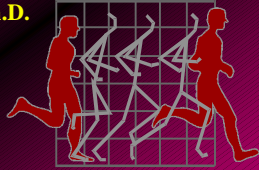


## Segmental Power Analysis

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## Calculate Net Forces and Moments of Force using Inverse Dynamics

- first measure the ground reaction forces
- and film the motion
- then apply inverse dynamics



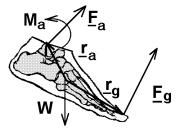
## Kinematic Analyses

- linear position, velocity and acceleration of markers and joints ( $v_j$ )
- linear position, velocity and acceleration of body segments (used for inverse dynamics)
- angular velocity of joints ( $w_j$ )

## Divide Limb into Segments and Make Free-body Diagrams

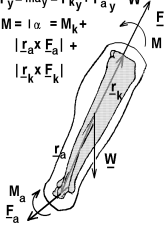


## Apply Newton's Laws of Motion to Terminal Segment

$$\begin{aligned}\Sigma F_x &= ma_x = F_{ax} + F_{gx} \\ \Sigma F_y &= ma_y = F_{ay} + F_{gy} - W \\ \Sigma M &= I\alpha = M_a + |r_g \times E_g| + |r_a \times E_a|\end{aligned}$$


## Apply Reactions to Next Segment

- apply reactions of terminal segment to distal end of adjacent segment (leg) in kinematic chain
- compute its net forces and moments at proximal end

$$\begin{aligned}\Sigma F_x &= ma_x = F_{kx} + F_{ax} \\ \Sigma F_y &= ma_y = F_{ky} + F_{ay} - W \\ \Sigma M &= I\alpha = M_k + |r_a \times E_a| + |r_k \times E_k|\end{aligned}$$


## Repeat with Next Segment

- compute thigh's net forces and moments



## Sources of Power to the Segments

- joint forces (ligamentous, joint capsular, cartilaginous [bone-on-bone] and muscular forces)
- moments of force (caused mainly by muscles, ligaments at end of ROM)
- external sources (elevators, diving or spring boards, fluid resistance, surface friction, wind resistance, etc.)

## Compute Powers due to Forces and Moments of Force

- power transfers **due to forces** are equal to dot products of net forces and joint velocities (i.e.,  $\underline{F}_j \cdot \underline{v}_j$ )
- powers delivered **by moments of force** are equal to products of net moments of force times segmental angular velocities (i.e.,  $M_j \omega_s$ )

## Moments of Force

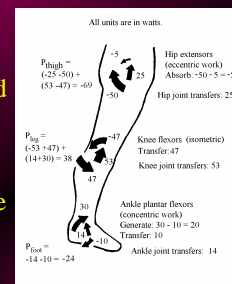
- moments of force can transfer energy across a joint
- moments of force can also either generate or dissipate energy to one or both segments that they act upon. The rates of work done or energy dissipated, is equal to  $M_j \omega_j$ , where  $\omega_j$  is joint angular velocity.

## Powers across Joints

- transfers **through joint forces**
- transfers **through joint moments of force**
- generation or absorption **by moments of force**
- elastic storage **and** recovery assumed to be zero

## How to Interpret Segmental Force and Moment Powers

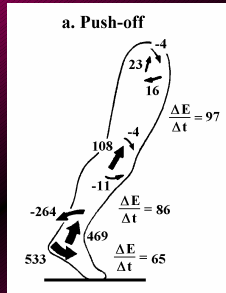
force and moment powers should be equal to rates of segmental energy change ( $\Delta E/\Delta t$ )



moment powers can show if moment is generating or dissipating energy and/or transferring energy

### Push-Off

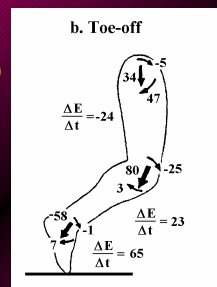
plantar flexors provide sufficient work (269 W) to supply foot (65 W), leg (86 W) and trunk (23 W)



knee extensors dissipate energy (-15 W) while hip flexors begin swing of thigh (12 W)

### Toe-Off

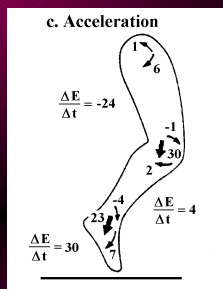
dorsiflexors do work (6 W) flex foot to clear floor during swing



knee extensors still dissipating energy (-22 W) while hip flexors continue working to cause swing of leg (42 W)

### Early Swing

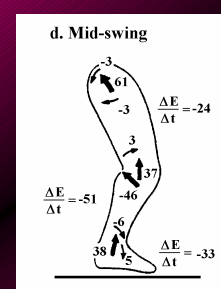
dorsiflexors continue to flex foot to clear floor



knee and hip moments are essentially inactive. Extremity is almost a compound pendulum.

### Midswing

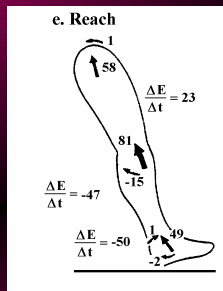
dorsiflexors transferring energy (5 W)



knee flexors begin slowing the leg (-43 W) to prevent full extension at foot-strike. Thigh extensors do the same (-6 W).

### Late Swing

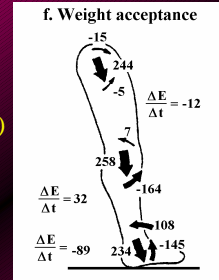
ankle and hip moments essentially inactive



knee flexors continue to reduce rate of extension (-15W) of knee prior to foot-strike

### Weight-Acceptance

ankle dorsiflexors dissipate energy (-37 W) to control "foot-slap"



knee extensors dissipating energy (-157W) with hip flexors dissipating at rate of -20 watts

### Summary

- plantar flexors supply power to all segments during push-off
- hip flexors supply power to swing the lower extremity
- knee flexors control rate of extension during swing
- knee extensors control rate of flexion during push-off and early swing and control flexion during early stance
- dorsiflexors flex foot to allow foot to clear floor during swing and to control foot-slap