FILTERING GRF DATA AFFECTS THE CALCULATION AND INTERPRETATION OF JOINT KINETICS AND ENERGETICS DURING DROP LANDINGS

Steven T. McCaw, Jacob Gardner and Lindsay Barlow
Illinois State University, Normal, USA
email: smccaw@ilstu.edu

INTRODUCTION

A joint kinetic and energetic analysis uses inverse dynamics to calculate joint moment of force (JMF), and joint mechanical power (JMP) as the product of JMF and joint angular velocity (ω) [6].

A kinetic and energetic analysis has been used to analyze contributions of the ankle, knee and hip joints to energy absorption during landing (i.e. [2, 3]) by integrating critical phases of the JMF and JMP data. However, compared to using unfiltered ground reaction force (GRF) data in the inverse dynamic analysis, digital filtering of the GRF causes dramatic differences in the JMF-time curves, especially at the hip and knee joints in the sagittal plane [1,4,5] where high frequency oscillations are attenuated. No project has quantified the altered JMF curves (integrals or peaks) and none has reported the effect of the altered JMF on subsequent calculation and integration of JMP.

We hypothesized that GRF filtering would decrease the calculated angular impulse (∫JMF) and negative work (∫JMP) at each joint, affecting the relative contribution of each joint to the total energy absorbed by the lower extremity.

METHODS

Six healthy, active, injury-free students (5 ♀, 1 ♂; age: 21.3±.7 y; ht: 1.67±.05 m; mass: 61.3±6.6kg) volunteered and provided informed consent. Subjects performed 5 soft and 5 hard (total 10 trials) two-legged landings off a 32 cm platform with the right foot landing on an AMTI forceplate (1000 Hz). Soft and hard landings differed in knee flexion range of motion during ground contact. Reflective markers, applied according to the *Plug-in Gait* template (Vicon), were tracked with 8 infrared cameras (200 Hz).

Hip, knee and ankle JMFs in the sagittal plane were calculated using two methods of data filtering (4th order low-pass Butterworth). In *Unfiltered*, marker data were filtered at 10 Hz, but the GRF were unfiltered. In *Filtered*, both GRF and marker data were filtered at 10 Hz. JMP was calculated as JMF • ω. Angular impulse and joint work were calculated for each trial by integrating the JMF and JMP time curves, respectively, between ground contact and maximum knee flexion. Total work was calculated as $\Sigma\ W_{Ank} + W_{Knee} + W_{Hip}$. The % of work by each joint was calculated as $Work_{Joint}$ / $Work_{Total}$.

Five-trial mean values for each variable were entered into a 2x2 (style x filtering) repeated measures ANOVA (α=.05).

RESULTS AND DISCUSSION

There were no significant style x filtering interactions on the measures. There were significant main effects of both style and filtering. For brevity and to emphasize the effect of GRF filtering, results were pooled across the soft and hard landings (Table 1). For presentation clarity, grande ensemble averages were compiled from the linear envelopes of JMF and JMP data (Fig. 1) of individual subjects over the period between 10ms pre-contact and maximum knee flexion; only the grande ensemble curves for hard landings are presented.

GRF filtering attenuated the high frequency oscillations in the JMFs of the knee and hip, similar to [1,4,5]. The dominant, sharply peaked hip flexor JMF (15% of contact) and the rapid transition from a maximum to a minimum in the knee extensor JMF (15-25% of contact) were both eliminated. JMPs similarly exhibited reduced minima and maxima when JMF were calculated from filtered GRF data.

The extensor angular impulse and the negative work at all joints were significantly reduced compared to using unfiltered GRF to calculate JMF (Table 1). Although total and joint works were reduced, relative joint contributions changed < 2%. Thus, although statistically significant, the alterations do not seem clinically meaningful.

Table 1. Descriptive statistics (Mean & SD) for angular impulse and work values calculated with and without filtering GRF data before the inverse dynamic analysis, pooled across soft and hard landings.

