Basic Biomechanics for Horizontal Jumps

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An understanding of basic scientific principles, particularly biomechanics, should be a given for athletes and coaches. Knowing the science behind athletic skills will help you understand your event and what’s required to perform it, and by understanding the science you will be better able to carry out or teach the skill.

Isaac Newton (1642 – 1727) must be the greatest athletics coach of all time – he came up with the basis of every physical thing you do as an athlete – everything. Newton’s three laws of motion relate to everything about movement – and everything in athletics is about movement.

When you understand the basic physics of jumping it helps to make sense of what you do in training and how you jump in competition.

Long and triple jumps are very basic, so let’s start with the basic principles – and as it is all governed by laws of physics we’ll start with basic biomechanics.

- There are just three requirements:
  - Take off
  - Flight
  - Landing.

An understanding of basic biomechanical principles will help understand the requirements of each.

Principle 1. Parabola

- Body centre of mass (CoM) follows a parabolic curve that cannot be altered after take off. (See Principle 3, below)
- The parabolic curve is determined at take off. (curve A)
- Faster the take off the higher the parabolic curve, the further the distance. (curve B)
- And, the higher the start of the parabolic curve the further the distance (you can throw a stone further from up on a hill than from on the flat (curve C)

Implication: importance of speed and ensuring CoM is high as possible at take off – this means hips high and not sagging from your middle or running/taking off with backside tilted back (push backside out and you lower CoM – and you also tilt upper body forward which means trajectory (parabolic curve) will be lower

Principle 2: Rotations

Newton’s first law can be stated mathematically as
Put simply in plain English, something that is moving wants to stay moving and something that is stopped wants to stay stopped and will stay that way unless something else acts upon it. This is called inertia. When a jumper hits the board to take off the foot stops momentarily but inertia has the head keeping going. Hitting the board is acting on movement (stopping it) but there is no action to stop the head and upper body from keeping going. If this continues the jumper will at best have feet well behind the body at landing, reducing measurement, and at worst, face plant in the sand. This is why various techniques to prevent this rotation – hang, hitch kick and stride – are used.

- Inertia means resistance to change – with the deceleration of the feet at take off the upper body wants to keep going.
- As feet decelerate the momentum transfers to the head that now accelerates
- Push back with feet at take off and head pushes forward.
- Result of all the above is a rotation that has body tilting forward unless checked.
- A short lever rotates faster than a long lever.
- Every force has an equal and opposite force

Implication: **Rotations need to be minimised to avoid feet rotating back and reducing landing distance. A body position with a short lever speeds up rotation – and a body position with a long lever reduces rotation (stride and hang). And movements opposite to the rotation reduces rotation. (Hitch kick)**

**Principle 3: Centre of Mass (CoM)**

- It is the body’s CoM that follows the predetermined parabolic curve.
- Lower one part of the body and another will be raised.
- You cannot change the parabola but you can change your CoM by shifting parts of the body.

Implication: **lower the CoM and you raise the body in relation the parabolic curve, extending landing point by delaying moment of impact (A1 and B1) – move CoM back and you push body forward, gaining ground. (A2 and B2 below)**

$\sum F = 0 \Rightarrow \frac{dv}{dt} = 0.$
B: driving arms back takes COM back, pushing body forward.

Everything from here on relates to those principles:

- Speed
- Take off angle
- CoM at take off
- Flight
- Landing

Skills.

1. The Run Up.

- No part of long jumping is more important!
- Run up needs to be the shortest distance to achieve maximum speed
- Longer the run up the greater the chance of error – fewer stride the less opportunity for error
- Jump run up has max speed at t/o with acceleration is controlled and gradual as opposed to a sprint race where acceleration is rapid from the gun with acceleration – max speed – decline
- You need to be concentrating on speed, not on where the board is.
- Three phases – 1/3 acceleration (pushing – see pics below), 1/3 fast, tall,
- 1/3 preparation for takeoff. (sighting and making final adjustments to hit board - relaxing, lowering C of M penultimate step, preparing for correct T/O angle).

Run up drive phase – note athletes are “pushing” foot behind body
• You must relax over final 4 – 6 paces
• Acceleration must be constant and practised.
• Errors often in first or second step – too easy for these to vary. In training have a check mark at one and/or two paces.
• Adjustments are automatic, subconscious – do not look at the board but know where it is – peripheral vision only.
• Needs to be practised until it is automatic.
• Run up technique is similar to sprint technique and is closest to the middle section of a sprint race (back straight of a 200m, middle part of a 100m)

2. The Take Off

Of all the factors relating to take off, horizontal (forward) speed is the most important. Too much vertical (going up rather than forward) speed sacrifices horizontal velocity and thereby distance (Principle 1, Physics Lessons). In plain English, jump up and you lose forward speed. Most effective take off angle is between 20 and 24 degrees for long jump and 12-13 degrees for triple jump.

