Terrestrial locomotion

Walking is a transfer of kinetic and potential energy. With each step we fall forward and then catch ourselves.

\[ E_{kf} = \frac{1}{2}mV^2 \]

\[ Ep = mgh \]
Running is a bounce, a mass and a spring.

\[ E_{es} = \text{elastic strain energy} \]

We all walk and run the same way.
Two types of work in locomotion: “external” and “internal”.

In humans, $W_{\text{int}}$ increases as the square of locomotor speed.
In cursorial birds and mammals, $W_{\text{int}}$ increases as the 1.5 power of locomotor speed.

These data are from humans
Tyrannosaurian
Oviraptor

Cursorial Archosaurs

Crocodilomorph
Ornithomimid

Bird

Selection on locomotor performance of young
Selection on locomotor performance of young

Cougar attacks 1890-2000

http://cougarinfo.com/

<table>
<thead>
<tr>
<th>Age</th>
<th>Serious injury</th>
<th>Fatal</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>1 - 5</td>
<td>4 girls, 3 boys</td>
<td>2 boys</td>
<td>4 girls, 5 boys</td>
</tr>
<tr>
<td>6 - 10</td>
<td>4 girls, 10 boys</td>
<td>6 boys</td>
<td>4 girls, 16 boys</td>
</tr>
<tr>
<td>11 - 15</td>
<td>2 girls, 4 boys</td>
<td>1 boy</td>
<td>2 girls, 5 boys</td>
</tr>
<tr>
<td>16 - 20</td>
<td>0</td>
<td>1 boy</td>
<td>1 boy</td>
</tr>
<tr>
<td>21 - 25</td>
<td>1 woman</td>
<td>0</td>
<td>1 woman</td>
</tr>
<tr>
<td>&gt; 25</td>
<td>4 women, 4 men</td>
<td>3 women, 1 man</td>
<td>7 women, 5 men</td>
</tr>
</tbody>
</table>
Ontogeny of jumping performance

- Velocity (m/s)
- Average acceleration (m/s²)
- Tetanic force (N)
- Mechanical advantage

Graphs showing the relationship between body mass and jumping performance metrics.
Ontogeny of locomotor performance

Optimal walking speed (solid dots) and leg length (open dots) versus body mass for a growth series of humans: children (2-12 years) and adults. 
(Cavagna et al., (1983) J. physiol. 343, 323-339)
Locomotor versus Fighting Dichotomy

Fighting Specialists  
Selection:  
- Male competition  
- and territory defense

Fighting and Locomotor Generalists

Distance or Speed Specialists  
Selection:  
- Predator-prey and migration

http://images.google.com
Selection Experiment
- Form of selection was specific.
- Environment was controlled.
- Not replicated.

Cursorial adaptation - relatively weak forelimbs!
Anatomy of a runner
Gracile distal limb muscles
Gracile forelimb muscles
High potential for elastic storage
High bone elastic modulus
Low energy to bone fracture

Anatomy of a fighter
Stout distal limb muscles
Stout forelimb muscles
Low potential for elastic storage
Low bone elastic modulus
High energy to bone fracture

The evolution of short legs?
Pleiotrophy
Selection on limb length:
digging
climbing
branch walking
agility
fighting
Shorter legs increase the cost of running!

Energetic cost to travel a meter.

Step length.

The product of cost of transport and step length is a cost coefficient that is independent of body size, indicating that the cost of transport is inversely proportional to step length.

From Kram and Taylor, 1990

Short legs increase stance stability

long legs

short legs
Short limbs may increase force applied to the ground by reducing the ground force moment arm.

Do the most aggressive species have short legs?

How can aggression be quantified?

http://animals.timduru.org
Size sexual dimorphism - a proxy for aggression

Among mammals, body size sexual dimorphism is generally found in polygynous species in which males compete through fighting and the threat of fighting.

(Darwin, 1871; Clutton-Brock et al., 1977, 1980; Alexander et al., 1979; Parker, 1983; Jarman, 1983; Andersson, 1994; Mitani et al., 1996; Plavcan, 2004)

Size sexual dimorphism is correlated with the intensity of male mating competition.

Mitani et al., 1996. Amer. Nat. 147, 966-980
The relation between maximal running speed and body mass in terrestrial mammals.

Garland, T., Jr. 1983. Speed versus size sexual dimorphism in artiodactyls

The evolution of short legs?

Forelimb length versus size dimorphism in Bovidae

The negative correlation between leg length and SSD is consistent with relatively short legs being an adaptation in Bovidae for physical aggression.
Evolution of long legs in *Homo* is thought to be associated with improved locomotor economy.

Short legs were retained in australopiths for more than 100,000 generations.

*Klein, 2000*
Scaling of Hindlimb Length on Cube Root of Body Mass

Minimizing \( d \) reduces \( A_h \). (Cartmill, 1974)

Climbing Trunks

Minimizing \( d \) reduces \( A_h \). (Cartmill, 1974)
Body Size and Quadrupedalism on Branches

Larger primate species are less adept at arboreal locomotion and rely less on quadrupedal progression on branches.

Fleagle and Mittermeier (1980),
Crompton (1984)

Adult male and female chimpanzees differ in their arboreal locomotor behavior, with the larger males using less quadrupedalism and more climbing, scrambling, and aided bipedalism than females.

Doran (1993)

The best acrobats have long legs!