

# SPORTS BIOMECHANICS FOR CRICKET COACHES



**Level 4: Sports Biomechanics**  
**English & Wales Cricket Board**  
**February 2013**



# **OVERVIEW**

- \* SPORTS SCIENCE**
- \* SPORTS MEDICINE**
- \* SPORTS TECHNOLOGY**
- \* EXAMPLE OF VIDEO ANALYSIS**
- \* THE FUTURE**
- \* SUMMARY**

**CAN TECHNOLOGY HELP? YES / NO**

**SUCCESS / FAILURE**

**SUPPORT SERVICES ARE ESSENTIAL TO  
HELP CRICKETERS (& *COACHES*)  
ACHIEVE THEIR POTENTIAL**

**Supplement not Substitute**

**What is Biomechanics?**

**The Role of Biomechanics in Cricket?**

# What is Biomechanics?

The word 'biomechanics' is derived from the Greek bios meaning life and mekhaniki meaning mechanics, so that biomechanics may be said to be the study of the mechanics of life forms. The extent of this subject area is evident in research of plants, insects, reptiles, dinosaurs, birds, fish, whales, elephants, kangaroos.....and humans. In the biomechanics of humans, topics range from the mechanics of bone, tooth, muscle, tendon, ligament, cartilage, skin, prostheses, blood flow, air flow, eye movement, joint movement to whole body movement. In human movement biomechanics, topics include injury, clinical assessment, rehabilitation, ergonomics and sport.

Sports biomechanics uses the scientific methods of mechanics to study the effects of various forces on the sports performer. It is concerned, in particular, with the forces that act on the human neuromusculoskeletal system, velocities, accelerations, torque, momentum, and inertia. It also considers aspects of the behavior of sports implements, footwear and surfaces where these affect athletic performance or injury prevention. Sports biomechanics can be divided up into two sections:

## Performance Improvement & Injury Prevention

With the help of Quintic, we aim to provide answers to performance related topics such as:

- What is the best run-up for a high jumper?
- How should the knee angle be modified for the delivery stride of a fast bowler in cricket?
- What is the velocity of the swimmer after the tumble turn?

These questions are of the form: What is done? How is it done? Why does it work?

The answers to What? How? and Why? are important to the athlete, coach and scientist...

*Biomechanics is the science concerned with the internal and external forces acting on a human body and the effects of these forces...*

# **BIOMECHANICS**

## ***BASIC PRINCIPLES***

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

# MOMENTUM

The momentum of an object can be conceptually thought of as the tendency of an object to continue to move in its direction of travel, unless acted on by a net external force. As such, it is a natural consequence of Newton's laws of motion.

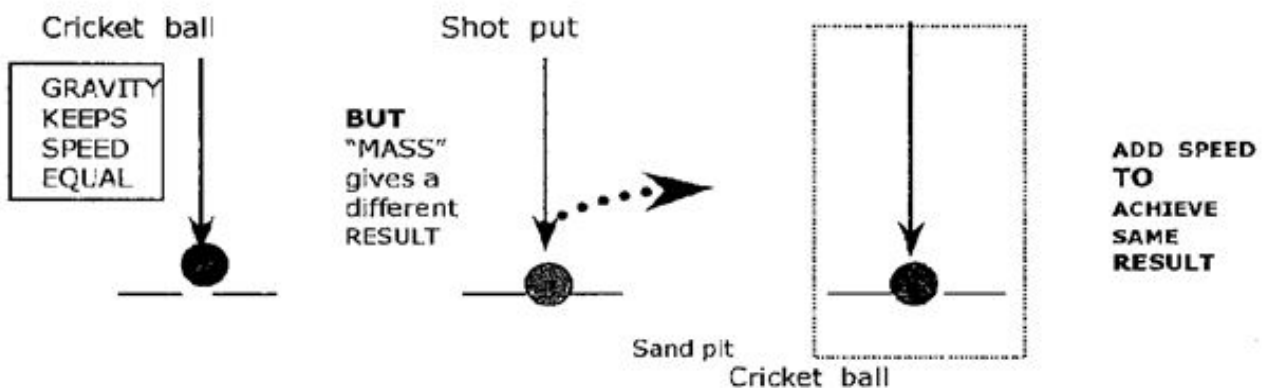
The amount of momentum that an object has depends on two physical quantities: the MASS and the VELOCITY of the moving object. The symbol for momentum is usually denoted by a small **p** (bolded because it is a VECTOR)

**$p = mv$**  Where **p** is the momentum, *m* is the mass, and *v* the velocity.

The velocity of an object is given by its speed and its 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.

**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 posses...**

*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, slow but first to move!*

BODY PART	BODY MASS	BODY PROPORTIONS
2 Legs	50%	50Kgs
Trunk	30%	30kgs
Arms	12%	12Kgs

## HEAVY BODY PARTS (SHOT PUTT)

- ARE COSTLY TO MOVE
- SLOW
- BUT DO PROVIDE A GOOD BASE TO INITIATE POWER

**THEREFORE THEY MUST MOVE FIRST**

## LIGHTER BODY PARTS (CRICKET BALL)

- ARE EASY TO MOVE
- FAST
- ADJUST FINAL POWER OUTPUT BY THE SPEED

**THEREFORE THEY MUST MOVE LAST!**

**e.g. In bowling / batting / throwing the wrist is light, fast & last to move...**

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

## Velocity

The velocity is a physical quantity of an object's motion. Velocity is speed that has a clearly stated direction; e.g., "5 miles per hour" is not a vector, whereas "north at 5 miles per hour" is a vector. If the motion is in a straight line in only one direction, it is the same as speed. The average velocity ( $v$ ) of an object moving a displacement ( $s$ ) in a straight line during a time interval ( $t$ ) is described by the formula

$$v = \frac{s}{t}$$

## 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

Everybody 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 rotation. Its ANGULAR MOMENTUM is unchanged, unless an external TORQUE is applied; this is also called conservation of angular momentum.

