Morphology of the hoof
“The influence of force & time”
Mark N Caldwell MPhil; F.W.C.F.
Black Holes
& Fundamental laws of physics that govern the Universe & Shoeing.

Newton
Pythagoras
Galileo
Cartesian
Einstein
Hawkins
The science that deals with force's acting upon & within a biological structure
• **Kinematics the study of movement** –

• **Kinetics the study of energy or force causing a movement**

• *Farriery intervention affects not only movement (gait) but also the levels of energy necessitated to effect that movement (kinetics).*

• *The skeletal structure imposed over the skin reminds us of the links between foot and skeletal structure.*
• Kinematics the study of movement –
• Kinetics the study of energy or force causing a movement

The interaction of anatomical components throughout the range of movement
Definition of terms.

- Newton’s 3rd Law
- Spatial dimension
- Gravity
- Force vectors
- Centre of mass
- Centre of pressure
- Remote forces
- Breakover
Definition of terms.

**Spatial dimension**

- **Geometry describes every point in three-dimensional space with three axis & six coordinates.**
- **Each axis is perpendicular to the other two**
- **They are usually labelled x, y, and z**
- **Newton's law of motion**
  - Force is subject to a reaction equal in magnitude and direction
Definition of terms.

- **Gravity** – physical bodies attract each other with a force proportional to their mass.

- **Action force** - displacement of body mass via bone to bone contact
  - the suspensory apparatus complies, resulting in a redistribution of the total load between the individual feet.

- **Remote Action Force** - Weight transfer occurs as the body CoM shifts during manoeuvres.
Force = Mass × Acceleration (9.8 metres per second)

Action force through bone to bone contact
Remote action force (gravitational pull at CoM)
Torque, (rotational forces), also called moment or moment of force is the tendency of a force to rotate an object.
Definition of terms.

- **GRF**, - the force exerted by the ground on a body

- **GRFv** - a "reflection and passes upward from the foot and produces movement"

- **CoM** – the relative position of the distributed body mass sums to zero.

- **CoP** - the integrated pressure exerted on a supporting surface,
  
  - Note: CoP commonly changes as different parts of the foot are loaded to different degrees.
Forces & force vectors

A Force has magnitude, direction and duration
A Force has magnitude, direction and duration

**Force**
- **Magnitude** = hammer weight \( \times \) speed
- **Direction** = trajectory of hammer / resistance (GRFv)
- **Duration** = force / time curve

**Compression**

**Pressure**

**Reaction Force**

**Tension**

**Reaction Force vector**
Balance

• maintaining the centre of gravity within the envelope of the base of support with minimal postural sway

• Part of this complex system are the legs and feet

• Maintaining balance requires coordination of input from multiple sensory system

Balance is the Key to Life
Balance

- The senses detect changes of body position with respect to the base of support, regardless of whether the body moves or the base moves or changes size.

- CoP and CoM are related to balance and are dependent on the position of the body with respect to the supporting surface.
  - Centre of mass is subject to change based on posture.
Balance

• Centre of pressure is the location on the supporting surface if a vertical line could be projected from the digits point of force to the ground.

• A shift of CoP is an indirect measure of postural sway and a measure of an object's ability to maintain balance.
Even with no perceptible movements of the body, tension in the muscles is constantly changing. This causes very slight adjustments in the weight distribution and in location of the centre of pressure.

This is called postural sway.
Equilibrium

- Equilibrium is a state where all action forces are cancelled out by reaction forces

SCHWARZKOPF 1991
Equilibrium

Mechanical equilibrium for a biomechanical system such as the foot are:

(i) The vector sum of all external forces is zero;

\[
\text{Force} = \text{GRF}
\]
\[
\text{Acceleration} = \text{Deceleration}
\]
\[
\text{Extensor} = \text{Flexor}
\]

(ii) The sum of the moments of all external forces about any line is zero.
Breakover

- **Breakover** - the portion of the stance phase measured from when the heels begin to leave the ground until the toe leaves the ground.

- **Point of breakover** - the pivot point of breakover. The point of force of the DDFT

- **Mediolateral breakover** - the portion of the stance phase (turning) measured from the time the medial wall begins to leave the ground until the lateral wall leaves the ground (or vise versa).
Propulsion

- Chemical conversion of energy to kinetic force combined with the release of potential energy

Newton’s third law of motion

if at rest, to move forwards an animal must push something backwards. Terrestrial animals must push the solid ground
Stability & Movement
(anatomical considerations)
The Equine Stance Phase
Computed Muscle And Tendon Strain

Semispinalis capitis
What's all this got to with Farriery then?
1. **Orbits are always ellipses from a single focus**

2. **Although different areas are swept out in equal times.**

3. **The period of orbit is related to average separation.**
- The foot segment centre of mass is located at the point where the DDFT inserts into P3.

- The hoof rotates in an elliptical orbital arc in relation to the focal point CoR DiPJ.

[Graph showing the elliptical trajectory of CoM with force curves indicating deceleration and acceleration phases, with horizontal and vertical components labeled.]
Feet are Subjected to Variations in Force over time

“deceleration”  “stability”  “propulsion”

1° impact  2° impact  Support (mid stance)  Rollover
Variation in Magnitude, Direction and Duration of Force

Changes in magnitude and direction of FORCE & G.R.F.
Point of force trajectory
Point of force magnitude and trajectory influenced by gait, velocity and footing
Overall stance time is constant. Magnitude, direction and duration of force changes.

“deceleration”

“stability”

“propulsion”

Vertical ground reaction forces of the forelimb of a sound horse, and the lame and compensating forelimbs of a horse (Clayton 2012)
Magnitude, Direction and Duration of Force

“deceleration” “stability” “propulsion”

Moleman & Van Heel 2006

COP Velocity from mid stance (Van Heel 2005)

FLAT SHOE
ROLLED TOE SHOE
0 = COP mid stance
200 = toe leaving ground
Shock attenuation

Thomason 2009
Heel Movement - Which causes more heel movement?

1. Heel expansion on impact.
2. Heel contraction during breakover.
Hoof strain / stress
**Hoof strain / stress**

Unloaded

Loaded

*Toe down + back ➔ Quarters out ➔ Sole flattens*
Influence of conformation on hoof form

There was a strong inverse relationship $p>0.62$ between a reduction in heel width and an increase in the COP - COR distance.
Influence Of Conformation On Foot Shape

*N = 50*

C. D’Arcy BSc (Hons) AWCF, P. Brennan FDSc AWCF
Biomechanical feedback loop

Loading - Impact Force

Mechanical Behavior

Strain

Responses

Over days or weeks

Altered by: gait, ground speed, direction, rider weight, trim, shoe, etc.

Altered by: biomechanical and environmental variations hoof shape, material properties, etc.

Passive: wear
Active: growth, morphology
Equilibrium

Hoof morphology A result of changes in the magnitude and direction of force, environmental management & biological variation.
Warning

Smoking Damages Your Health
Responding to Mechanical Behavior

Hoof deformation follows the orientation of stress

\[ R^2 = 0.9573 \]

\[ R^2 = 0.9563 \]
Responding to Mechanical Behavior

Moleman & Van Heel 2006
Responding to Mechanical Behavior

Reducing Moment Arms

- Deceleration
- Acceleration

Ground Reaction Force

Force

Vertical

Horizontal

20% 60% 20%
Responding to Mechanical Behavior
Responding to Mechanical Behavior

“deceleration”  “stability”  “propulsion”
Responding to Mechanical Behavior
QUESTIONS?