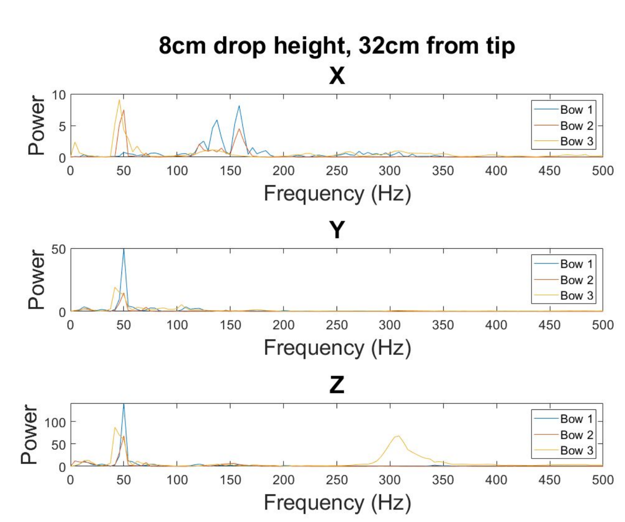




Bow 1 was made of carbon fiber material (top left), bow 2 was made of fiberglass material (bottom left), and bow 3 (top right) was made of wood. Based on the decay rates, bow 1 showed the longest decay rate overall and bow 3 showed the fastest decay rate overall. All taps were collected at a drop height of 1 cm and a contact point of 2 cm from the tip.

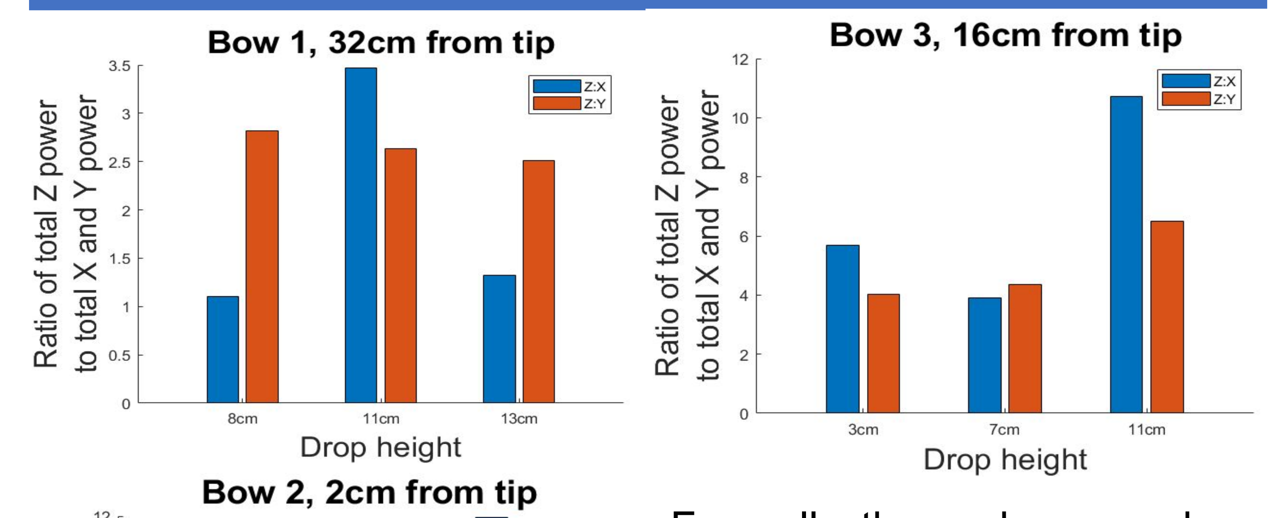
All bows tested showed robust vibration near 50 Hz