## TRANSFER OF MOMENTUM

**Larger** body parts slow, stabilise and transfers their speed to



**smaller** body parts

*Every time a large muscle group slows it supports the movements of the next smaller muscle group... which in turn seeks to maintain the same momentum value by increasing its speed.*

### **BATTING Apply the 5 "s"**

STEP  
STABILIZE  
SHOULDERS  
SWING  
STRAIGHT

### **THE "S"UMMMATION SEQUENCE**

SET THE BASE SO THAT THE PLAYER IS ABLE TO :

- STEP TO SET THE BODY POSITION
- STOP NO FURTHER MOVEMENT
- STABILIZE LOCK THE BODY

then

TO SUM ROTATIONAL MOMENTUM THE BODY

- SEGMENTS ARE PUT ON OPTIMUM
  - STRETCH AND MOVE IN A
  - SEQUENCE LARGE TO SMALL IN A
  - SMOOTH WELL TIMED ACTION TO
  - SUM MOMENTUM OVER THE GREATEST RANGE OF
- MOMENTUM TO GENERATE THE HIGHEST  
*SPEED possible*

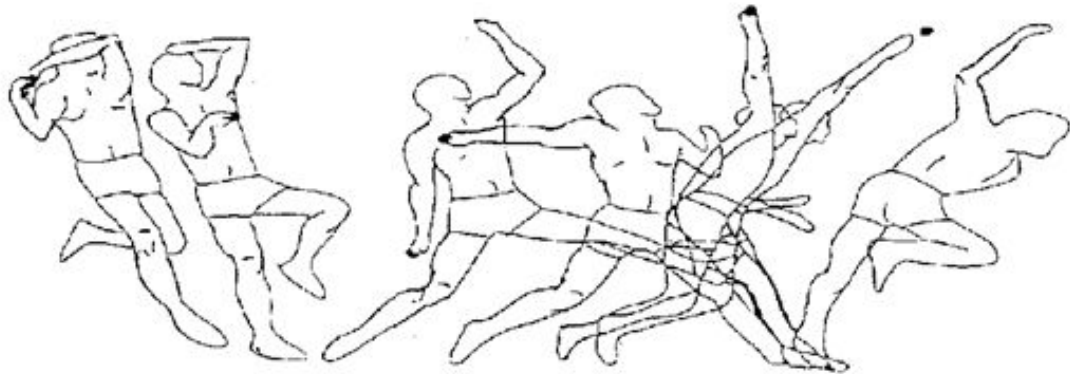


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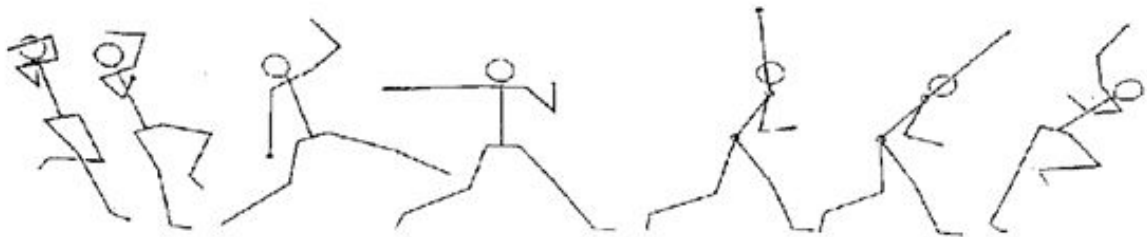


## TRANSFER of MOMENTUM

- BOWLING**    *Legs Brace : then*
- *Hips Rotate*
  - *Shoulders Rotate*
  - *Arms Rotate*
  - *Wrist Rotates*



**LARGE** muscles move **FIRST**, then **STABILIZE** so that the **NEXT SMALLER** muscle group is able to **ACCELERATE** therefore **ADDING SPEED** to the **BALL** as it gets closer to **RELEASE**



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



# STABILITY

**STABILITY** IS CONCERNED WITH THE CENTRE OF GRAVITY:

*which is the balance point within the body where all forces counteract each other to produce a zero force therefore balance is achieved.*



## DYNAMIC STABILITY

the balance of the body while in motion

## STATIC STABILITY

the balanced position of the body when it is still

BOTH SITUATIONS RELY ON THE  
POSITION OF THE **C of G**  
RELATIVE TO THE BASE OF SUPPORT

## STABLE

CENTRAL POSITION



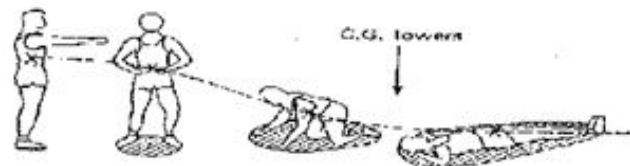
MASS CLOSE TO BASE

INCREASED FRICTION

FIXED VISION POINT

## UNSTABLE

OFF CENTERED POSITION



MASS HIGH OVER THE BASE

DECREASED FRICTION

MOVING VISION POINT



# STABILITY

WIDE BASE OF SUPPORT

NARROW BASE OF SUPPORT



ALIGNED FORCES TO BASE WIDTH

MISALIGNED FORCE TO BASE



Question 4: Describe how STABILITY & width of support relates to slip fielding?

