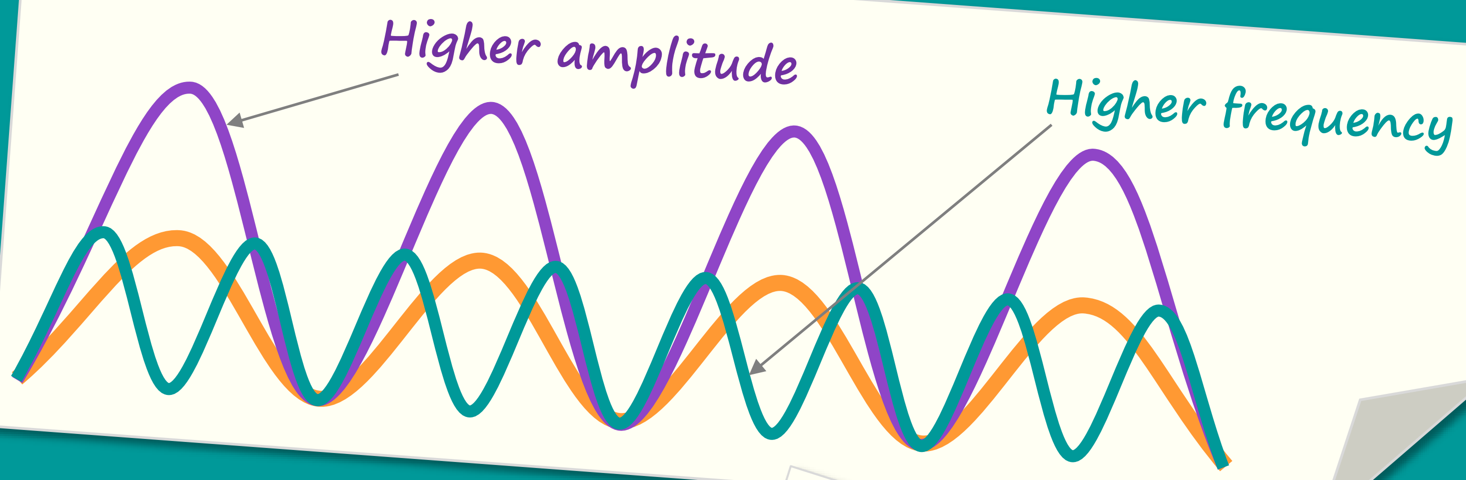
1. MATHS

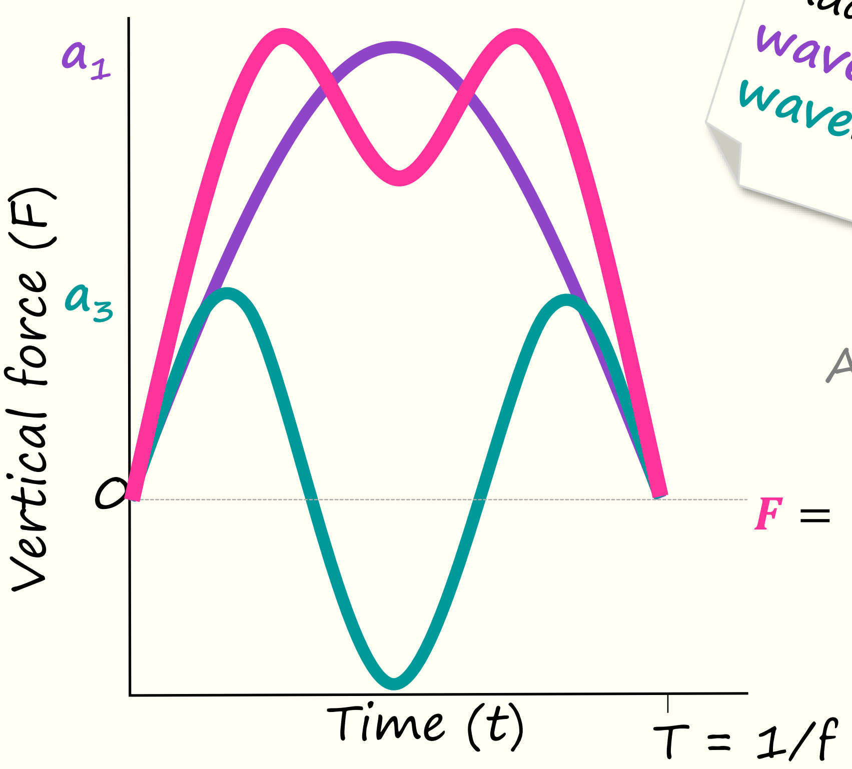
Today we're collecting force traces from LOTS of people, but how do we get our heads round all these wiggly lines?

