# PROCESSING EFFECTS ON JOINT MOMENTS DURING IMPACT LANDINGS

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## INTRODUCTION:

Joint loads calculated from rigid body, inverse dynamic models provide unrealistic estimates of active moments generated by muscles during impact (Gruber et al, 1998). The moments oscillate (McNitt-Gray, 1993) and the magnitudes may be overestimated (Gruber et al, 1998). Recent evidence suggests that errors are introduced when segment position data and ground reaction forces (GRFs) are processed differently (Bisseling & Hof, 2006). Filtering segment position at lower cut-offs than the GRF data attenuates equalizing segment acceleration moments in the inverse dynamic equations. A cut-off frequency of 20 Hz for both has been recommended when assessing knee moments during impact (Bisseling & Hof, 2006). Given the interest in joint loads during impact, selecting appropriate filter cut-offs is important. We propose that filter selections should be based on a frequency analysis of the GRFs. This study presents information on predominate frequencies for different impact-like scenarios and shows how three different processing methods change the calculated joint moments.

## METHODS:

Six subjects performed five impact-like movements typically reported in the literature. Three involved an acceleration over a 1.5 meter distance to a sudden stop (L1), a plant and push off to the left (L2) and a plant and cross over to the right (L3). In each case GRFs were measured for the right foot landing. The fourth movement was a drop landing from a 20 cm height (L4) and the fifth involved stepping down and out from a 10 cm height to land in single leg support (L5) Vertical and shear forces were measured (Kistler force plate) and digitally sampled at 2400 Hz. The frequency content for GRFs during landing were determined (~1.0 Hz resolution) using a Fast Fourier Transform sampled to the nearest power augmented with zero endpoint padding. The 98$^{th}$ percentile frequencies for the GRFs were determined from the cumulative sum of the integrated power-frequency spectrum.

Joint moments were calculated for L5 with each subject modeled as a two dimensional, sagittal plane, three segment, rigid body. Segment position coordinates were digitized (60 Hz) from video. In the first method (SM), joint moments were calculated using inverse dynamics (Winter, 1990) with unfiltered GRFs and filtered position data at cut-offs based on Jackson's method (Jackson, 1979). In the second technique (RM), moments were calculated after filtering the position and the force plate data based on the 98$^{th}$ percentile of GRFs. In the third approach (AM), moments were filtered (98$^{th}$ percentile) after they had been calculated with no filtering of the position and the force plate data. A zero-lag, fourth order, Butterworth filter was used for each.

## RESULTS AND DISCUSSION:

The 98$^{th}$ percentile frequency was highly variable both within and between subjects for the five impact-like movements (Table 1). A common 20 Hz filter cut-off for forces and position data would not be suitable for all impact-type movements. Filtering data is always a compromise between removing noise and signal; therefore, it is recommended that filter cut-offs be selected based on an objective criterion such as frequency analyses of GRFs.

Knee and hip moments calculated with the standard processing method (SM) were greater than those calculated by the RM or AM methods; they also peaked early after impact (0.517 s; Fy = 22 N) and oscillated at the knee (Fig. 1) and at the hip. In agreement with others, filtering GRFs and marker coordinates with a common filter cut-off reduces “artifacts” when calculating net joint moments during impact (Bisseling & Hof, 2006). Gruber et al (1998) attributed these moment “errors” to rigid body assumptions and proposed wobbling-mass models to account for soft tissue effects. Magnitude and timing errors can be attributed to inconsistencies in data processing; therefore, the relevance of soft tissue motion on joint kinetics should be revisited.

Much of the literature has used SM processing approaches to calculate and compare lower limb joint kinetics (McNitt-Gray, 1993; Cowling & Steele, 2001). The magnitude and timing of joint moments may have been affected by inconsistent processing of input data. Future analyses of impact-like activities need to consider these effects on joint moment values.

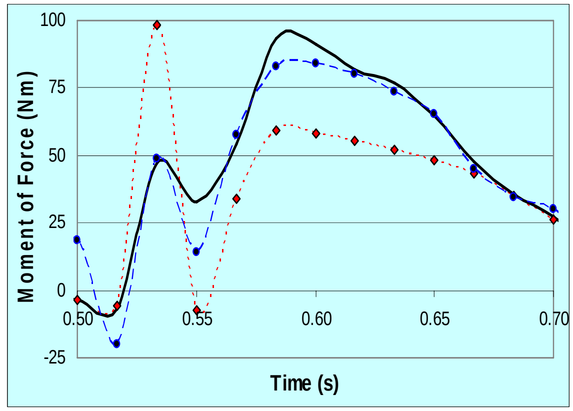


**Fig. 1:** Knee moment calculate with AM (solid black) SM (dashed-diamond red), RM (dashed-circle blue).

**Table 1: 98th percentile frequency (Hz).**

| Landing | Fx | Fy | Fz | Fx, Fy Range |
|---|---|---|---|---|
| L1 | 26 (19) | 17 (12) | 39 (7) | 7 – 50 |
| L2 | 18 (8) | 10 (6) | 10 (8) | 2 – 28 |
| L3 | 23 (15) | 8 (6) | 7 (4) | 2 – 39 |
| L4 | 27 (9) | 11 (3) | 39 (16) | 9 – 59 |
| L5 | 19 (9) | 12 (7) | 24 (11) | 8 – 38 |

**Notes**: L1 to L5 = different impact-like landings. Fy = vertical, Fx = anterior-posterior, Fz = medial-lateral. “( )” = standard deviation.

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