Sports Biomechanics for Cricket Coaches

Level 4: Sports Biomechanics
English & Wales Cricket Board
Dr Paul Hurrion

Context – Overall Aim
• The course structure and content will reflect the applied application of Sport Biomechanics, in a framework of high performance coaching.
• To develop awareness and understanding of technique and Sport Biomechanics in cricket, and the integration and application of this support into performance cricket programs.

AIMS / Learning Outcomes
• Explain the role of human movement in developing and delivering cricket skills.
• Describe the role and implications of sports biomechanics in cricket coaching.
• Apply the underpinning principles within their day to day coaching with nominated cricketers with whom they work.
• Reflect on the effectiveness of the interventions prompted by biomechanical analysis.

OVERVIEW
• Sports Science & Biomechanics?
• Sports Medicine & Biomechanics?
• Sports Technology & Biomechanics?
• Data Collection for Biomechanics?
  Video, High-Speed, 3D, Force, EMG...
• The FUTURE
• Timetable

Timetable - Day 1
Day 1 Subject area
9.00 - 11.00am Recap - ECS Level III Technology and pre course reading (basic principles)
  • The Role of Sports Biomechanics - High speed cameras
  • Define and describe the knowledge and skills base of a Biomechanist
  • Understand how they might evaluate the effectiveness of a Biomechanist
  • Review fitness for cricket material - Biomechanics covered at level 3
11.00 - 11.15am BREAK
11.15 - 1.30pm Biomechanics & Principles – Bowling – Force Alignment – Transfer of Momentum
  • Fit for purpose and fast bowling – Stability / Mobility
  • The physical, biomechanical & physiological demands of fast bowling
1.30 - 2.30pm LUNCH
2.30 - 4.15pm Force Reception - Practical (Classification of Bowling Action)
  • The effect of Footwear on Injury
  • Equipment Design - (Video at FFC / BFC)
  • The application to cricket to exemplify the science & mathematics
4.15 - 4.30pm BREAK
4.30 - 5.00pm Looking at the action differently, why do we get injured?
  • At what point in the chain, as a coach do we start to modify an action?

Timetable - Day 2
Day 2 Subject area
9.00 - 11.00am Batting Biomechanics Principles and Research
  • Practical – Force & Pressure Platform
  • The Role of Biomechanics in Batting
  • Point of Ball Release – Position of Readiness
  • Research and Future Direction
11.00 - 11.15am BREAK
11.15 - 1.30pm Debate – ‘If it ain’t broke I don’t fix it!’ Biomechanics vs. Match Effectiveness
2.45 - 4.15pm Force Reception
  • Inertia & Rotational Inertia
  • Momentum – Transfer of Momentum
  • Stability
  • Projectile Motion
  • Newton’s Law of Motion
  • Throwing (left vs right hand)
4.15 - 4.30pm BREAK
4.30 - 5.00pm Summary – final questions : Recap on any outstanding questions / clarification
  • Assessment Instructions
CAN TECHNOLOGY HELP? YES / NO
SUCCESS / FAILURE
SUPPORT SERVICES ARE ESSENTIAL TO HELP CRICKETERS (& COACHES) ACHIEVE THEIR POTENTIAL

Supplement not Substitute…

The Role of Biomechanics in Cricket? Can it help you become a better coach?

Example Videos - Biomechanics

BIOMECHANICS in Cricket
- TECHNIQUE ANALYSIS
- FORCE ANALYSIS
- MUSCLE ACTIVITY
- EQUIPMENT DESIGN

BIOMECHANICS IN CRICKET
- ASSESSMENT OF FAST BOWLING ACTIONS (SAFETY)
- ICC’S ASSESSMENT OF BOWLING ACTION (LEGALITY)
- ASSESSMENT OF MOVEMENT + BALANCE (EFFICIENCY)
SPORTS MEDICINE

- INJURY+ ILLNESS
  - PREVENTION
  - MANAGEMENT
  - REHABILITATION

MEDICINE IN CRICKET

- PRIMARY CARE (GP)
- HEALTH + INJURY SCREENING
- SCANNING
- SURGERY
- REHAB/PHYSIO

ALL ARE IMPROVING

TECHNOLOGY

- SCIENCE AND MEDICINE RELY ON TECHNOLOGY
- EQUIPMENT DESIGN ALSO DEPENDS ON TECHNOLOGY

TECHNOLOGY IN SPORTS

“NEXT TO THE MOTOR CAR THE RUNNING SHOE IS ONE OF THE MOST RESEARCHED PRODUCTS OF THE LAST 30 YEARS.”