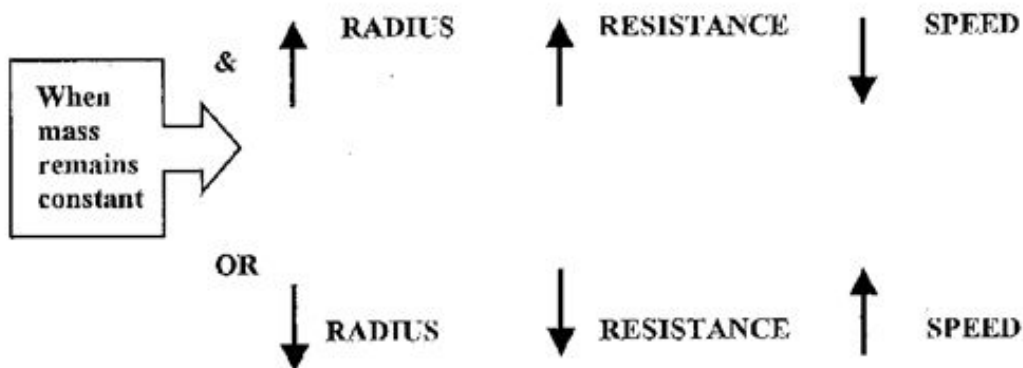
# ROTATIONAL RESISTANCE

## *Spinning, turning or rotating speed*

THE **EFFORT** NEEDED TO PRODUCE MOVEMENT INVOLVES AN INTERPLAY BETWEEN:

- the length of the limb & the compactness of the body
- the mass of the limb
- the joint around which the limb moves

IT IS FOUND BY MULTIPLYING THE MASS BY THE SQUARE OF THE RADIAL LENGTH.



## BOWLER'S ARM SPEED

"THOMMOS" ARM FROM VERTICAL TO RELEASE  $23 \times 1/50$  th sec  
 BUT  
 RODNEY HOGG'S ARM FROM CHIN TO RELEASE  $11 \times 1/50$  th sec



**Question 5: Describe how ROTATIONAL RESISTANCE relates to the off-drive in batting?**



## ACTION / REACTION

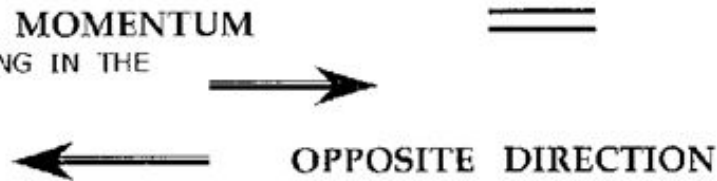
### BALANCING TECHNIQUE

*the body's method of equalizing momentum within the limbs to maintain a balanced movement pattern.*

*This is best seen when the body is airborne!!*

EVERY MOVEMENT THE BODY MAKES SOMEWHERE WITHIN THE BODY OR IN THE GROUND THERE IS AN RE-ACTIVE RESPONSE THAT HAS:

EQUAL MOMENTUM  
TRAVELLING IN THE



BATTING : FIRST STEP IN UNISON WITH THE BACKSWING  
BOWLING : OPPOSING ARM ROTATION IN THE DELIVERY STRIDE



No



Yes



No

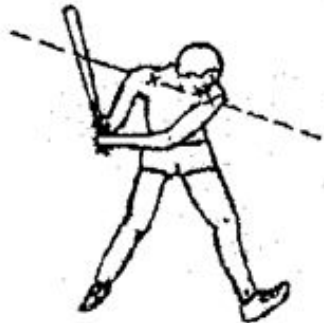
Question 6: Describe the action reaction effect during fielding and throwing on the run?

## FORCE ALIGNMENT

Keep ALL body levers moving along the target plane to maximise power & control

- Align the body levers with the oncoming force
- Align all body levers in the direction of the movement

### BATTING



Shoulders rotated slightly forwards by the top of the backswing



The width of the bat encompasses the arms and shoulders

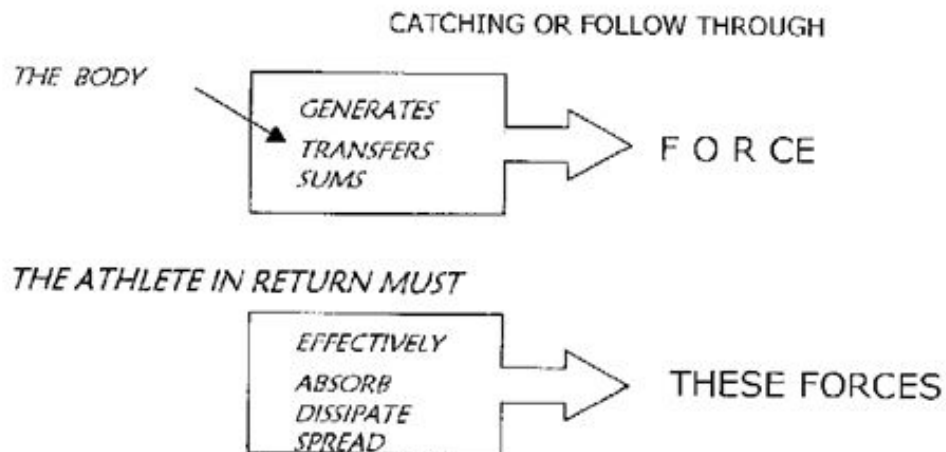
### BOWLING



Rotate the shoulders vertically towards the target during the delivery phase!