	Unfiltered GRF	Filtered GRF	
Moments($N \cdot m \cdot s \cdot kg^{-1}$): contact to max knee flexion			
Hip extensor impulse	0.093 0.059	0.081 0.055	*
Knee extensor impulse	0.289 0.077	0.285 0.077	*
Ankle Plantarflexor impulse	0.168 0.034	0.166 0.034	*
Powers ($J \cdot kg^{-1}$): contact to max knee flexion			
Work at hip	-0.20 0.16	-0.15 0.12	*
Work at knee	-1.37 0.37	-1.32 0.36	*
Work at ankle	-0.68 0.09	-0.65 0.09	*
Total Work	-2.26 0.50	-2.12 0.45	*
Relative Joint Contributions (% Total Work)			
Hip	7.8 4.2	5.8 3.7	*
Knee	59.2 4.0	60.8 5.1	*
Ankle	33.0 5.9	33.4 5.8	*

* $p < .05$

Of tremendous import is that GRF filtering altered *the fundamental patterns* of the JMF and JMP. Joint kinetics and energetics provide insight to the goals and strategies of the central nervous system [6]. The rapid oscillations in JMF and JMP calculated with unfiltered GRF data led to speculation on CNS strategies involving knee and hip joint trade-offs during landing [i.e. 2, 3] that may not be warranted with appropriate processing of GRF data.

CONCLUSIONS

Angular impulse and work values differ when JMF and JMP are calculated with and without filtering of GRF data, although the interpretation of individual joint contributions to total energy absorption is not affected. However, the attenuation of high frequency oscillations in both JMF and JMP time curves will influence interpretation of CNS strategies during landing.

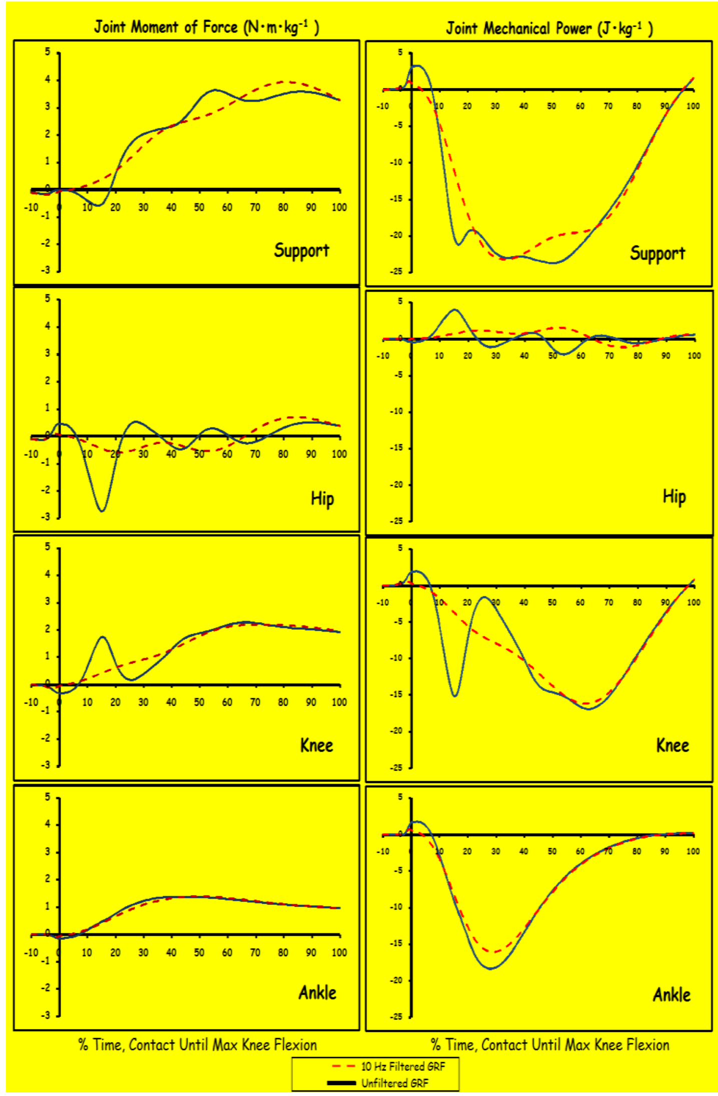

Figure 1. Grande ensemble average curves (n = 6, 5 trials) of JMFs (left) and JMPs (right) calculated with and without GRF filtering (10 Hz low-pass).
JMF: – flexor, + extensor
JMP: - Eccentric, + Concentric
(Hard Landing Data only)

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