The Effect of Smoothing on Lower Limb Linear and Angular Kinematics

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Introduction

- When collecting biomechanical data of human movement, often reflective markers are attached to a subject on areas of interest (i.e bony landmarks).
- Reflective markers should make the digitisation process easier and more accurate.
- Errors can still occur within the data collected due to:
  - Vibrations of the Marker (e.g. foot contact)
  - Inability to locate the centre of the marker
  - Skin Movement over a joint centre (Barlett et al., 2006)
- Therefore it is important to smooth the data, to remove any unwanted data frequencies.
- Human movement tends to occur at lower frequencies, meaning important to remove any unwanted noise at higher frequencies (Robertson et al., 2014).
- **Aim – The aim of this study is to highlight the effect of smoothing and different filter values on peak velocities and angles.**

Methods

- One participant was used within this study (n=1, age = 21, Gender = M, Height = 1.78 m, Mass = 60 kg).
- Required to run at 10 km race pace.
- A USB3 camera (1280 x 650, 250 fps), 8 mm – 48 mm zoom lens, LED light and 19 mm reflective markers were used. Set up is shown in Figure 1.

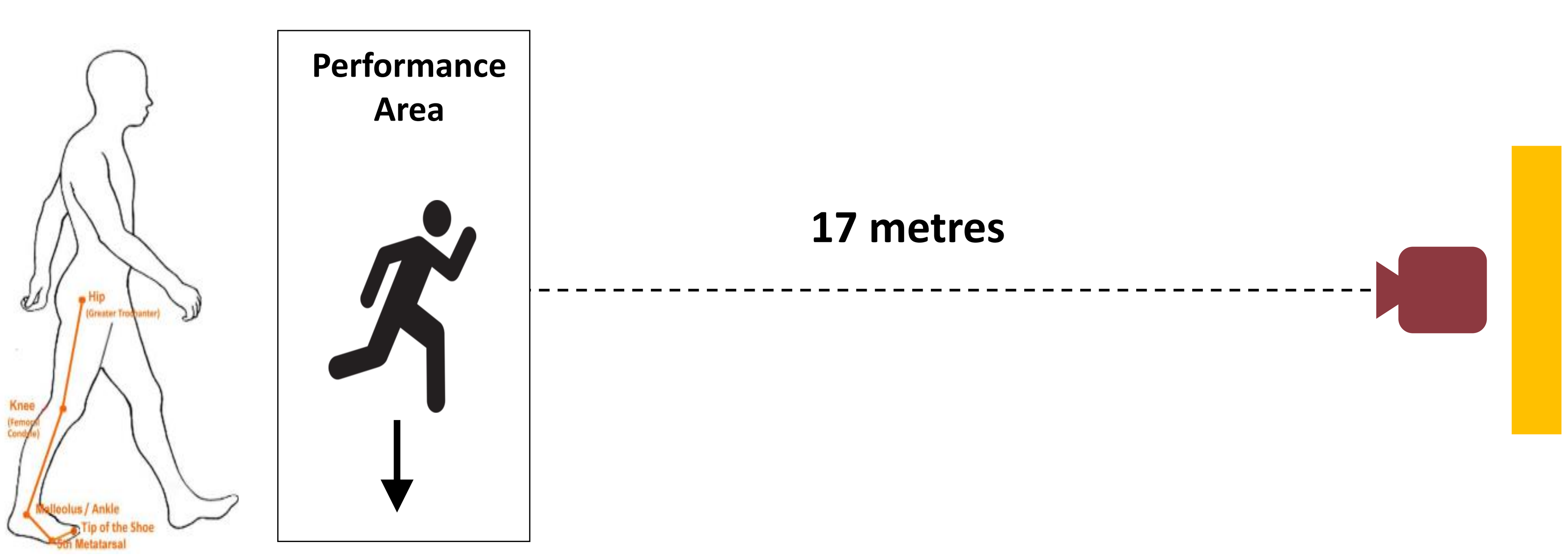

Figure 1: Shows camera set up and reflective marker placement.

- Automatic Digitisation was used to measure linear and angular displacements, velocities and accelerations of the hip, knee and ankle.
- Data Filtering, shown in figure 2, was then used to smooth the data at 5 Hz intervals starting from 1 Hz (Most smoothing) up to 62 Hz (Least smoothing) for both the X and Y values independently.