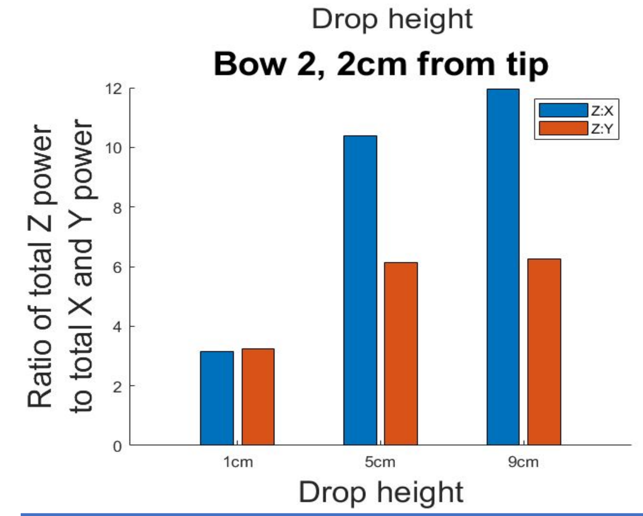




For all three spectra, no matter the contact point, drop height, or bow, there was a clear vibrational peak in power at the fundamental frequency. The fundamental frequency is defined as the lowest frequency of a periodic waveform at about 50 Hz. There is some variation in the exact frequency of the fundamental, ranging from 42 Hz to 54 Hz.

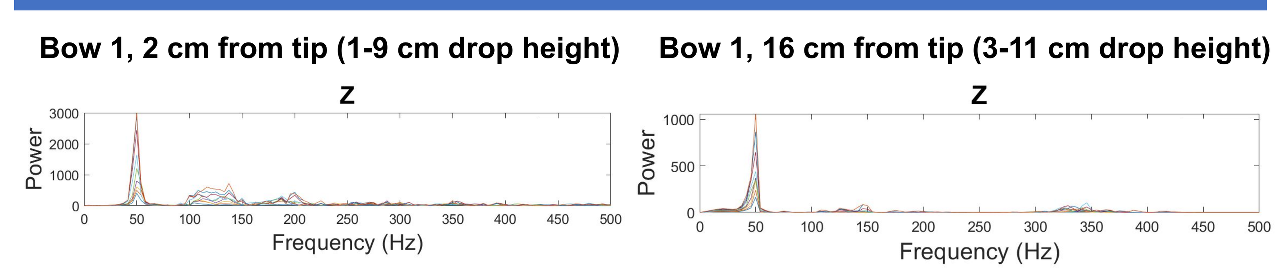
The Z vibration (direction of the tap) showed the most power

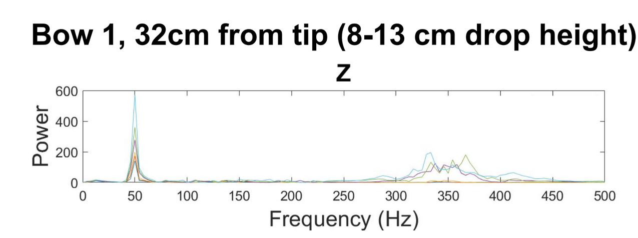




For all three bows, when comparing the ratio of the total Z power to total X and Y power, the ratio was always greater than 1, showing that the vibrations are primarily excited in the Z direction.