We have a trick in maths called **Fourier Analysis** which helps us describe these lines in numbers.

Sine waves can be described in terms of how high they go (their **amplitude**) and how close together they are (their **frequency**).



The pink force trace is made up of the purple sine wave plus the green sine wave.

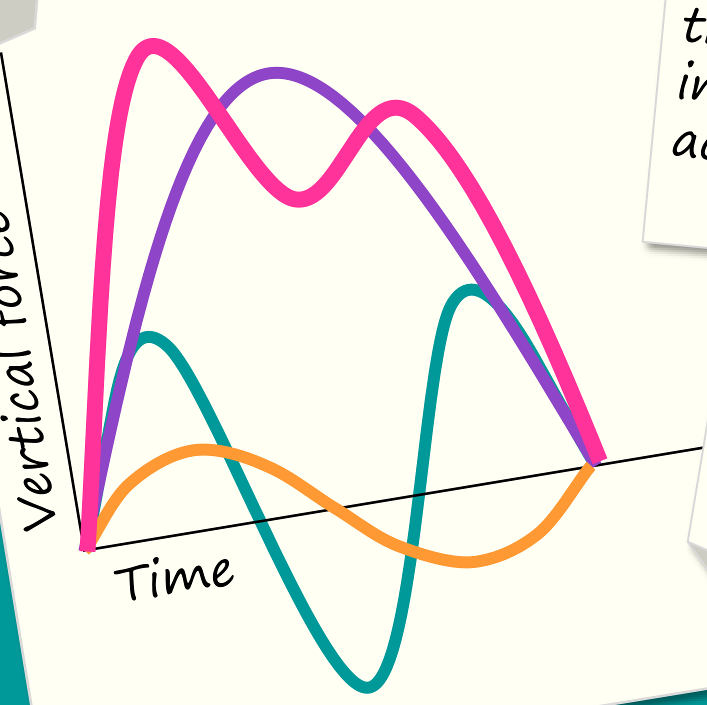


Amplitude

$$F = a_1 \sin(\pi t f) + a_3 \sin(3\pi t f)$$

Frequency

But why do the force traces look like this??? See the MECHANICS and MUSCLES sections...



The force traces for children are wonky compared to those in adults. We can add in a third (orange) wave to account for this.

The PAST section discusses this difference between children and adults.