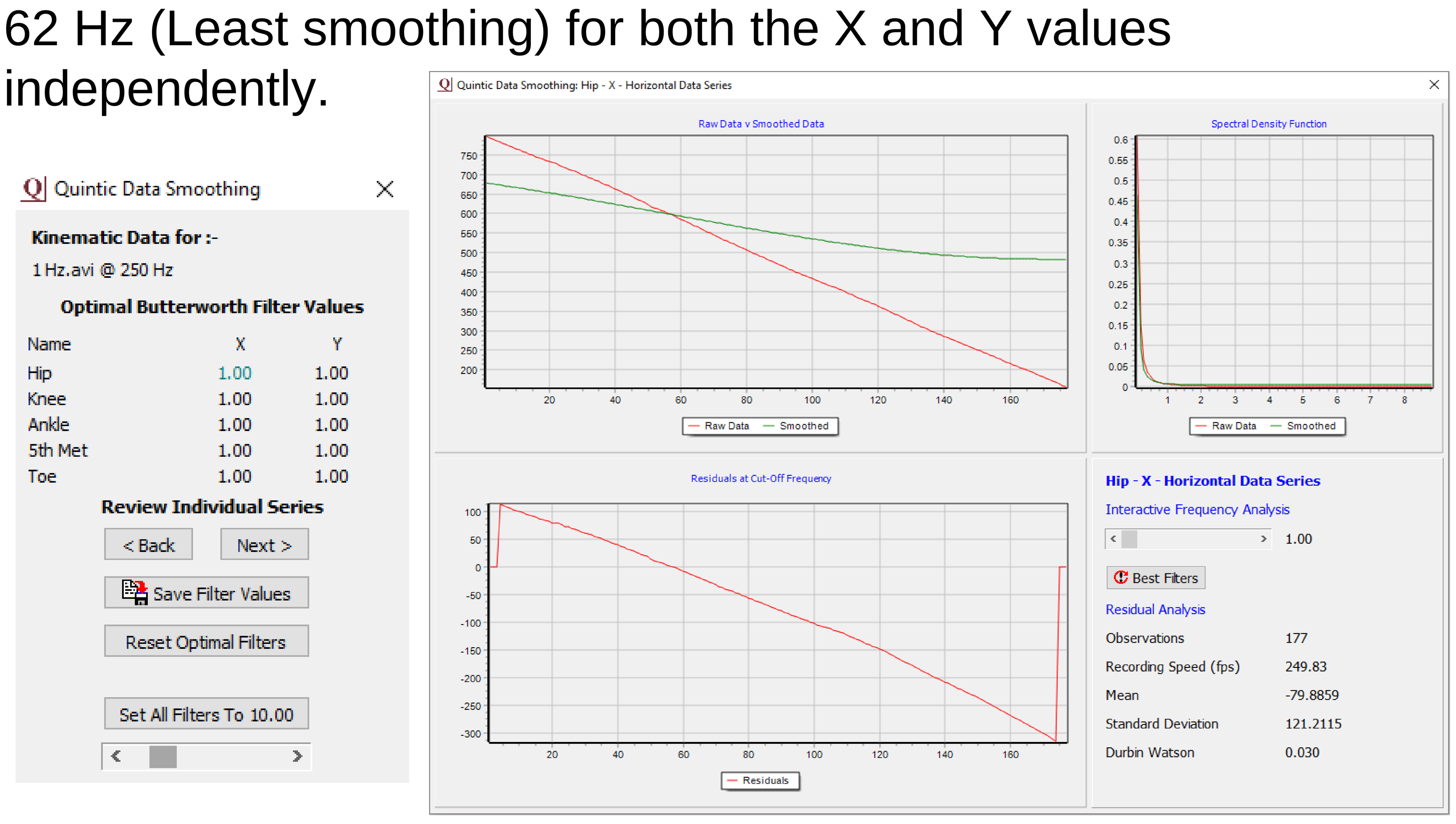

Figure 2. Shows the Quintic Filter window. The filter values used are displayed, alongside analysis of the smooth v raw data

Results

- Smoothing was shown to have a greater effect on maximum velocity of the ankle (-85.9%) and the least effect on hip maximum angle (-9.1%).
- As shown in Table 1, the effect of smoothing seemed to increase for both maximum velocity and maximum angle the further down the limb the measurements were recorded.
- As the range of movement increases, do does the effect of smoothing.
- However, this is not the case for minimum angle as the knee showed the greatest effect of smoothing.

Table 1: Max Velocity, Max Angle and Min Angle difference between most smoothed (1 Hz) and least smoothed (62 Hz) data for the Hip, Knee and Ankle during the running stride.