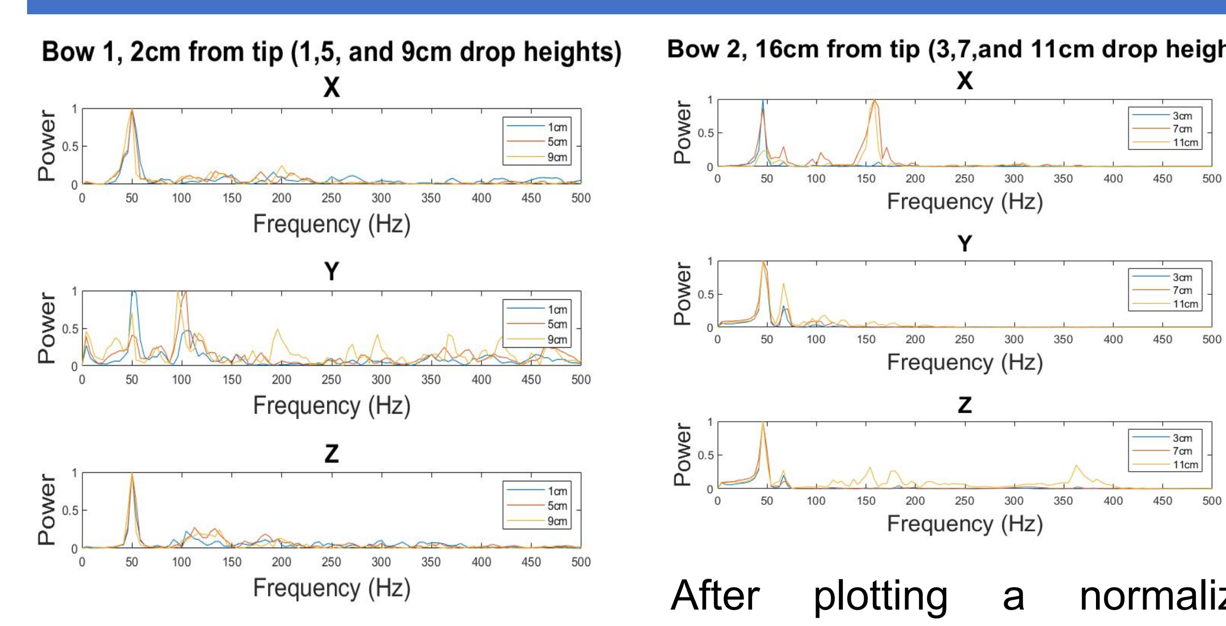
Tapping at the tip gave the most power at the Fundamental Frequency Mode

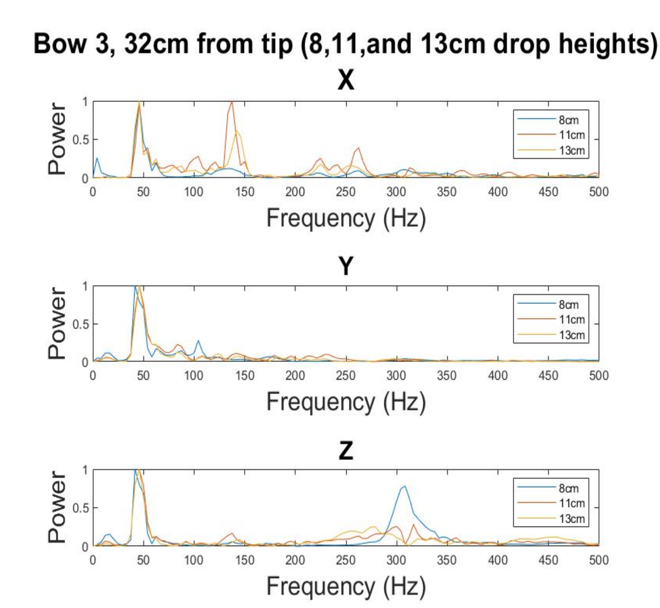




In the fundamental frequency mode, power increased from 600 to 1000 to 3000 when moving closer to the tip.