Question 7: Describe the force alignment during Spin Bowling?

# FORCE RECEPTION



## HOW? THE "TRAM" TECHNIQUE

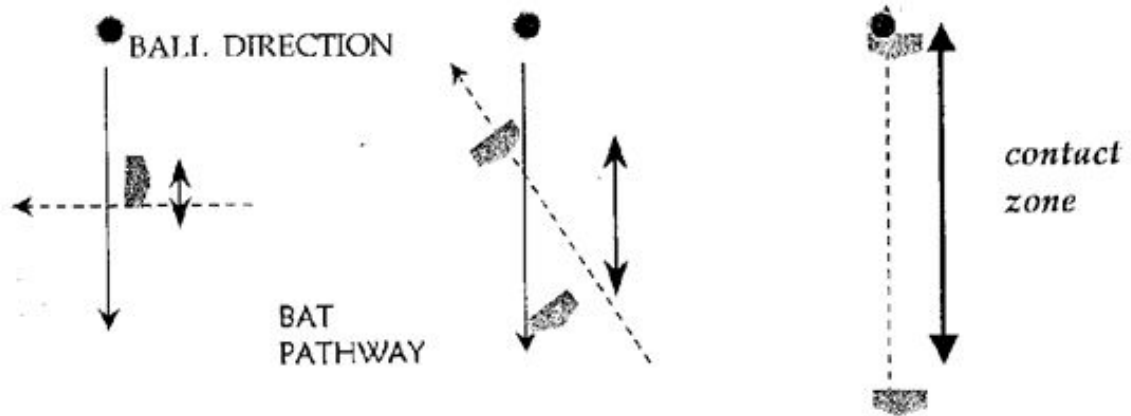
- T** → INCREASE THE TIME TO ABSORB THE FORCE
- R** → INCREASE THE RANGE OF MOVEMENT TO ABSORB THE FORCE
- A** → INCREASE THE AREA TO ABSORB THE FORCE
- M** → INCREASE THE MASS TO ABSORB THE FORCE



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

## ACCURACY

### A) ALIGNMENT OF BAT SWING & BALL'S FLIGHT PATH

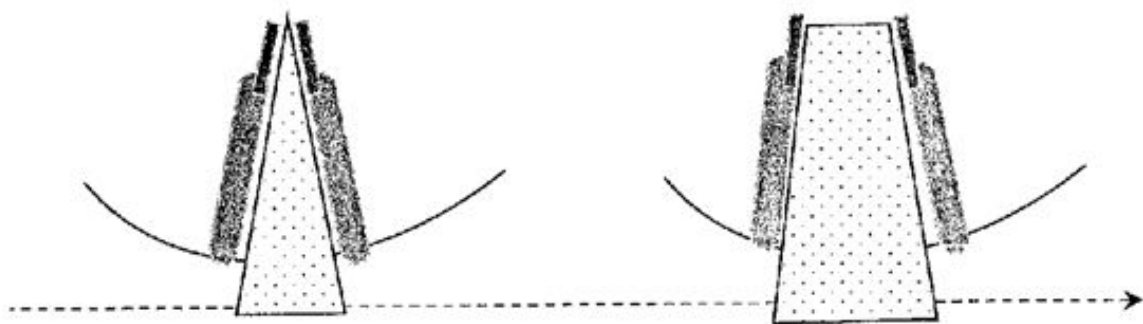


Principle applies to the cross bat strokes as well as the vertical strokes...

A flattened arc through impact or release is achieved through a delayed wrist action...

CLOSED BOTTOM HAND

OPEN BOTTOM HAND



CONTACT ZONES GIVING THE " **SAME** " IMPACT RESULT  
HOWEVER IT IS MADE WIDER BY DELAYING THE OPENING OF THE WRIST

THE SAME PRINCIPLE RELATES TO THROWING A BALL...

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



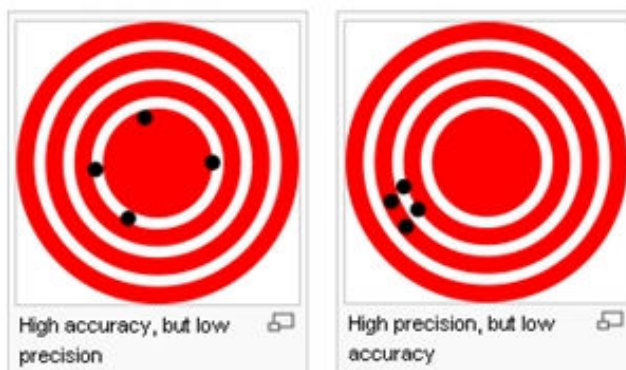
## Accuracy vs. precision - the target analogy

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.

In this analogy, repeated measurements are compared to arrows that are fired at a target. Accuracy describes the closeness of arrows to the bulls-eye at the target centre. Arrows that strike closer to the bull's-eye are considered more accurate. The closer a system's measurements to the accepted value, the more accurate the system is considered to be.