Cricket Shoe Technology

1950’s 2010’s

“Have injury rates reduced ?!”

OTHER TECHNOLOGY

MATCH ANALYSIS
HIGH SPPEED VIDEO
VIRTUAL REALITY...
Biomechanics: Basic Principles

- **MOMENTUM**
- **TRANSFER OF MOMENTUM**
- **STABILITY**
- **ROTATIONAL RESISTANCE**
- **ACTION / REACTION**
- **FORCE ALIGNMENT**
- **FORCE RECEPTION**
- **ACCURACY**
- **PROJECTILE MOTION**
- **NEWTON’S LAWS OF MOTION**

### MOMENTUM

- Amount of momentum depends on 2 physical qualities: mass & velocity
  - $p = mv$
- where, $p =$ momentum, $m =$ mass & $v =$ velocity
- Velocity ($v$) is given by its speed and direction. Because momentum depends on velocity, it too has a MAGNITUDE and a direction and is a VECTOR quantity.
- For example, the momentum of a 1.5 kg ball, with a velocity of 7 m/s = 10.5 kg m/s of momentum.

### Therefore...

- To make the "same impact force the lighter cricket ball must travel faster":
- Lighter limbs must also travel faster to carry the same momentum as larger limbs. Compared to the trunk which is HEAVY and slow but first to move!

### Heavy vs. Light Body Parts

<table>
<thead>
<tr>
<th>BODY PART</th>
<th>BODY MASS</th>
<th>BODY PROPORTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Legs</td>
<td>50%</td>
<td>50 kg</td>
</tr>
<tr>
<td>Trunk</td>
<td>30%</td>
<td>30 kg</td>
</tr>
<tr>
<td>Arms</td>
<td>12%</td>
<td>12 kg</td>
</tr>
</tbody>
</table>

### Question 1: Cricket Ball 0.5kg  Shot Put 7.5kg

Both balls have a constant velocity = 2m/s: Calculate the momentum for both balls.

- Momentum is the product or combination of the speed and mass that the moving object or objects possess...

### Question 2: Describe how this would relate to throwing (long throw from the boundary)?

**STRIDE LENGTH**
X Factor - Power

- The downswing begins with the forward movement of the hips (what direction?)
- With good golfers, the hip move actually begins approx. 0.1 – 0.2 seconds before the completion of the backswing.
- This movement rotates the upper body.
- The muscles of the hips and legs generate the main power of the golf swing – however the left hip & lower legs must create resistance at the point of impact.
- Power comes from the bodies ability to decelerate... (Crack the whip)
- Physical Conditioning / Flexibility...

Transfer of Momentum (Batting)

1. Lower body pivot - allows acceleration and transfer of energy.
2. Every time a linear motion occurs, there is a transfer of momentum, which in turn helps to maintain the same momentum that is being generated.

BATTING Apply the "5"
- STANCE
- STABILITY
- START...LOCK THE BODY

THE "5" MUSCLE SEQUENCE
1. BODY SLANT: FACE THE TARGET
2. STANCE
3. HIPS: growing
4. Shoulders: pivot
5. HANG: right arm is in a "ýt" position

Transfer of Momentum (Bowling)

TRANSFER OF MOMENTUM
- LEGS/pro: internal
  - HIPS
  - SHOULDERS
  - ARMS
  - WRIST

Crease: FACE THE TARGET
1. Arm up
2. Shoulder up
3. Close the angle of the front knee
4. HANG: in a "ýt" position
5. HIPS: growing
6. SHOW: through the front leg

Golf swing: keep the hips on the ball, avoid turning to the body.

Ernie Els
Padraig Harrington
Jan Zelezny - Olympic Record: 92.46m
Transfer of Momentum (Bowling)

Question 3
Describe how TRANSFER OF MOMENTUM would relate to wicket keeping?