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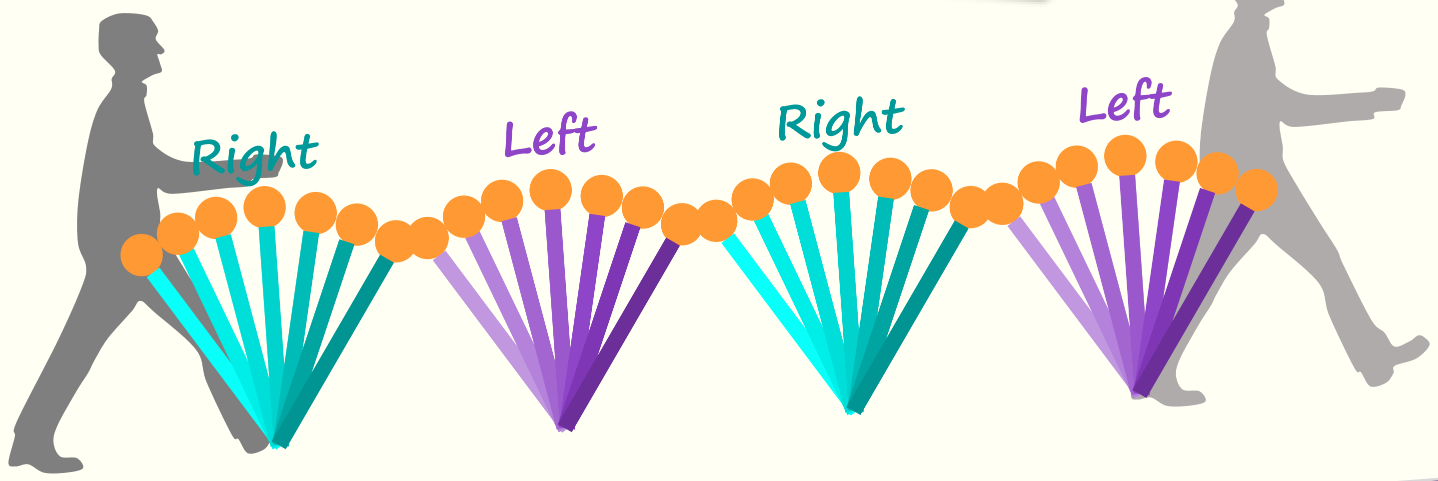
2. MECHANICS

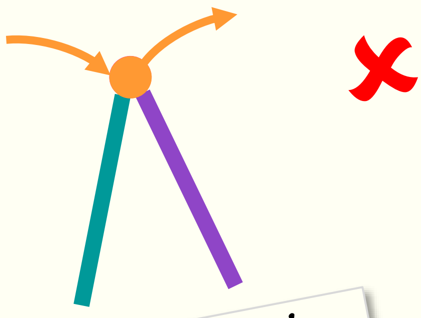
If you ask an engineer "what's the best way of walking?" they will suggest minimising work.

Walking with a **stiff leg** means not much mechanical work is done by muscles as they don't have to change in length a lot.

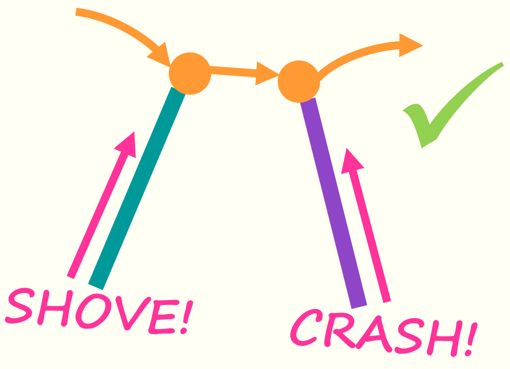
We view walking as being a bit like an '**inverted pendulum**'. The ball at the top represents the mass of the body and vaults over the stick which represents the leg.



