Application of Motion Analysis Technology to Olympic Sports

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US Olympic Training Center, Chula Vista CA
Chula Vista Training Center
Definitions
Motion Analysis

• The science of analyzing human movement using the principles of physics
  – Clinical Motion
  – Sports Motion

• Steps
  – Capture the motion with video or sensors
  – Compute physical parameters
  – Analyze using statistics
  – Compare the motion to the best in the world

• Principle tool used in Biomechanics
Biomechanics

• The study of human motion using the principles of physics, engineering, anatomy and physiology

• In sports we use biomechanics to provide rational to why we teach specific techniques

• Two goals of biomechanics
  – Rapidly Improve Performance
  – Reduce Injury Risk
Motion Analysis
Methods

A history of ways to capture and analyze human motion from my experience
• Electrical Engineering Degree, UNSW, Sydney, Australia

• Olympian in Gymnastics
  – 1976 Montreal
  – Came to Arizona State University to prepare for 1980 Olympics
• Master of Science Degree
• Physical Education, Biomechanics
• ASU, Tempe, Arizona
  – Developed 2D Film Analysis System for Thesis
  – Analysis of the Handspring Front Flip on Vault
Manual Digitizing from Film

- Locam 16mm Film Camera
- 16mm Projector
- Graphics Digitizing Tablet
- Digitize Joint Centers
  - Frame by Frame
  - Crosshair Cursor
  - Very Laborious
- Tektronics 4052 Computer
  - Wrote my own software
• Research Engineer, 
Sports Science Program 
Olympic Training Center, Colorado Springs 
  – Co-Developed 2D Optical Motion Analysis System 
• Started a Company called 
Peak Performance Technologies
3D Manual Digitizing from Video

• Peak Performance Technologies Inc.
• Multiple Camera Views
• Calibration Frame
• Digitize Body Points in Sequential Images
  – Crosshair Cursor on Joint Centers
• Advantages
  – No need to bother the athlete
  – Only way to get data in a competition
• Disadvantages
  – Tedious and time consuming
  – Impractical for immediate feedback
  – Digitizing Error
• Used this at Barcelona Olympics 1992
  – IOC Project
  – Gymnastics, Diving, Track and Field
• Still use this Method Today
  – High Jump, Discuss, Hammer
Optical

• Reflective Markers
• Video or Infrared Cameras
• Automatic Tracking
  – Markers automatically tracked
  – Lots of cameras (8 – 24 or more)

• Advantages
  – Markers are light
  – No Wires
  – High Sample Rates (500Hz)
  – Can now do real-time display

• Disadvantages
  – Can’t be used in Sunlight
  – Maybe time consuming
  – Expensive
  – Complex
Optical Systems

- Qualisys
- Motion Analysis Corp.
- STT
- Vicon
- Natural Point
- Motion Reality
Electromagnetic

• Transmitter and Sensors
  – 4 to 12 Sensor Typical

• Advantages
  – Small Sensors
  – Fast 240 Hz
  – Real-Time
  – 6 Degrees of Freedom
  – Accurate Anatomical Alignment
  – Full Body Capture

• Disadvantages
  – Wired
  – Metal Sensitive (but works on any club)
Anatomical Alignment

• Align Markers Directly to Body
  – Use Digitizing Pen on Body Points
    • Used by AMM 3D-Golf
  – Use Static Markers on Body Points
    • Typically for Optical Systems
• Get “True” Body Angles and Positions
• More accurate but more time consuming
Wireless Electromagnetic – G4

Self Contained and Battery Operated

Quick to Set Up and Teatherless
Inertial Systems – K-Vest

• **3DOF**
  – Bend
  – Side Bend
  – Turn

• Inertial Hardware
  – 3DOF
  – Portable
  – Each Sensor is Wireless

![Image of K-Vest in action](image-url)
Intertial Systems - Noitom
Inertial - Xsens
Many Inertial Companies

- Zepp
- Blast Motion
- YEI
- APDM
Markerless Tracking
Markerless Systems – Swing Guru
Markerless Systems - Organic Motion

Markerless System – No Markers Needed
Markerless Systems – Microsoft Kinect
Examples in Golf
AMM and TPI

AMM 3D Motion Measurement

• 12 Sensor, 6DOF, Full Body
• Upper Body
  – Head
  – Thorax (Ribcage)
  – Arms and Hands
    • Shoulders, Elbows, Wrists
  – Club
• Lower Body
  – Pelvis
  – Legs and Feet
    • Hips, Knees, Ankles
    • Feet - Stance

TPI Biomechanics and Database

• TPI 3D Advanced Layout
• Pro Databases
  – PGA
  – LPGA
  – Long Drive
  – Amateur
• Comparative Reports
  – Over 400 values
• Comparison Table
  – Nearly 200 Graphs
AMM3D Electromagnetic
View 3D Image from Any Direction
Multiple Mode for Club Plane View
Screen Layouts with Synchronized Graphs
### Comparison Table and Database