	Max Velocity Difference ms^{-1} (%)	Max Angle Difference ° (%)	Min Angle Difference ° (%)
Hip	3.88 (-63%)	19.79 (-9.1%)	43.16 (28.3%)
Knee	6.63 (-76.5%)	22.64 (-13.9%)	60.1 (82.8%)
Ankle	8.8 (-85.9%)	27.99 (-19.3%)	23.89 (25.5%)

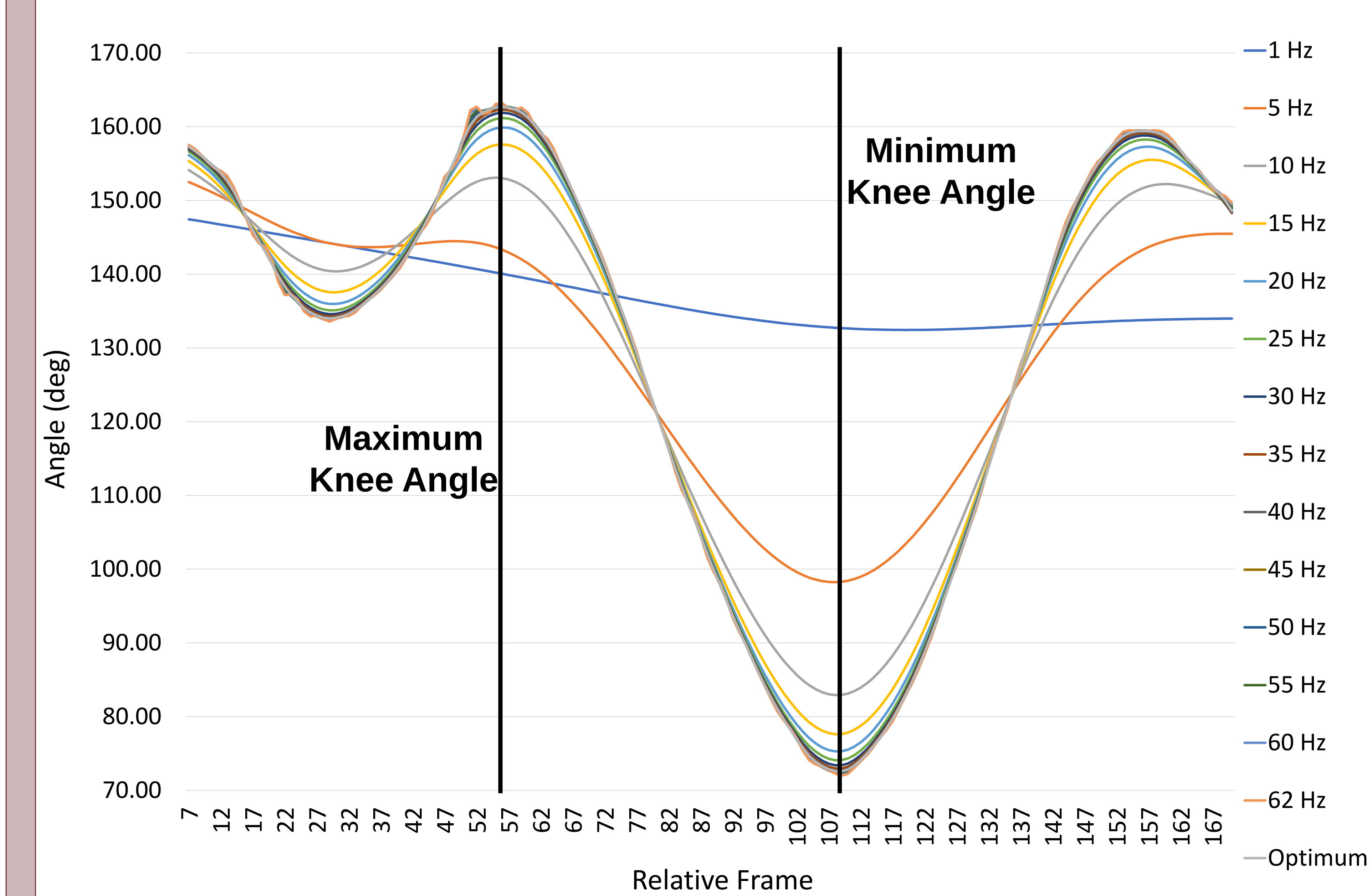

Figure 3: Shows the effect of smoothing for maximum and minimum knee angle during the running stride.

Discussion

- Results show that 'one for all' smoothing is not best practice for biomechanical movement analysis.
- The amount of smoothing depends on the movement that is occurring and what the researcher is measuring.
- There was a range of 76.8% between the least affected value (Hip Maximum Angle) and most affected value (Ankle Max Velocity).
- Quintic Software is able to smooth each variable independently in the X and Y axis to ensure that 'Optimum' smoothing occurs and data is not over or under smoothed.
- **Conclusion – Biomechanists should use optimum smoothing to ensure data is represented appropriately**

References - Barlett, R., Bussey, M., & Flyger, N. (2006). *Journal of Biomechanics, 39* (16), 3076-3079. https://doi.org/10.1016/j.jbiomech.2005.10.020
Robertson, G., Caldwell, G., Hamill, J., Kamen, G., & Whittlesey, S. (2014). *Research methods in biomechanics*. United States, Champaign IL: Human Kinetics