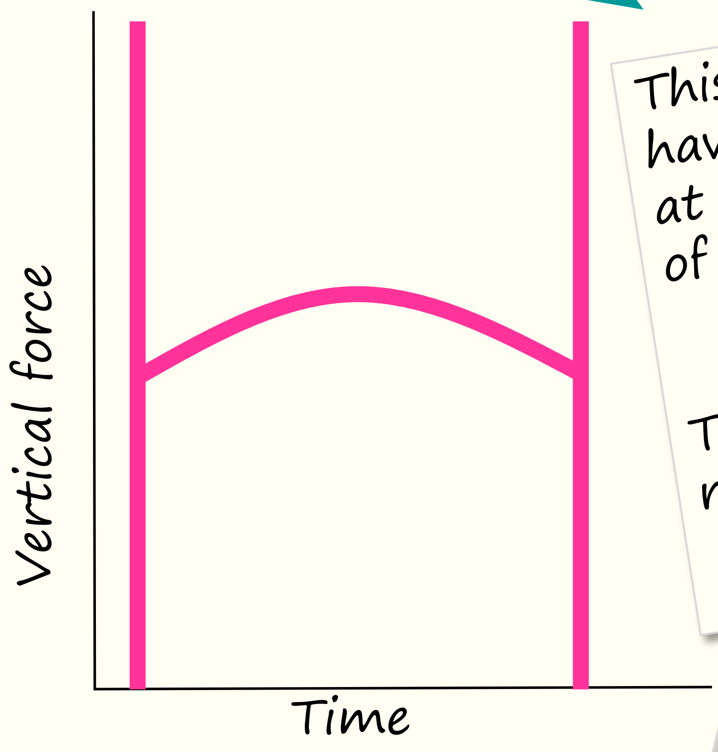
Problem: how do we get from one stiff-limb to the next without a massive clunk and 'collisional' energy loss?



Like walking in ski-boots!



BUT...



This means you'd have to have infinitely high forces at the beginning and end of your foot fall!

That's definitely not right!

See MUSCLES for how we deal with this.....

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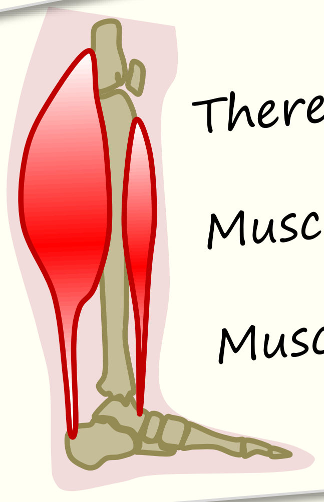
3. MUSCLES

In MECHANICS, we saw that minimising work would result in infinite forces…

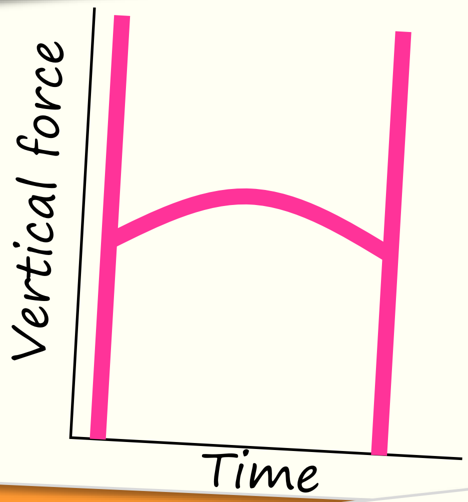
But, we're using muscles to drive walking…



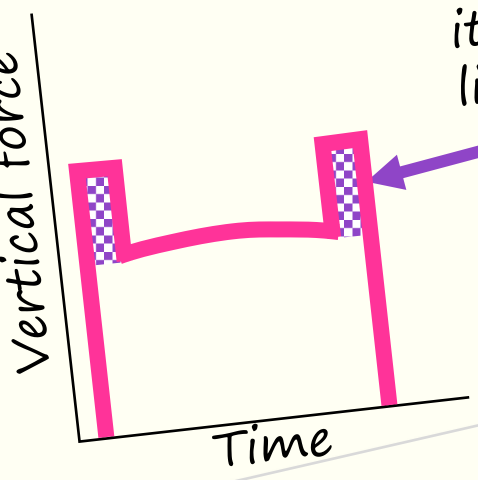
There is a cost to switching muscles on and off.

Muscles can only do so much work (per kg).

Muscles can only achieve so much power (per kg).

