Introduction to Biomechanics, Part II

Jonathan Lam

11/22/21

Contents

1 Inverse dynamics

- Combine motion and force plate measurements to estimate forces at joints
- Essentially Newton's second law on body
- Treat body as linked together rigid points (big assumption)
- Also assume that we know the mass, moment of inertia of body segments
  - Can measure using MRI/CT, is expensive
  - Cadaveric studies
- Start at the foot
  - $m_f a + f = F_{gr} + m_f g + F_{body}$ to solve for the force from the body
  - Can solve for moment around the ankle
- Non-invasively estimate forces and moments in joints
- Good for predicting pathology (e.g., arthritis looking at knee adduction moment)
- Caveats

  - Extremely accurate force measurements, motion measurements, but inertial properties of the body are crazy inaccurate
    * Also error propagation the farther you get from the force plate
  - Only an estimate of the joint forces
  - Only talks about net forces, not a specific muscle; at best qualitatively describe muscle
  - Need a lot of space
  - Expensive equipment
- Internal (from muscle forces) vs. external (from outside forces) torque (these are just equal and opposite)
- Best to record kinetics (force), kinematics (movement), EMG (muscle activity)
  - Still hard to model every muscle

2 Gait analysis

- A particular example of biomechanics
- **Gait**: a repetitious sequence of limb motions to move body forward
  - One limb is mobile source of support
  - Other limb advances to new support site
  - Limbs support roles
- **Limb cycle**: single sequence by one limb
  - Defined by initial contact with ground (i.e., **stride**)
- **Stance** phase when foot is on the ground, **swing** phase when foot in the air
  - Stance: 60%
  - Swing: 40%
  - Double support part (difference between running and walking)
- **Stride** from one contact to another contact on the *same* foot
- **Step** timing between *two limbs*

- Efficient gait will minimize COM motion
  - Walking speed and style
  - Knee flexion in stance, pelvic tilt, heel rise in terminal stance
- Use energy storage in tendons
- Use passive momentum of the body
  - Running is "controlled falling" (Marey)
- Measure efficiency using metabolic cart
- Measurements:
  - Joint angles: ankle, knee, hip
  - Joint forces/moments/power: inverse dynamics
  - Rates of change of everything
  - Muscle activation: timing, amount, frequency
- Measurement of ground reaction forces
  - Vertical ground reaction force
    - F1 (onset of mid-stance), F2 (mid-stance valley), F3 (second peak, starting to push off)
  - Only a small amount of lateral (side-to-side) force; some anterior-posterior movement
- The ankle/foot is more complex than a single joint; can treat it more accurately as three joints
- What's interesting is the muscle activity right before landing a jump/other impact; see what the body does to accept the impact
- Other measurements:
  - Stride/step length/time
  - Center of pressure progression (look at the bottom of your shoes)
  - Rearfoot angle
  - Foot switches (put a switch into your shoes)
  - Pressure-sensitive insoles (similar to the above)
  - Instrumented walkway