To continue the analogy, if a large number of arrows are fired, precision would be the size of the arrow cluster. (When only one arrow is fired, precision is the size of the cluster one *would* expect if this were repeated many times under the same conditions.) When all arrows are grouped tightly together, the cluster is considered precise since they all struck close to the same spot, if not necessarily near the bull's-eye. The measurements are precise, though not necessarily accurate.

However, it is *not* possible to reliably achieve accuracy in individual measurements without precision — if the arrows are not grouped close to one another, they cannot all be close to the bull's-eye. (Their *average* position may be an estimation of the bull's-eye, but the individual arrows are inaccurate...)



**Question 10: Can the above analogy be related to any cricket specific tasks?**

## NEWTON'S LAW OF MOTION

### 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 speed 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.

The net force on an object is the VECTOR SUM of all the forces acting on the object. Newton's first law says that if this 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.

If one slides a hockey puck along a table, it doesn't move forever, it slows and eventually comes to a stop. But according to Newton's laws, this is because a force is acting on the hockey puck and, sure enough, there is frictional force between the table and the puck, and that frictional force is in the direction opposite the movement. It is this force which causes the object to slow to a stop. In the absence of such a force, as approximated by an air hockey table or ice rink, the puck's motion would not slow.

### Question 11: Relate a cricket specific task 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.

LAW II: The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed. — If a force generates a motion, a double force will generate double the motion, a triple force triple the motion, whether that force be impressed altogether and at once, or gradually and successively. And this motion (being always directed the same way with the generating force), if the body moved before, is added to or subtracted from the former motion, according as they directly conspire with or are directly contrary to each other; or obliquely joined, when they are oblique, so as to produce a new motion compounded from the determination of both.

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

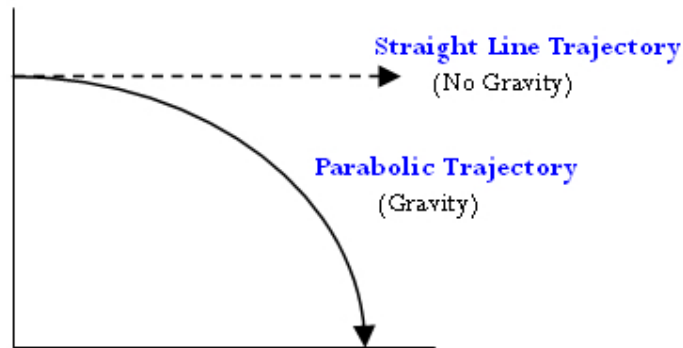
### Newton's third law: law of reciprocal actions

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 ( $9.81\text{ms}^{-2}$ ) and air resistance. An object must be dropped from a height, thrown vertically upwards or thrown at an angle to be considered a projectile. 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.



**The factors that affect the trajectory are:**

- Angle of projection
- Projection velocity
- Relative height of projection

In order to analyse projectile motion, it is divided into two components, horizontal motion and vertical motion. Perpendicular components of motion are independent of each other i.e. the horizontal and vertical motions of a projectile are independent. Horizontal motion of an object has no external forces acting upon it (with the exception of air resistance but this is generally not accounted for). Due to this absence of horizontal forces, a projectile remains in motion with a constant horizontal velocity, covering equal distances over equal periods in time. Thus no horizontal acceleration is occurring. The degree of vertical velocity however, is reduced by the effect of gravity. Force of gravity acts on the initial vertical velocity of the javelin, reducing the velocity until it equals zero. A vertical velocity of zero represents the apex of the trajectory, meaning that the projectile has reached its max height. During the downward flight of the projectile, vertical velocity increases due to the effect of gravity.

The laws of constant acceleration can be used to derive the horizontal and vertical components of a projectile. These equations can only be applied to the horizontal and vertical motions of the projectile – they cannot be used on the resultant motion. The three equations that are used are:

$$v = u + at \qquad v^2 = u^2 + 2as \qquad s = ut + \frac{1}{2}at^2$$

Where:

$u$  = initial velocity ( $\text{ms}^{-1}$ )

$v$  = final velocity ( $\text{ms}^{-1}$ )