Velocity and Mass

**Velocity:**
- Velocity is speed that has a clearly stated direction. It is a vector quantity. Average velocity \( v \) of an object is displacement \( s \) divided by time \( t \).

\[ v = \frac{s}{t} \]

**Mass**
- The SI system of units, mass is measured in kilograms (kg).
- Inertial mass is the mass of an object measured by its resistance to acceleration.
- Gravitational mass is the mass of an object measured using the effect of a gravitational field on the object.

Inertia & Rotational Inertia

**Inertia**
- Every body perseveres in its state of being at rest or of moving uniformly straight ahead, except in so far as it is compelled to change its state by forces impressed.

**Rotational Inertia**
- Refers to the fact that a rotating rigid body maintains its state of uniform rotational. Its ANGULAR MOMENTUM is unchanged, unless an external TORSION is applied; this is also called conservation of angular momentum.

Balance and Stability cont…

- A state where things are of equal weight or force;
- A state of equilibrium or equipoise; equal distribution of weight.
- A stable base or a position of dynamic balance at Point of Release (POF) would ensure:
  - Increased resistance to work the body levers against other body parts – summation of force.
  - Heavy parts move first, transferring momentum to the lighter, faster moving body parts...
  - Body energy transferred efficiently to the bat
  - Full force generation.

Stability

- Body energy transferred efficiently to the bat

Transfer of Momentum (Bowling)

15/02/2013
Position of Readiness: Everybody can get this right!

Posture at address – COP what is optimum?

1) Where do you think the weight is distributed for each individual?  
2) Are they balanced at the point of release?  
3) Can they go forward or back, left and right with the same amount of effort, or do they favour one particular movement?  
4) Are they in a state of dynamic balance?

Point of Release – Spot the difference

Supposing the attached diagram is relatively accurate / true… would this change the bio-mechanical best fit position of readiness in terms of weight distribution across the feet with a batter?
Every batter needs to be able to get their weight going back towards the umpire to a straight delivery.

Their ability to execute a wider range of strokes is then dependent on how well they can get their weight moving towards other areas when the appropriate delivery comes along. The more effective they are at this, the more scoring areas they open up.

**Rotational Resistance**

Spinning coming or rotating speed

The resistance between the ball and the hand will occur when:

- The weight of the hands
- The movement of the body
- The angle of the bat

The bowler’s arm speed

**BOWLER’S ARM SPEED**

- Throwing arm to horizontal to release
- Front foot landing of the bowler.

**Question 4**

Describe how STABILITY & width of support relates to slip fielding / wicket keeping?

**Question 5**

Describe how ROTATIONAL RESISTANCE relates to the off-drive in batting?

Each of the six-image sequences is made up of the following events:

- Frame 1: The bowler is in the pre-delivery position. Note: All four of the players’ hands hang directly under their shoulders.
- Frame 2: Trigger Movement, un-weighting of the front foot - Back foot landing of the bowler.
- Frame 3: Bowler – Front Foot Contact
- Frame 4: Point of Release (POR)
- Frame 5: Ball – approximately half way down the wicket - Top of Backswing
- Frame 6: Ball Impact.
The position of the hands directly under their shoulders enables the wrists to remain close to their body. As a result the mass of the bat remains close to the base of support.

This will decrease the 'ROTATIONAL Inertia' of the system.

In addition, the toe of the bat remaining close to the body, allows the mass of the bat to remain close to the base of support and effectively makes the bat feel lighter.

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**Question 6**

Describe the action reaction effect during fielding and throwing on the run?

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**Question 7**

Describe the force alignment during Spin Bowling?
**Question 8**
Describe the force reception of bowling on hard or soft ground? What effect do bowling boots / trainers have on the TRAM effect?

**Question 9**
Describe the Accuracy of the bowling accuracy relating to the path of the bowling arm? What technical characteristics are important for accuracy?

**Newton’s Laws of Motion**

**Accuracy vs precision - the target analogy**
- Accuracy is the degree of veracity while precision is the degree of reproducibility.
- The analogy used here to explain the difference between accuracy and precision is the target comparison.