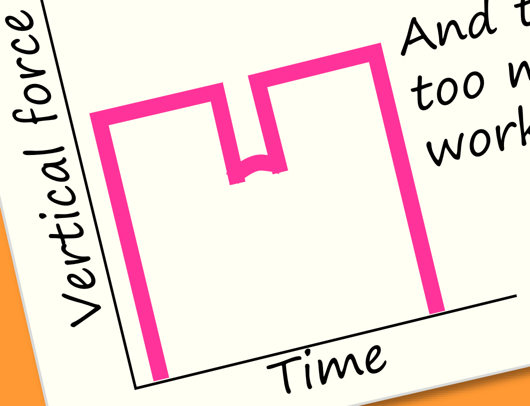


We can't do the infinite forces in the engineer's version… Because this would mean an infinite power demand.

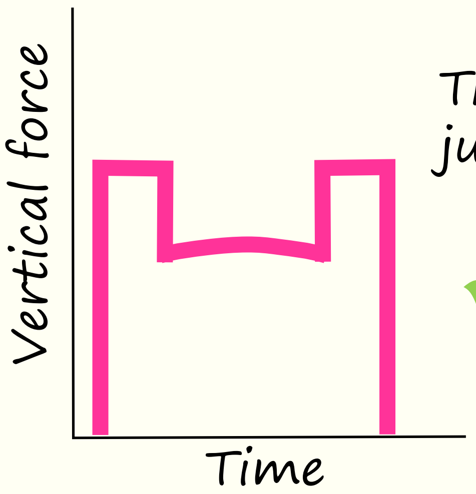


So, we can buy some time as it's actually this area under the line that's important.

BUT this one still requires too much power…

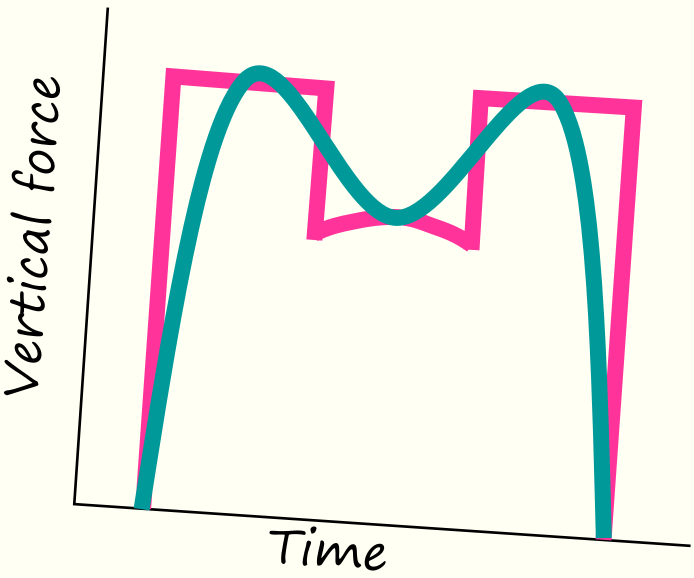


And this is too much work…



This one is just right!

Real force traces show the compromise between low work and low power…. and then for some reason the sharp edges get nicely rounded off!



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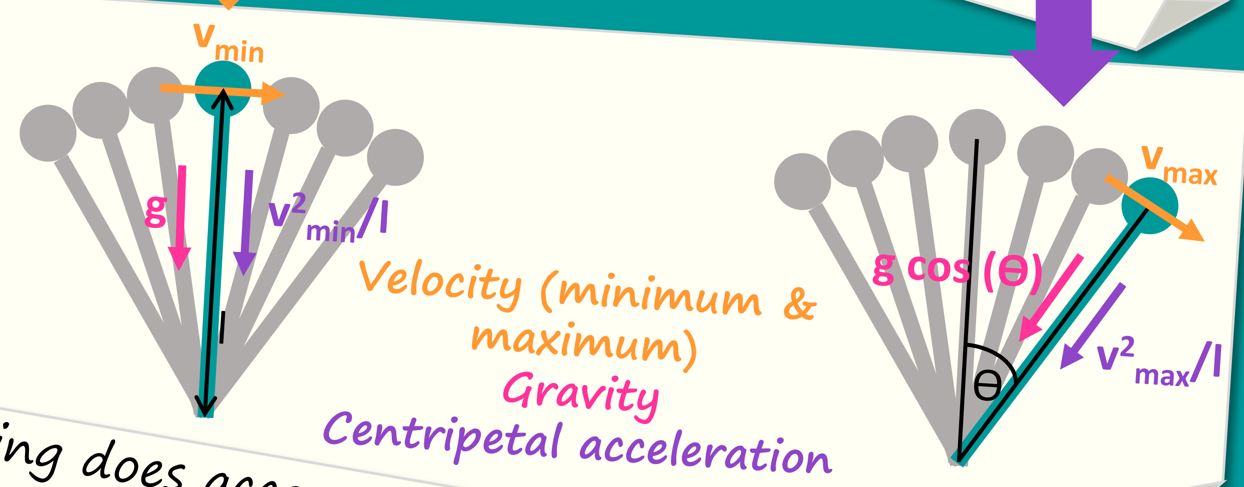
1. PAST