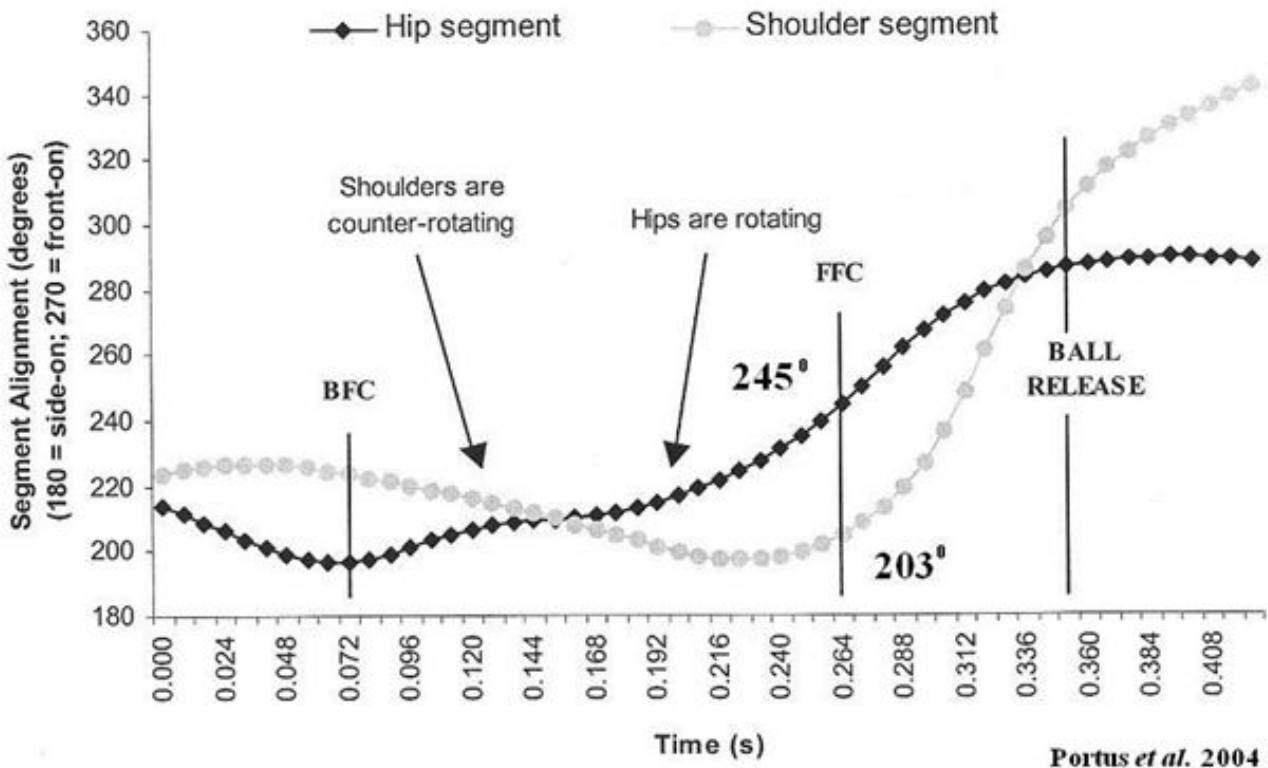
$a$  = acceleration ( $\text{ms}^{-2}$ )

$t$  = time (s)

$s$  = displacement (m)

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

## BOWLING BIOMECHANICS



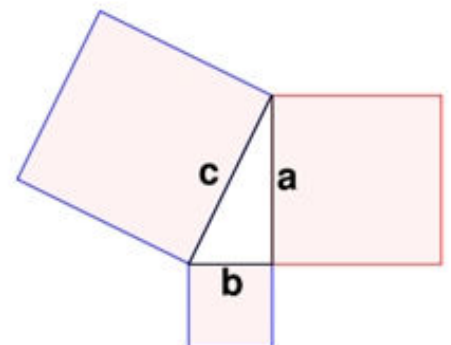
**Pythagorean Theorem:** The sum of the areas of the two squares on the legs ( $a$  and  $b$ ) equals the area of the square on the hypotenuse ( $c$ ).

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).

If  $c$  = the length of the hypotenuse and  $a$  and  $b$  be the lengths of the other two sides, the theorem can be expressed as the equation.

$$a^2 + b^2 = c^2.$$

This equation provides a simple relation among the three sides of a right triangle so that if the lengths of any two sides are known, the length of the third side can be found. A generalization of this theorem is the LAW of COSINES, which allows the computation of the length of the third side of any triangle, given the lengths of two sides and the size of the angle between them.



**Question 15:** How does Pythagoras theorem relate to fast bowling and injury?

# SAMPLE BIOMECHANICS IN BOWLING

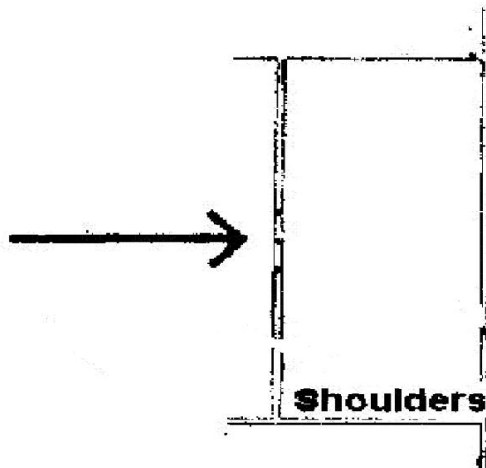
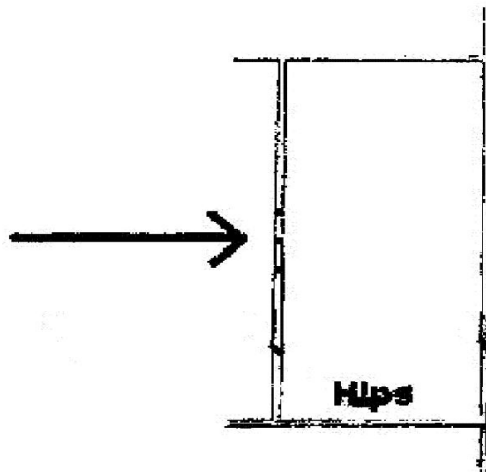
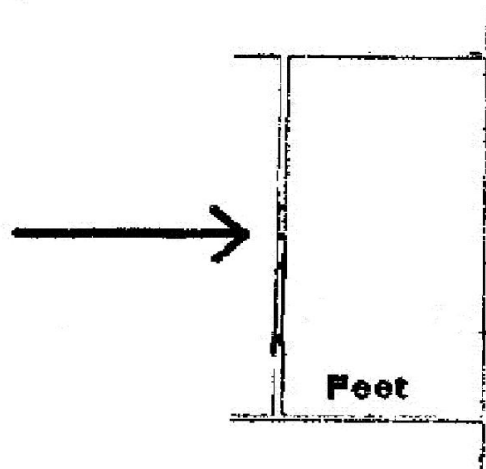
(Question 16: Please fill in the two empty columns)