Question 10: Can the above analogy be related to any cricket specific tasks?
Newton's First Law: Law of Inertia

- A body at rest remains at rest unless acted upon by an external and unbalanced force.
- A body in motion continues to move in a straight line with a constant velocity unless and until an external unbalanced force acts upon it.
- That is, an object with no net force acting upon it has a constant velocity.
- Newton's first law says that if the vector sum is zero, the state of motion of the object does not change. Essentially, it makes the following two points:
  - An object that is not moving will not move until a net force acts upon it.
  - An object that is in motion will not change velocity (accelerate) until a net force acts upon it.

Examples of Newton's first law

- Sliding hockey puck along table example

- Question 11: Relate a cricket specific tasks to Newton's first law?

Newton's Second Law: Law of acceleration

- The rate of change of momentum of a body is directly proportional to the impressed force and takes place in the direction in which the force acts.

- Question 12: Relate a cricket specific tasks to Newton's second law?

Newton's third law: law of reciprocal actions

- Whenever A exerts a force on B, B is simultaneously exerting a force of the same magnitude on A, in the opposite direction

- Question 13: Relate a cricket specific tasks to Newton's third law?

Projectile Motion

- A projectile is a body in free fall that is subject only to the forces of gravity (9.81ms\(^{-2}\)) and air resistance.
- The path followed by a projectile is known as a trajectory. If gravity were not present, a projectile would travel in a constant straight line. However, the presence of gravity forces projectiles to travel in a parabolic trajectory, thus gravity accelerates objects downwards.

Factors that affect trajectory:
- a) Angle of projection
- b) Projection velocity
- c) Relative height of projection

Without the use of a camera!
Projectile Motion

Question 14: Calculate the distance travelled, initial velocity and angle of release of the cricket ball during a throw from the boundary?

<table>
<thead>
<tr>
<th>Initial Horizontal Velocity</th>
<th>Time to max height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vi (ms⁻¹)</td>
<td>Hvi = g</td>
</tr>
<tr>
<td>Where:</td>
<td>G = Gravity</td>
</tr>
<tr>
<td>Vi = initial velocity</td>
<td>Hvi = Initial Horizontal Velocity</td>
</tr>
<tr>
<td>θ = angle of release</td>
<td>TMH = Time to max height</td>
</tr>
</tbody>
</table>

Max Height:

\[
\frac{G}{2} \times (TMH)^2 + (Hvi \times TMH) + h
\]

Where:

- G = Gravity
- Hvi = Initial Horizontal Velocity
- h = Height of release

<table>
<thead>
<tr>
<th>Initial Velocity (ms⁻¹)</th>
<th>Angle of Release (deg)</th>
<th>Height of Release (m)</th>
<th>Initial Horizontal Velocity (ms⁻¹)</th>
<th>Time to Max Height (s)</th>
<th>Max Height (m)</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.48</td>
<td>45°</td>
<td>1.8</td>
<td>15.189</td>
<td>1.548</td>
<td>13.558</td>
<td>47.26</td>
</tr>
<tr>
<td>21.48</td>
<td>35°</td>
<td>1.8</td>
<td>12.320</td>
<td>1.256</td>
<td>9.537</td>
<td>45.50</td>
</tr>
<tr>
<td>21.48</td>
<td>20°</td>
<td>1.8</td>
<td>7.347</td>
<td>0.749</td>
<td>4.551</td>
<td>34.02</td>
</tr>
</tbody>
</table>

Initial Horizontal Velocity:

\[ Vi (\sin \theta) \]

Where:

- Vi = Initial velocity
- θ = Angle of release

Time to max height:

\[ \frac{Hvi}{G} \]

Where:

- G = Gravity
- Hvi = Initial Horizontal Velocity

Max Height:

\[ \frac{G}{2} \times (TMH)^2 + (Hvi \times TMH) + h \]

Where:

- G = Gravity
- Hvi = Initial Horizontal Velocity
- h = Height of release

Bowling Biomechanics

Pythagorean Theorem

- The sum of the areas of the two squares on the legs (a and b) equals the area of the square on the hypotenuse (c).

- In any right triangle, the area of the square whose side is the HYPOTENUSE (the side of a right triangle opposite the right angle) is equal to the sum of areas of the squares whose sides are the two legs (i.e. the two sides other than the hypotenuse).

- Question 15: How does Pythagorus theorem relate to fast bowling and injury? What is the angle of the front leg at FFC?

