Skeletal Adaptation to Training Responses to Injury

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Musculoskeletal System
Skeletal Organization

System

Organ

Tissue
Bone Architecture

- Related to mechanical function
  - Supports the weight of animal
  - Energetically expensive because mineral is heavy
## Effect of Architecture on Strength

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>100%</td>
</tr>
<tr>
<td>I</td>
<td>350%</td>
</tr>
<tr>
<td>II</td>
<td>588%</td>
</tr>
<tr>
<td>III</td>
<td>533%</td>
</tr>
</tbody>
</table>
Bone structures adapt to …

minimize mass (weight)

while …

maximizing stiffness and strength

for common loading conditions
Exercise
Three different 2-yr-old Thoroughbred Horses

Untrained    Training, unraced    Raced
Exercise

- Needed to *maintain* bone mass

- However...
  - Less exercise is needed to maintain mass than is needed to gain mass
  - Fewer load cycles on a regular basis
Inactivity

- If you don’t use it – you lose it
STRENGTH is exponentially related to skeletal MASS.
Maintaining Fitness

- Relatively little exercise is required to maintain bone mass

- The work must be relevant to the work the horse is expected to do
Bone Fatigue

- Degradation in stiffness
- Degradation in residual strength
- Failure with cyclic loading
Repetitive Loading

- ↓ stiffness
- ↓ strength
- ultimately failure
Musculoskeletal System

Courtesy of Mitch Taylor
Injury

- Stimulates adaptation or repair depending on the severity of injury and opportunity for repair
Adaptation
Increase the Daily Burden of Injury

- More severe damage
- Necessitates the removal of devitalized tissue
Bone Physiology

- Bone is actively being repaired throughout life

*However, the time for repair is rate-limited*
osteoclasts

microcracks

osteoblasts

Bone Remodeling Unit (BMU)
1-2 weeks

3 months
Injury stimulates repair & induces transient bone loss.

2-3 wks
Repair takes TIME

2-3 wks

3 mos
Bone Physiology

- Bone is actively being repaired throughout life

A transient period of enhanced weakness follows injury during repair
Humeral Stress Fracture
Training Intensity

Given TIME - damaged bone can heal

Early clinical signs  1 month later  3 months later

Courtesy of Dr. Rick Arthur
Damage exceeds Repair

Continued loading of damaged, WEAKENED bone
Catastrophic Injury
Repetitive Loading

- ↓ stiffness
- ↓ strength
- then failure
Damage accumulation affects risk of failure

- Number of load cycles
- horse strides (distance)
- over time (rate of distance accumulation)
- Magnitude of load per cycle
- horse speed
- hoof conformation
- horseshoes
- race surface
Training Intensity

Graph showing the relationship between distance trained (furlongs) and racing career (days) for FMI and Normal conditions. The graph highlights Layups and Breakdown points.
Fetlock Injuries

Risk Factors
Load Magnitude

Risk Factors

Courtesy of Mitch Taylor
Long toe / underrun heel

- Increases risk for fetlock injuries

Kane, et al. AJVR 1996;57:1147-1152
Balch, et al. AAEP 2002;47:334-338
### Traction Devices and Risk for Fetlock Breakdown

<table>
<thead>
<tr>
<th></th>
<th>OR*</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>low toe grab&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.5</td>
<td>1.2-34.1</td>
</tr>
<tr>
<td>regular toe grab&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.6</td>
<td>2.8-87.1</td>
</tr>
<tr>
<td>rim&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.3</td>
<td>0.1-0.9</td>
</tr>
</tbody>
</table>

<sup>a</sup> compared to no toe grab  
<sup>b</sup> compared to no rim

*Kane, et al. AJVR 1996;57:1147-1152*
Load Magnitude

Hoof-Ground Reaction Force

Race Surface

Courtesy of Mitch Taylor
Limb loading
Load transferred to hoof varies with surface
Fatality Rates at California Racetracks

Rick M. Arthur, DVM  AAEP PROCEEDINGS / Vol. 56 / 2010

Race Surface

2004-2009: HP, DM, GGF, SA converted from dirt to synthetic surfaces
Synthetic Surface

Heel

Toe

-0.250 -0.240 -0.230 -0.210 -0.190 -0.170 -0.150 -0.130 -0.110 -0.090 -0.070 -0.050 -0.030 -0.010

meters

-0.500 -0.480 -0.460 -0.440 -0.420 -0.400 -0.380 -0.360 -0.340 -0.320 -0.300 -0.280 -0.260 -0.240

meters

Hind Heel Y, Heel Toe vs Hind Heel X, Heel Toe
Hind Toe Y, Heel Toe vs Hind Toe X, Heel Toe
- Bone alters its size and shape in very specific ways to training and to inactivity
- Bone adapts specifically to the job it performs
- Bone is actively being repaired throughout life
- A transient period of enhanced weakness may follow injury during repair
Race between 2 rates:

- Rate of damage accumulation
- Rate of damage repair

- Exercise intensity and schedule
- Hoof conformation and shoeing
- Surface materials and management
Many OPPORTUNITIES for injury prevention

Injuries are multifactorial

- Hoof conformation
- Race surfaces
- Training intensity
- Horseshoe appliances

...
Thank-you for your attention

CHRB RACING SAFETY PROGRAM

Horses, Horsemen and Horsewomen