Effect of sampling rate and low pass filter frequency cut-off on the results from a KAM signal

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Summary

The choice of low-pass filter frequency will influence the magnitude as well as the timing of the peak knee abduction moment of the stance phase but minimally affect values extracted exclusively in the first 100ms of the stance phase.

Introduction

The knee abduction moment (KAM) is one component of the ACL injury mechanism [1], and therefore a candidate risk factor of the same injury. The timing of the injury [2] indicates that the forces created by the impact with the ground produce the injury. This poses a problem for researchers as the motion analysis signals will be a mix of low and high frequency signals. The current literature uses various low-pass filters and has been collected using moderate sampling frequencies [3–5], but recent advances in motion capture technology allow for greater resolution and higher sampling rates. The aim of this paper was to analyze the extent to which the observed values of KAM are affected by sampling rate and low-pass filter frequency.

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[6]. 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 Hz. The peak normalized KAM (Nm/kg) during the initial 100 ms after ground contact, as well as over the entire stance phase was extracted as well as the timing of the peak.

Results and Discussion

The absolute differences between the low pass filters for the 1400 Hz sample frequency were most pronounced during the early stance phase, within 100ms after initial contact with the ground. This was consistent across movement tasks with the exception of the crossover cut (Figure 1). The 2 Hz cut-off frequency resulted in pronounced changes in the signal throughout the stance phase, which is expected as the frequency of the movement itself is around 1-3 Hz.

The mean peak stance KAM at a sampling rate of 1400Hz was 0.32, 0.47, 0.67, and 0.88 for filter cut-offs of 2, 6, 20, and 38 Hz. The mean early stance phase KAM sampled at 1400Hz was 0.20, 0.33, 0.60, and 0.83 Nm/kg for the same cut-off frequency. The difference is explained not only by the effect of the filtering but also because the timing of the peak KAM was different between conditions. The mean timing of the stance phase peak KAM was lowest for the 38 Hz filter frequency (89ms), and all other frequencies resulted in mean timing of over 100 ms indicating that the values were observed after the timepoint an ACL injury would have occurred. The sampling rate only had a minimal effect on the magnitude of the KAM regardless of phase (early stance or full stance).

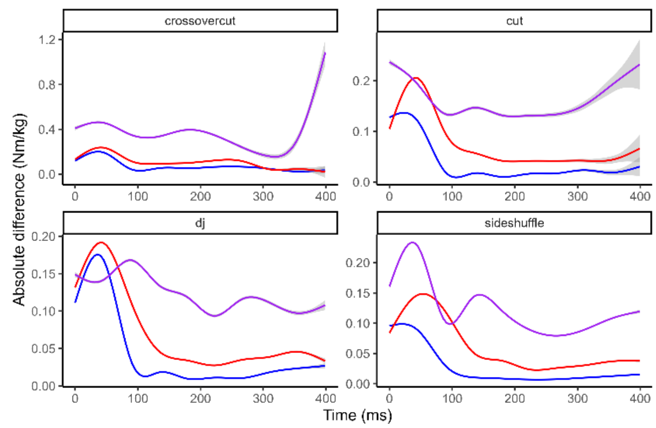

Figure 1: Absolute differences between signals filtered with different low pass cut-off frequencies sampled at 1400 Hz. Purple = 2 vs 6 Hz. Red = 6 vs 20 Hz. Blue = 20 vs 38 Hz.

Conclusions

The choice of low-pass filter cut-off frequencies primarily influences the early stance phase KAM, with large changes in the timing of the observed peak for the full stance phase. Researchers should consider the low-pass filter frequency in light of the planned data analysis process, and while higher frequencies retain more of the signal it is not known how much of the retained signal is noise or artifacts. The sampling rate only had a minimal influence on the magnitude of the peak, or timing of the peak KAM during sports maneuvers.

References

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