EXTRACTION OF THE IMPACT FROM VERTICAL GROUND REACTION FORCES

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INTRODUCTION

Vertical ground reaction forces (VGRF) are composed of a high frequency (impact) and a low frequency (active) component. The impact component is associated with the acceleration the stance leg during running [1]. This impact component has been associated with both positive (bone strengthening) and negative (injury) effects. The impact and active components are superimposed in the time domain and contain significant overlap in the frequency domain. Therefore, spectral methods are inadequate as a means of separating the components. The purpose of this research was to determine if spline techniques could be used to separate the impact from the active portion of a VGRF.

METHODS

A cubic smoothing spline with a weighting variable was used to remove the impact peak from a VGRF curve. The curve was split into 4 regions (Figure 1). Region A consisted of the first 8 ms of the curve. The values were set to the reverse of the last 8 ms of the curve and the weights were set to 0.1. Region B was from 8 ms to approximately twice the time to the impact peak. This assumes a symmetric impact curve. The weights were set to 0.0 in this region. Region C was from the end of Region B to one data point prior to the end of the VGRF. The weights in this region were set to 0.1. The final data point was set to 1.0 to force the curve through this value. Application of the spline resulted in the active force. The impact force was obtained from subtraction of the active force from the VGRF.

A mass-spring model was used to simulate impact curves. Stiffness was originally set to 100 kN/m, mass was 8.5 kg and initial velocity was -1.0 m/s. The active curve was simulated

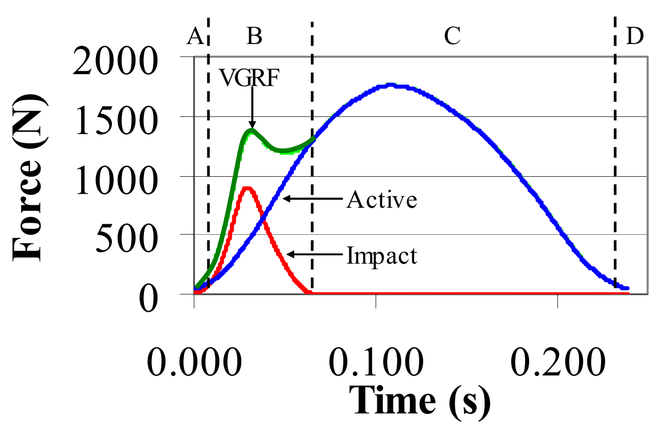

Figure 1. Spline extraction of the impact portion of an actual running vertical ground reaction force curve. Regions A, B, C and D indicate different weights of the spline.

using a Kaiser window (β=5) scaled in magnitude to 1200 N and scaled in time to 0.25 s. Simulated VGRF curves were constructed by adding the impact and active curves. The ability of the spline to accurately extract the impact portion of the curve was assessed by comparing the actual mass-spring impact peaks to the extracted impact peaks while changing the parameters of spring stiffness, impact velocity and stance time.

The spline method of impact extraction was also applied to actual VGRF curves obtained while running across a force platform in 4 conditions. Seven subjects (mass: 66±7.5 kg) were first asked to run at a normal pace. They were then asked to run at the same pace off of a raised platform while flexing the knee normally, with excessive flexion and with minimal flexion. Ten trials of force platform data were recorded at 1000 Hz for each of the four conditions. Actual running VGRF impact peaks were compared to impact peaks extracted using the spline technique.

RESULTS AND DISCUSSION

Although simulated VGRF impact peaks ranged from 649 to 1543 N, the extracted impact peaks were never more than one N different than the mass-spring simulated impact force peaks.

Table 1 indicates the average VGRF and extracted impact peaks for each running condition. Note the magnitudes are substantially different, yet there is a correlation of 0.98 between actual and extracted peak values.

Extraction of impact peaks allows the determination of impact parameters independent of the active portion of the curve. This has applications for assessing both the injury and osteogenic potential of impacts. The extracted impact forces could be used to estimate the effective mass of an impact.

Table 1. Peak impact values for actual VGRF curves.

Running Condition	Peak VGRF Impact Force (N)	Peak Extracted Impact Force (N)
Normal	1182±227	705±227
Platform Normal	1925±404	1484±379
Platform Flexed	1855±479	1569±457
Platform Extended	2290±539	1888±538

REFERENCES

1. Bobbert, et al., *J. Biomech.*, **24**:1095-1105, 1991.