Description	PRINCIPLE	BOWLING	Other Sporting Examples
	Momentum	Run-up	
	Stability	Delivery Stride at Back & Front Foot Landing	
	Momentum Transfer	Joint Stabilisation throughout bowling action. Increases body speed.	
	Rotational Inertia	Run-up, Arm rotations in delivery stride, compactness of style	
	Action / Reaction	Arm rotation, hip & Shoulder rotation. Front leg brace & depress front elbow	
	Force Alignment	Total Action directed towards the batter, vertical rotation of shoulders and arms.	
	Accuracy	Release Point & obliqueness of delivery arm's arc.	
	Force Reception	Follow Through Shoe Design Impact Loading	

## SAMPLE BIOMECHANICS IN BATTING

(Question 17: Please fill in the two empty columns)

Description	PRINCIPLE	BATTING	Other Sporting Examples
	Momentum	STEP & SHOULDER Rotation	
	Stability	Stance, Joint Stabilisation, base of support	
	Momentum Transfer	Joint Stabilisation throughout action. Increases body speeds.	
	Rotational Inertia	Top of backswing, follow through, downswing, compactness of technique.	
	Action / Reaction	Step & Backswing, leg brace whilst shoulders rotate, shoulder position relative to downswing & impact.	
	Force Alignment	Total Action directed towards the ball, shoulder position relative to downswing & impact.	
	Accuracy	Impact angles & control	
	Force Reception	Follow Through Shoe & Bat Design	

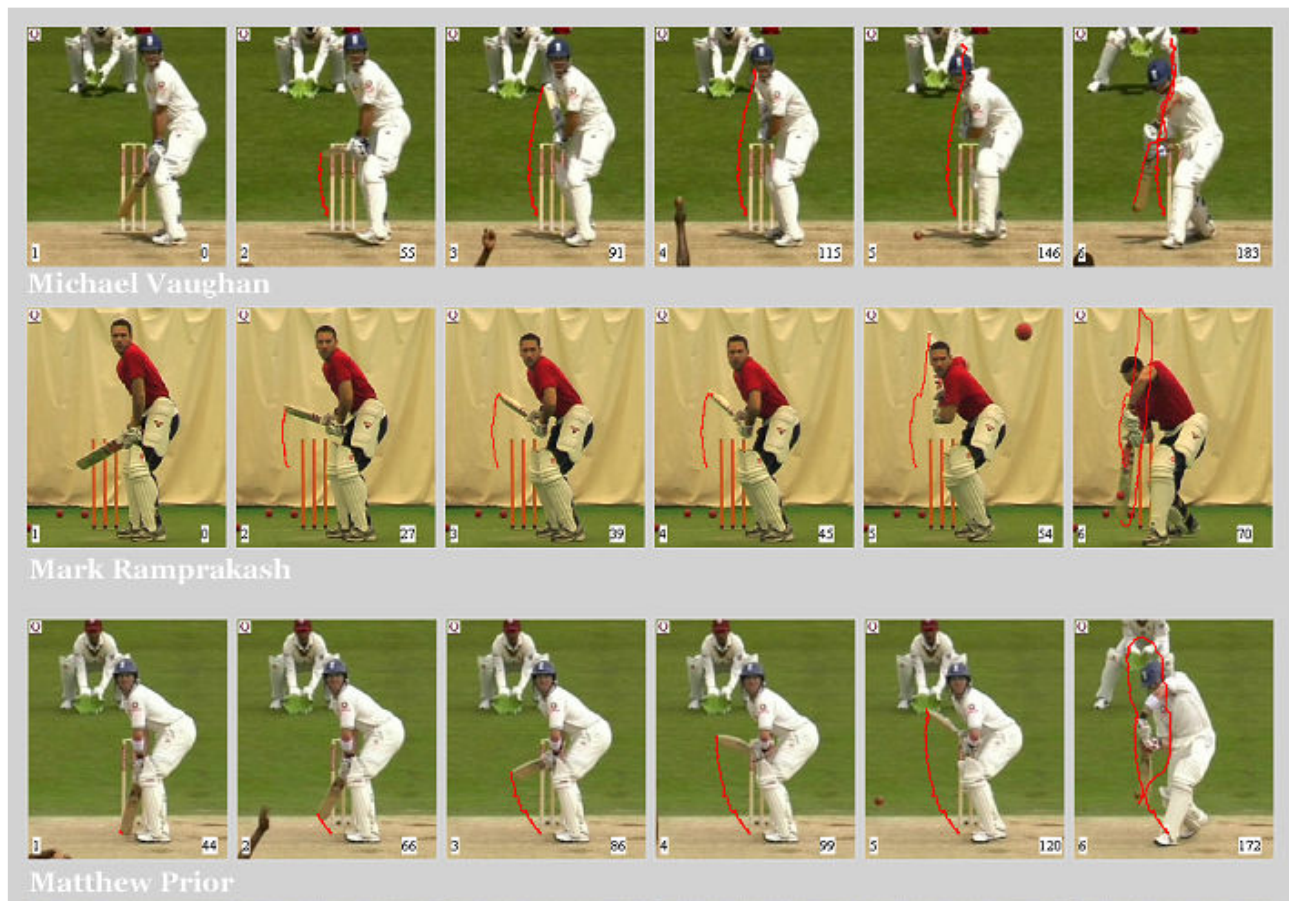


**Bowlers Name:** \_\_\_\_\_

**1: Pre Delivery Take Off / 2: BFC / 3: FFC / Follow Through**



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...



