USING ANKLE, KNEE, AND HIP PEAK ANGULAR VELOCITIES TO PREDICT LOWER EXTREMITY WORK DURING DROP LANDINGS

Lindsay Barlow, Jacob Gardner, Steven T. McCaw
School of Kinesiology and Recreation, Illinois State University, Normal IL
email: lnbarlo@ilstu.edu

INTRODUCTION

A kinetic and energetic analysis is useful for determining the relative joint contributions to skill performance, but remains a relatively time and labor intensive method of assessment despite the availability of commercial software. Additionally, the clinical applications and interpretations of such biomechanical analyses are often not fully understood [1]. Kinematic data, including joint angular velocity evaluated qualitatively, has long been proposed as a biomechanical "tool" to effectively evaluate performance [3].

During the absorption phase of landing, the rapidly flexing joints of the lower extremity are brought to rest by eccentric activity of the appropriate muscles. The angular version of the work-energy relationship (Equation 1) suggests that, as angular velocity (ω) increases, greater angular work is required to bring the rotating body to rest:

$$\mathcal{T}\theta = \frac{1}{2} I \left(\omega_f - \omega_i\right)^2 \qquad \text{(Eq. 1)}$$

This study examined the relationship between peak ω and mechanical work at the ankle, knee and hip joints during drop landings. We looked at both soft and stiff landings while wearing a variety of different ankle braces. We hypothesized that there would be a strong positive correlation between peak dorsiflexion/flexion ω and negative work during the landing, as could be predicted with the angular analog of the work-energy relationship.

METHODS

Sixteen female university students (age, 20.6 ± 1.0 y; ht, 1.66 ± 0.07m; mass, 66.5 ± 10.8 kg) volunteered as participants. All were free of injury for 6 months prior to data collection and were experienced in landing as determined by a questionnaire.

Participants performed two-legged landings off a 0.32-m platform onto a force platform as in previous research [2]. Only the right leg was analyzed.

Five soft and five stiff landings were performed in five bilateral ankle stabilizer conditions (no stabilizer, standard taping, lace-up boot, hinged boot, and stirrup style), for a total of fifty trials per subject. Stabilizers and style conditions were randomized across participants, and conveniently provided greater ranges in the peak ω and negative work data for establishing correlations.

Ankle, knee and hip kinematics, joint moment of force and energetics were calculated using standard inverse dynamic techniques combining an optotrak system (200 Hz), force platform (1000Hz), anthropometics. Joint work was calculated as the integral of the mechanical power-time curve from contact until $\omega_{joint} = 0$.

Pearson correlation coefficients were calculated between peak ω and negative work at each joint. A stepwise multiple regression was performed between total work (Σhip+knee+ankle work) and the peak ω of the three joints.

RESULTS AND DISCUSSION

Figure 1 presents grand ensemble mean curves by each condition for joint ω and joint mechanical power, and a scattergram of peak joint ω and joint mechanical work.

There was a statistically significant positive correlation between peak angular velocity and negative work at each joint. The r values ranged from .94 at the hip to .53 at the knee joint, reflecting strong to moderate relationships, respectively.

The statistically significant ($p<0.001$) multiple regression equation computed was

$$Work_{total} = -.287 + 0.006\,\omega_{hip} + .002\omega_{ankle}$$

($r^2 = 0.630$, standard error of estimate =.425).

CONCLUSIONS

The moderate to strong correlations between peak ω and joint work suggest that peak angular velocity can be used to qualitatively assess the negative work performed at the joints of the lower extremity during a landing. Since calculating joint ω is less labor and calculation intensive than calculating joint kinetics and energetics (primarily work and power) analyzing joint ω provides a simpler method of describing energy absorption by the lower extremity. This could provide a starting point for the teaching of joint energetics in the undergraduate sports medicine curriculum.

Changes in peak ω do not account for all the work done in the work-energy relationship. Fluctuations in joint moments can also contribute to work variability. Therefore, the next step to developing a qualitative "tool" for lower extremity performance assessment is to investigate the relationships among the joint moment, peak ω_{joint} and joint work.

REFERENCES

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Figure 1: Lower extremity grand ensemble curves and correlations. From left to right, peak ω flexion/dorsiflexion, negative mechanical power, and correlations between peak ω flexion/dorsiflexion and work.