Forward momentum is more important in triple jump, so take off angle is flatter. Horizontal speed must be maintained. Whereas the long jumper aims for UP and FORWARD the triple jumper emphasises the FORWARD. Action is like the stone skipping across water – low and fast gets it further, but if the stone bounces high it stalls and sinks. The object in the triple jump is to keep your speed so it is important not have a high hop, which causes loss of momentum at landing for step phase. The hop should be long and low, the step a bit higher and the jump the highest phase of the three.

Long Jump Take off.

Head up
Lead arm block up

Body vertical

Hips high
Thigh of free leg parallel to ground
Shin vertical or beyond vertical (don’t “kick the football”)

Full extension of take off leg


Foot contact is “long as possible in the shortest possible time”
Last three strides are medium (normal) – long – short. Objective of the last three strides (transition from running to t/o) is to lower CoM as much as possible without losing speed. Last stride is active foot plant – have it flat on landing – no braking.

Arms provide 30% of force – drive down – drive up – block
3. Flight

As described, once you take off flight is pre-determined by speed, take off angle and forces applied – there is nothing you can do to change your flight. Flight action is purely to maximise landing position and therefore jump distance. Refer to Principle 2: Rotations.

This leads to the types of jumps or flight styles to avoid rotations –

a. **Float**

This is what children do naturally – take off, bunch legs up with knees tucked then drop legs for landing. It is not efficient and should not be taught. Legs tucked mean a short level and fast rotation. Kids invariably drop legs to sand rather than raising feet.

b. **Stride**

Simple, and while not the most efficient is relatively easy to learn and progresses into hang and hitchkick styles. Advantage is the simplicity, disadvantage is with CoM in front of jumper (because of extended free leg) it exaggerates rotation although wide split does slow rotation down. On way down rear (take off leg) is brought forward to free leg for landing. Free leg stays extended ahead while t/o leg trails then is brought forward for landing.

c. **Hang.**

Effective and efficient and has come back into favour in recent years by top jumpers. From stride (above) the free leg is dropped with both legs having thighs pointing to ground and feet raised while arms are drive backwards and locked behind head. From here the body is in a long lever position that will slow rotations. Legs drawn up, arms driven forward and down then behind for landing.

d. **Hitch Kick**

Running in the air – counter rotations of arms and legs (circling back) reduces forward body rotation. A hitch kick is only effective for jumpers covering 7m or so, otherwise there is not enough time to execute.
Clockwise arm and leg rotation = opposite (counterclockwise) upper body rotation

4 Landing

Leg lifted as high as possible in relation to buttocks – every cm the heels are held up above the sand gains 2 cm in jump distance – arms driven down and back, hips pushed forward and arms then driven forward on contact with sand. As heels contact sand knees are bent and arms brought forward to avoid falling back. All problems at landing stem from take off – if landing inefficient think about and talk to the coach on what you did in the run up and take off.

\[ = \text{C of M} \]

Diag 1 – good landing position (head down, low C of G, max good distance between C of m and impact point (a))

Diag 2 – poor landing (head up, C of M high, reduced distance between C of M and impact point (a))

See how lowering C o M (by dropping arms, dropping head etc) raises the body on the straight line – and if straight line was a parabola the feet would reach the ground a fraction later, i.e. you delay landing, improving jump measurement. Photos below show this in action.

Arms coming down, lowering C o M .... arms and head down lowering CoM further
The jumper is using arms to lower CoM and raise body in relation to parabola thereby extending landing point by delaying moment of impact and moving C of M back to push body forward on parabola, thereby gaining ground. He hasn’t changed his flight path by moving arms, legs and head, just the position of his body on the path to gain the best position for landing.

For a jumper that is the be all and end all of a jump flight - getting into the best position to land.

Equal and opposite reactions – Greer Alsop with arms and torso coming forward and down bringing legs up for maximum jump measurement. Implication here is, every cm your feet are up from the sand becomes 2cm extra in distance. So what you do with your head, arms and torso is critical. Newton worked that out over 300 years ago.

..... have sand come to heels, not feet to sand
But when all is said and done it is the hard work that gets you there ...