Q



**FRONT-ON**  
Front View



**MIXED**  
Front View



**SEMI-OPEN**  
Front View



**SV**  
Front View

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Q



**FRONT-ON**  
Side View



**MIXED**  
Side View



**SEMI-OPEN**  
Side View



**SV**  
Side View

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Stride length as a % of your total height  
Measured from Toe to Toe

## Cricketers

Name	Height (m)	Delivery Stride Length (m)	SL / H (%)
Ajhumal	1.65	1.34	81
Boyd Rankin	2.04	1.35	66
Stuart Meaker	1.85	1.14	62
Brett Lee	1.87	1.42	76
Freddie Flintoff	1.95	1.52	78
James Kirtley	1.83	1.28	70

Coaching Speak - Stuart Meaker has a long delivery stride?

## Javelin

Name	Height (m)	Delivery Stride Length (m)	SL / H (%)
Steve Backley	1.96	1.43	73
Goldie Sayers	1.71	1.48	87
Keshorn Walcott	1.83	1.68	92
Tero Pitkamati	1.95	1.80	92
Jess Ennis	1.65	1.40	85
Babara Spotakova	1.82	1.70	93

Menzel (1988) - Biomechanics Analysis of the Javelin Throw (WC 1987 Final)  
Range 1.42m - 1.67m Men    Range 1.33m - 1.62m Women

## Baseball

Name	Height (m)	Delivery Stride Length (m)	SL / H (%)
Roger Clemens	1.93	1.64	85
Tim Lincecum	1.80	1.68	93
Hishashi Iwakuma	1.90	1.50	79
Justin Verlander	2.25	1.85	82
Brian Matusz	1.93	1.38	72
Colby Lewis	1.93	1.45	75

James Hay - The Biomechanics of Sports Techniques p 204 - 4th Edition

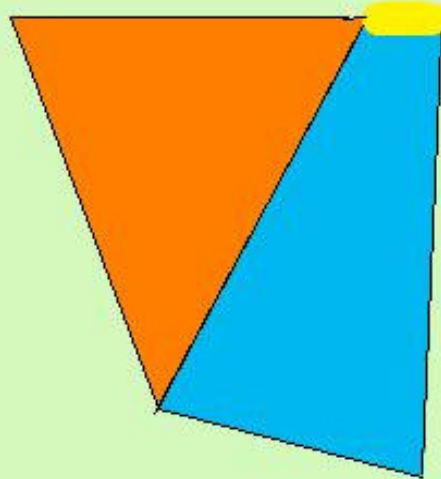
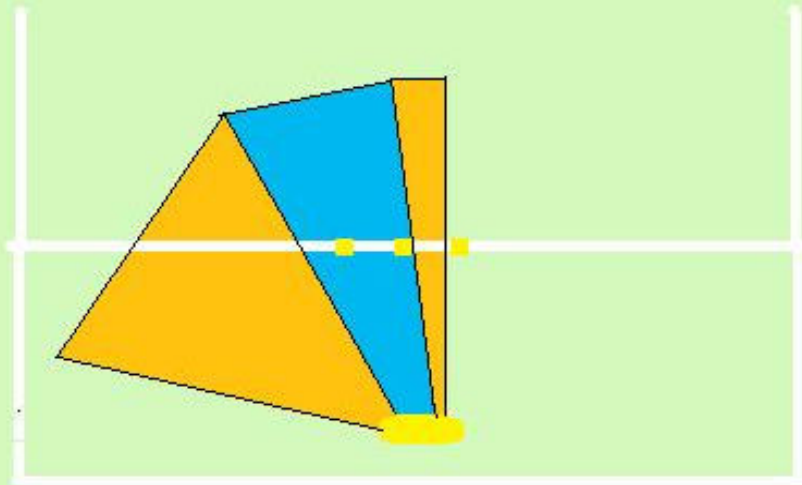
The average stride length of a baseball pitcher is 1.5m - 1.7m

Stride length 81 - 90% of height for maximum speed

Above 90% and you are overstriding

Note : Back foot can drag, but must remain in contact until after ball release.

## Foot movement patterns



## Biomechanics pre-course reading:

- 1) Introduction to Sports Biomechanics: Roger Bartlett ISBN: 0 419 20840
- 2) Bob Woolmer's Art and Science of Cricket
- 3) The Biomechanics of Sports Techniques: James Hay ISBN: 0 13 078494 x
- 4) [http://www.quintic.com/education/case\\_studies/Cricket%201.htm](http://www.quintic.com/education/case_studies/Cricket%201.htm)
- 5) [http://www.quintic.com/education/case\\_studies/Cricket%202.htm](http://www.quintic.com/education/case_studies/Cricket%202.htm)
- 6) [http://www.quintic.com/education/case\\_studies/Cricket%203.htm](http://www.quintic.com/education/case_studies/Cricket%203.htm)