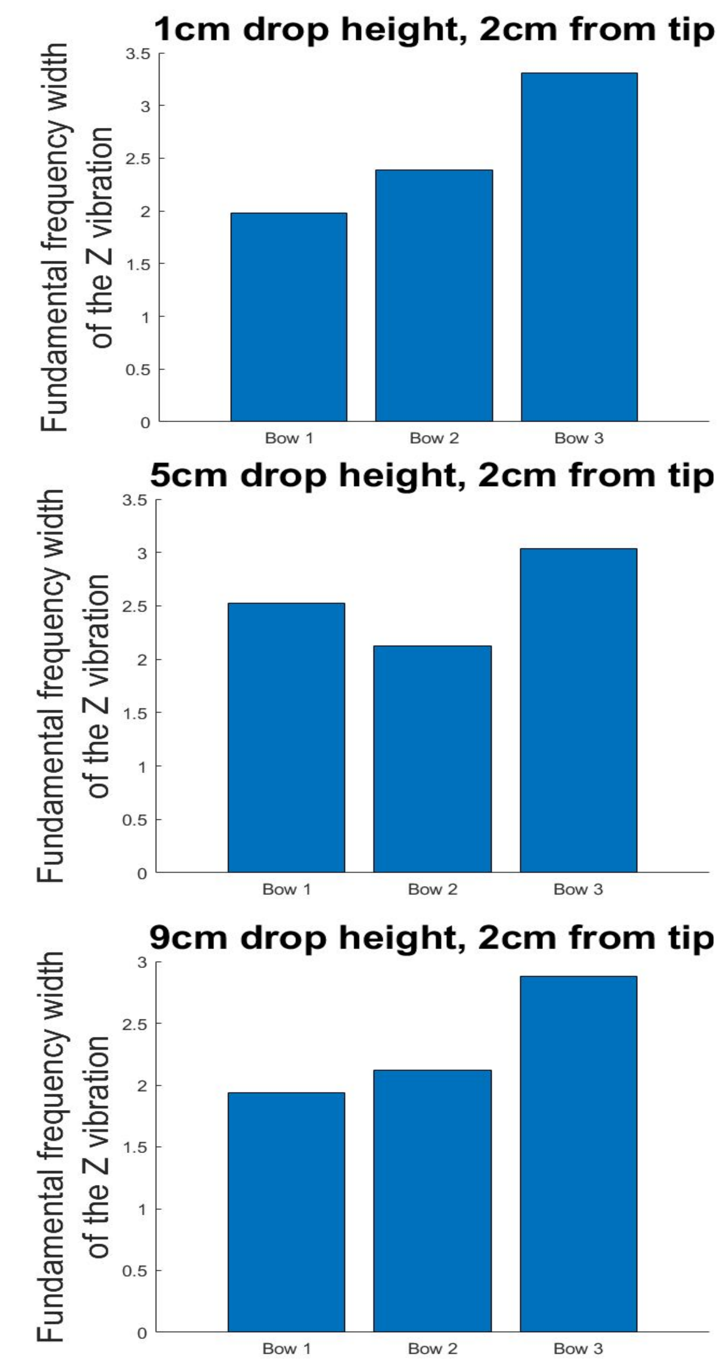
Vibration increased with drop height





After plotting a normalized spectra for each bow with three different drop heights (low, medium, high), overlaying the different drop heights on top of each other showed large similarity. This indicated that drop heights are directly proportional to power of vibration in all three directions, showing a direct relation between drop height and vibration power.

Different bows showed variation in fundamental frequency width for all conditions



The width of the fundamental frequency, a measurement of decay rate of the vibrational mode and taken by dividing the area of the peak by its height, was consistently larger for bow 3 (wood) than bow 2 (fiberglass), and was larger for bow 2 (fiberglass) than bow 1 (carbon fiber) except for at 5 cm. As the peak width correlates with the inverse of vibrational lifetime, these data show that the more costly wooden bow had the smallest vibrational lifetime in the fundamental frequency, while the cheaper carbon fiber bow had the longest vibrational lifetime.

Conclusions

- The Salchow test is a measurement of the fundamental bending mode.
- Salchow test showed clear differences in vibrational pattern among different contact points and different bows as well as clear power differences among different drop heights.
- Every test condition showed a consistent spectral peak in the fundamental frequency between 42-54 Hz and variation in the ratio of fundamental frequency to total frequency for each bow. Though there were vibrations in other frequencies, we did not study them because they were less consistent.
- Different bows (fiberglass, carbon fiber, wooden) exhibited different higher order frequency excitations.
- Power in vibration increased with drop height.
- This study revealed tapping at the tip showed the greatest vibrational lifetime in the fundamental frequency.
- Different bows showed variation in the fundamental frequency width, which is directly related to the vibrational decay rate. The cheapest carbon fiber bow showed the longest decay rate while the most expensive wooden bow showed the shortest decay rate.
- Future research will compare physical properties of the bow with subjective evaluation of their playing or tonal properties.

Acknowledgements

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