- Body Weight = 94Kg
- Body Weight = 94 x 9.81 = 922.14N
- Fz (Vertical) = 5689N = 6.17 BW
- Fy (Breaking) = 2345N = 2.54 BW
- Fx (Lateral) = 578N = 0.62 BW
- \( \sqrt{6.17^2 + 2.54^2} = 6.67 \) BW

Note: The sine of an angle is the ratio of the length of the opposite side to the length of the hypotenuse.

\[ \sin \theta = \frac{a}{\text{hypotenuse}} \]

\[ \sin \theta = \frac{6.17}{6.67} = 0.927 \]

Plant angle at FFC = 40 degrees
- The Red Angle = 67 degrees
- Why are they different?
- Loading Rate – When do these forces occur during FFC?
- Heel Contact, Mid Foot Strike, Toe off?

Question 15: How does Pythagorus theorem relate to fast bowling and injury? What is the angle of the front leg at FFC?
Loading Rates

- Body Weight = 82 Kg
- Body Weight = 82 x 9.81 = 804.42 N
- Peak Fz (Vertical) = 4074 N = 5.06 BW
- Time to Peak Force = 0.084s
- Loading Rate = 60.29 BWs⁻¹
- 0.020 = 1 frame at 50fps camera
- 0.080 = 4 frames at 50fps
- Where is the body / back at this position?

Loading Rates

- Body Weight = 82 Kg
- Body Weight = 82 x 9.81 = 804.42 N
- Peak Fz (Vertical) = 2912 N = 3.62 BW
- Time to Peak Force = 0.028s
- Loading Rate = 129.29 BWs⁻¹
- OVER DOUBLE THE LOADING RATE!
- 0.020 = 1 frame at 50fps camera
- Where is the body / back at this position?

Review: Biomechanics – Basic Principles

- MOMENTUM
- TRANSFER OF MOMENTUM
- STABILITY
- ROTATIONAL RESISTANCE
- ACTION / REACTION
- FORCE ALIGNMENT
- FORCE RECEPTION
- ACCURACY
- PROJECTILE MOTION
- NEWTON’S LAW OF MOTION

Level IV Sports Biomechanics Feb 2013 : Assessment Instructions

- Describe the technical & biomechanical aspects for both a batter and bowler. I would like you to use TWO of your OWN players for the assessment (Same players as Physiology Assessment. Please use three different batting shots:
  - Front Foot Drive, Back Foot Defensive Shot, Pull Shot, Cut shot for example… For the bowling assessment please use either a fast/medium OR Spin bowler for your subject. Using at least three different views on the video camera, in conjunction with any video analysis software you use. Describe your Key Observations.

Secondly, using biomechanical terminology and explanations to underpin your technical comments for both the batting & bowling. Please use any diagrams / stick figures / to aid your observations.

For the purposes of the assessment, divide the project into the 5 following sections:

1) Key Observations: Technical Comments – Two Sections Bowling & Batting
2) Bowling Analysis: Grip / Run Up (Momentum) / BFC (Stability) / FFC (Stability) / Release (Accuracy) / Follow Through (Forces Reception) / Approach speed / Pre-delivery Take Off / Mid Bound / Back Foot Contact / Front Foot Contact / Release / First Foot Follow Through… General Comments & Observations:
3) Batting Analysis: Grip / Stance / Back Lift (Action Reaction) / Trigger (Alignment of Forces) / Stability / Balance: General Comments & Observations:
4) Two Situations: (i) December 1st: Design a realistic twelve month technical, biomechanical & physical plan. (Batting or Bowling): This should include the following:
   - An outline of the phases of training and highlighting what you would do with a player in terms of monitoring their fitness developments (What assessments, why you are assessing them, when etc).
   - An appraisal of the training implications and potential impact for the player based upon the analysis of their fitness monitoring results for a 12 week period.
   - A rationale for your training plan (from your analysis) for this player. (ii) July 1st – Half way through the session. What do you do differently & why…

What technically change you hope to change?
- Cause & Effect? Which part of the chain do you need to address first & why?
- Was the work load manipulated to affect a physiological change? Work & rest ratios?
- Your role in the process? How you provided feedback to the player?
Biomechanical analysis is the ‘why’ something happens, it is down to the skill of the coach and relationship with the player to decipher correctly the ‘cause and effect’ of the any movement they observe...

Thank you...

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