Effect of sampling rate and low pass filter frequency cut-off on early peak KAM waveform

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Summary

The majority of the knee abduction moment signal from human sports movements is contained in frequencies less than 10 Hz. As sampling frequency is raised, a lower low-pass filter cut-off frequency is required to differentiate between early peak knee abduction moment waveforms, and others.

Introduction

Motion capture during the impact phase of a sports maneuver is a line of research with high potential value relating to risk of anterior cruciate ligament injuries [1]. It is also technically challenging due to the mixed frequency content inherent in impact signals [2,3]. Modern systems are capable of higher sampling frequencies with greater precision, but what effect this has on the choice of filter frequencies is poorly understood. The aim of this analysis is to describe the frequency content of knee abduction moment (KAM) signals, and explore the effects of different low-pass filter cut-off frequencies and sampling frequencies on the frequency of the early peak waveform.

Methods

Seventeen female athletes aged 18-23 and active in pivoting sports signed an informed consent and participated in the study. Ten repetitions per leg of three sports movements were collected using 12 marker-based infrared cameras sampling at 1400Hz and 1MP resolution. Concurrently, a force plate collected ground reaction force (GRF) data at 1400Hz. A 3D model was constructed as described previously[1]. For each trial, the first and last frame of the stance phase was when the vertical GRF crossed 50N. Each trial was down-sampled to 700, 350, and 175 Hz, and low-pass filtered at 2, 6, 20, and 38. Additionally, a 400Hz low pass filter was applied to the 1400 sampling rate to calculate the mean normalized (as % of peak) spectral density over the frequency range. The normalized KAM (Nm/kg) waveform during first 100ms was classified as either an early-peak or non early-peak using a cluster analysis method developed for this purpose [4].

Results and Discussion

The signal content was mainly in frequencies below 10Hz with significant high-frequency noise above 100Hz. When the first 100ms are included in the analysis, frequencies in the range between 10 and 100 Hz show increased density (Figure 1). There was a difference in how the waveforms were classified (Figure 2) according to the sampling frequency and the low-pass cut-off frequency. As the sampling frequency increased, a lower filter cut-off was needed to differentiate between the waveforms.

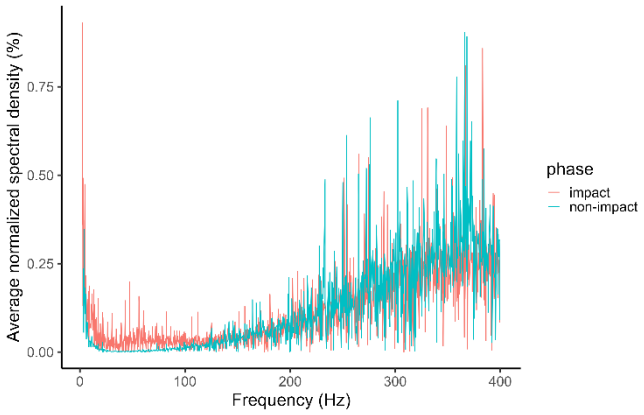

Figure 1: Average spectral intensity for the time periods 0-700ms (impact phase included, red line) 100-800ms (post-impact, teal line).

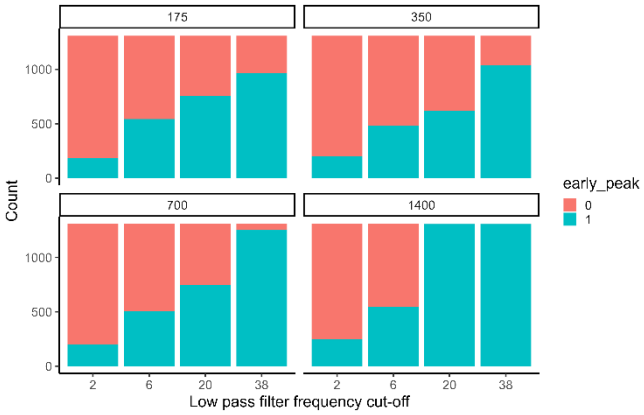

Figure 2: The number (y axis) of early peak waveforms (teal color) and non-early peak waveforms (red color) at different sampling rates (175, 350, 700, 1400) and low pass filter cut-offs (x-axis).

Conclusions

The majority of the KAM signal content is in the frequency below 10 Hz. The waveform shape is influenced by both sampling frequency and low-pass filter frequency and both should be carefully considered.

References

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