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Addr</th>
<th>HB</th>
<th>Top</th>
<th>HD</th>
<th>Imp</th>
<th>HF</th>
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<tbody>
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<td>Pelvis Rotation (Open-Closed)</td>
<td>deg</td>
<td>2.5</td>
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<td>18.5</td>
<td>37.2</td>
<td>20.0</td>
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</tbody>
</table>

Rng: PGA-Driven  Pj: Full Body 12R TPI 7.14-04
Comprehensive Biomechanics Report

**Downswing Sequence**

Angular Velocity: Pelvis Thorax Arm Club

<table>
<thead>
<tr>
<th>Sequence Parameters</th>
<th>Pelvis</th>
<th>Thorax</th>
<th>Arm</th>
<th>Club</th>
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<tbody>
<tr>
<td>Peak Order</td>
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<td>3</td>
<td>2</td>
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<td>Peak Timing Pre-Impact</td>
<td>ms</td>
<td>75</td>
<td>77 to 113</td>
<td>63</td>
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<tr>
<td>Peak Speed</td>
<td>d/s</td>
<td>357</td>
<td>415 to 522</td>
<td>570</td>
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<tr>
<td>% of Max</td>
<td>%</td>
<td>15</td>
<td>18 to 23</td>
<td>26</td>
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<tr>
<td>Acceleration</td>
<td>d/s</td>
<td>1405</td>
<td>1717 to 2585</td>
<td>2496</td>
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<tr>
<td>Deceleration</td>
<td>d/s</td>
<td>420</td>
<td>1223 to 2734</td>
<td>1279</td>
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</table>

**Segmental Interactions**

<table>
<thead>
<tr>
<th></th>
<th>Pelvis-Thorax</th>
<th>Thorax-Arm</th>
<th>Arm-Club</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Between Peaks</td>
<td>ms</td>
<td>13</td>
<td>5 to 43</td>
</tr>
<tr>
<td>Angular Speed Gain</td>
<td>d/s</td>
<td>203</td>
<td>164 to 272</td>
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<tr>
<td>Gain Factor</td>
<td>ratio</td>
<td>1.6</td>
<td>1.4 to 1.6</td>
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**Contribution by Joint**

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<tr>
<th></th>
<th>Legs</th>
<th>Core</th>
<th>Shoulder</th>
<th>Wrist</th>
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<tbody>
<tr>
<td>% Contribution</td>
<td>%</td>
<td>18 to 23</td>
<td>9 to 12</td>
<td>16</td>
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</tbody>
</table>
3D Motion Biofeedback

• Real-Time Audio Feedback of Position and Motion Accelerates Learning
• Student Learns to Recognize the Correct Posture and Motion
• Makes Feel Become Real
• Avoids Grooving Incorrect Repetitions
• Automatically Monitors Correctness of Drills, Exercises and Physical Screens
• Helps Implement Effective Block and Random Training where Appropriate
The Kinematic Sequence
Motion Analysis at the Olympic Training Center in Chula Vista
Wireless Inertial Sensors

- Practical and Easy
- Hips, Shoulders, Arm
- AMM Inc. AmmSensors
- Bluetooth Wireless
- Fast – 250 samples/sec
- Small, Light Weight
- Immediate Report
- Simultaneous Video

- Angles Only
Discus, Javelin, Shot, Hammer
Discus, Javelin, Shot, Hammer
Kinematic Sequence - Javelin

- Separation (X-Factor)
- X-Factor Stretch (Stretch Shorten Cycle)
- Finger Snap Demo
- Sequence and Timing

- Max Turning Speed
- Speed Gain
- Average Acceleration
- Average Deceleration
Javelin Workshop

- Three athletes used the sensor
- Enjoyed using it
- Were able to make changes
Example Athlete - Javelin

• Initially had minimal speed gain (red and green peaks almost the same in first graph)
• After working with Coach he was able to gain speed from Pelvis to Thorax (Red to Green)
• We did not measure the throw distance

Angular Velocities (deg/sec)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Peak Pelvis Angular Velocity</td>
<td>738</td>
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<tr>
<td>Peak Thorax Angular Velocity</td>
<td>741</td>
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<tr>
<td>Angular Speed Gain</td>
<td>4</td>
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Angular Velocities (deg/sec)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Peak Pelvis Angular Velocity</td>
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<td>Peak Thorax Angular Velocity</td>
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<td>Angular Speed Gain</td>
<td>171</td>
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Kinematic Sequence - Discus
Full Body Capture with Electromagnetic System

Field Hockey and Rugby
Drag-Flick
3D Motion – Scrum-Half Pass
Women’s Rugby 3D

• Scrum-Half Pass

• Interested variables include:
  – Foot placement
  – Body position before, during, and after pass
  – Rotation/rotational speeds
  – Resultant velocities of pelvis, thorax, and hands
  – Arm/wrist action
  – Timing
System of the Future

• Inside
  – Probably a combination of
    • Camera based, markerless tracker
    • Inertial Sensors

• Outside
  – Comfortable wearable suite with combination of sensors
    • Inertial, local GPS
End

Thank You