Biomechanical aspects of running injuries

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Introduction

• in US, 2002
  • 375 marathons & ~ 450,000 people completed at least one marathon
    USA Track and Field Road Running Information Center, 2003
  • ING Taipei International Marathon, 2005: 60,000
• People seeking medical attention during or immediately after completing the race: 2% to 8%
  • 17% of them musculoskeletal problems
  • muscle cramps, blisters, and acute ankle and knee injuries

Running Injury

• overuse injuries of the lower extremity
  • between 27% and 70% of recreational and competitive runners during any 1-yr period
• Type
  • stress fractures
  • medial tibial stress (shin splints)
  • chondromalacia patellae
  • plantar fasciitis
  • Achilles tendinitis
Factors causing running injuries

- Training
  - Excessive running distance or intensity
  - Rapid increases running distance or intensity
  - Surface and shoes
  - Stretching?
- Anatomical variables
  - Longitudinal arches (pes cavus)?
  - Ankle range of motion
  - Lower extremity alignment abnormalities
    - Tibia varum, rearfoot varus, Leg length discrepancies, Q-angle

Factors causing running injuries

- Biomechanical variables
  - Kinetic variables
    - Magnitude of impact forces
    - Impact loading rate
    - Magnitude of active (push off) forces
  - Kinematic variables (rearfoot)
    - The magnitude and rate of foot pronation

Introduction

- Biomechanics: Kinetics
  - Vertical ground reaction force vs. time curve for running.

Running cycle

- Stance phase
  - Foot strike
  - Mid-support
  - Take-off
- Swing phase
  - Follow-through
  - Forward swing
  - Foot descent
**Kinetics**

- Vertical impact forces, loading rates
  - Previous injured runners (both male and female) $> \text{uninjured}$
    (Hreljac et al., 2000)
  - Female runners with stress fracture $> \text{without}$
    (Ferber et al., 2002; Grimston et al., 1993)

**Kinematics**

- Magnitude and rate of foot pronation
  - Excessive pronation $\rightarrow$ running injuries
    (Messier et al., 1988; Viitassalo et al., 1983)

**Footstrike mid-stance later stance**

- Early studies of running generally focused on the movement of individual joints or segments
- Coordination of motion between joints and segments
- Joint timing
  - Peak frontal plane rearfoot motion
  - Peak sagittal plane knee motion
coupling mechanics

- subtalar joint pronate
  - eversion, abduction, dorsiflexion of the calcaneus with respect to the talus
- tibial internal rotation
- knee flexion
  - occur relatively synchronously

EV/TIR ratio

- 1.72 for the loading phase of gait (Stacoff et al., 2000a,b,c)
- 1.42 for nine uninjured runners (McClay and Manal, 1997)
- there is a greater amount of eversion as compared to tibial internal rotation during running

EV/TIR ratio

- high arch group
  - tibial internal rotation \(\uparrow\) \(\rightarrow\) EV/TIR ratio \(\downarrow\)
    (Nigg et al., 1993; Nawoczenski et al., 1998)
  - eversion \(\uparrow\) \(\rightarrow\) EV/TIR ratio \(\downarrow\)
    (Williams et al., 2001)
- pronator group
  - tibial internal rotation \(\uparrow\) \(\rightarrow\) EV/TIR ratio \(\downarrow\)
    (McClay and Manal, 1997)
**EV/TIR ratio**

- **Injury site**
  - High EV/TIR ratios (more rearfoot eversion motion) → foot related injuries
  - Low EV/TIR ratios (more tibial motion) → knee related injuries

- **Contrary**
  - High EV/TIR ratios (low arches) → knee related injuries
  - Low EV/TIR ratios (high arches) → foot related injuries

(Nawoczenski et al., 1998; Williams et al., 2001)

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**Dynamical systems approach**

- **previous research**
  - only addressed coupling at single occurrences during the gait cycle
  - Ex: maximal internal or external tibial rotation

- **continuous relative phase (CRP)**
  - normalized angular velocity plot against normalized angular position
  - phase angle
  - CRP angle (proximal — distal)

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- **Hamill et al. (1999)**
  - the first to introduce the use of CRP into the biomechanics literature

- **Subjects (I)**
  - Q-angles > 15°: at a higher risk of lower extremity injury
  - Q-angles < 15°: at a lower risk of lower extremity injury

- **Subjects (II)**
  - Healthy
  - Patellofemoral pain
**Dynamical systems approach**

- **segment**
  - Thigh flexion/extension and tibial rotation: \( (\text{ThF/E} \rightarrow \text{TibRot}) \)
  - Thigh abduction/adduction and tibial rotation: \( (\text{ThAb/Ad} \rightarrow \text{TibRot}) \)
  - Tibial rotation and foot eversion/inversion: \( (\text{TibRot} \rightarrow \text{Ft Ev/In}) \)
  - Femoral rotation and tibial rotation: \( (\text{FemRot} \rightarrow \text{TibRot}) \)

**Introduction**

- **Ⅰ** Low Q-angle vs. high Q-angle
  - There is no statistically significant differences in the mean CRP and the variability in CRP between the groups for all couplings (\( P > 0.05 \))

- **Ⅱ** Healthy vs. PFP
  - About 15° of CRP variability similar to previous investigation
Healthy vs. PFP - CRP variability

- **Healthy**: out-of-phase, especially strong
- **PFP**: in-phase

**Healthy vs. PFP**
- **Healthy**
  - greater degree of *repeatability* of action in the PFP data
  - inflexible patterns of coordination
  - possible emergence of patellofemoral pain

**Conclusions**
- **Lower** CRP variability
  - an indicator of a *non-healthy state*
  - segment actions were *repeatable* within a very narrow range
  - enabled these individuals to accomplish this task with a minimum of pain
- **Higher** CRP variability
  - there were multiple combinations of coupling *patterns* that could be utilized
  - *no tissue is repeatedly stressed* which results from the relatively greater variability of joint couplings

**Other literature**
- Ferber et al. (2002)
  - CRP for EV/TIR
  - healthy group: more *in-phase* relationship
  - injured group: more *out-of-phase* relationship
- Stergiou et al. (2001)
  - CRP for EV - tibial abduction
  - Heel strike: out-of-phase
  - Midstance: in-phase
  - From midstance to toe-off: out-of-phase
Other literature

- DeLeo et al. (2004)
  - There are a number of limitations to the CRP approach
    - Many variables are not relatively sinusoidal
    - Whether the data should be normalized
    - The difficulty in interpreting the results as they relate to injury

- Heiderscheit et al. (2002)
  - Vector coding technique
    - Angle–angle diagram

Summary

- In terms of relative timing
  - There is synchrony between peakversion, peak tibial internal rotation and peak knee flexion, which takes place near mid-stance in healthy runners
  - Normal EV/TIR during running > 1
    - Does not lend insight into location of injury
  - CRP, vector coding and variability techniques have provided new perspectives in understanding running biomechanics

Future

- With larger subject numbers to further define the normal bounds of joint coupling
  - Other joint coupling relationships, including tibiofemoral and hip–knee coupling are needed
  - Prospective studies are needed to establish relationships between joint coupling and injury prevalence
Thanks for your attention!