What we know so far.....

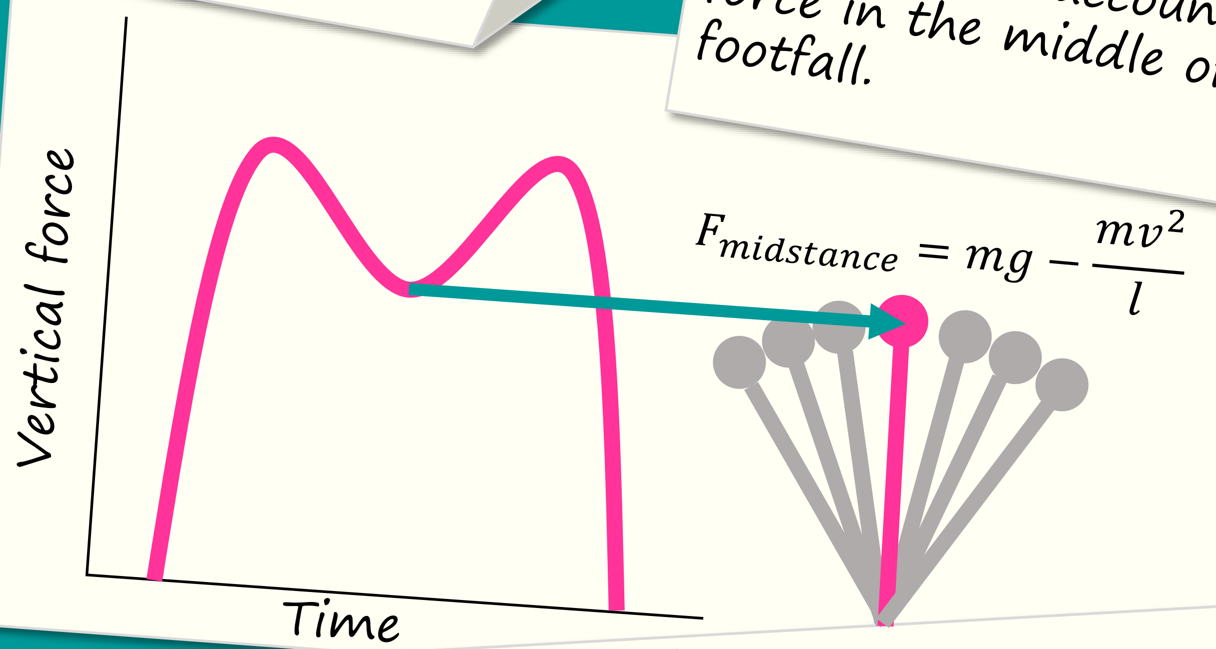
Why can't I walk faster?
If you walk too fast, there is not enough gravity acting down your leg to keep you on the ground at midstance.

What's the longest step I can take?
There is a maximum leg angle for walking and going beyond this, your foot will drag.

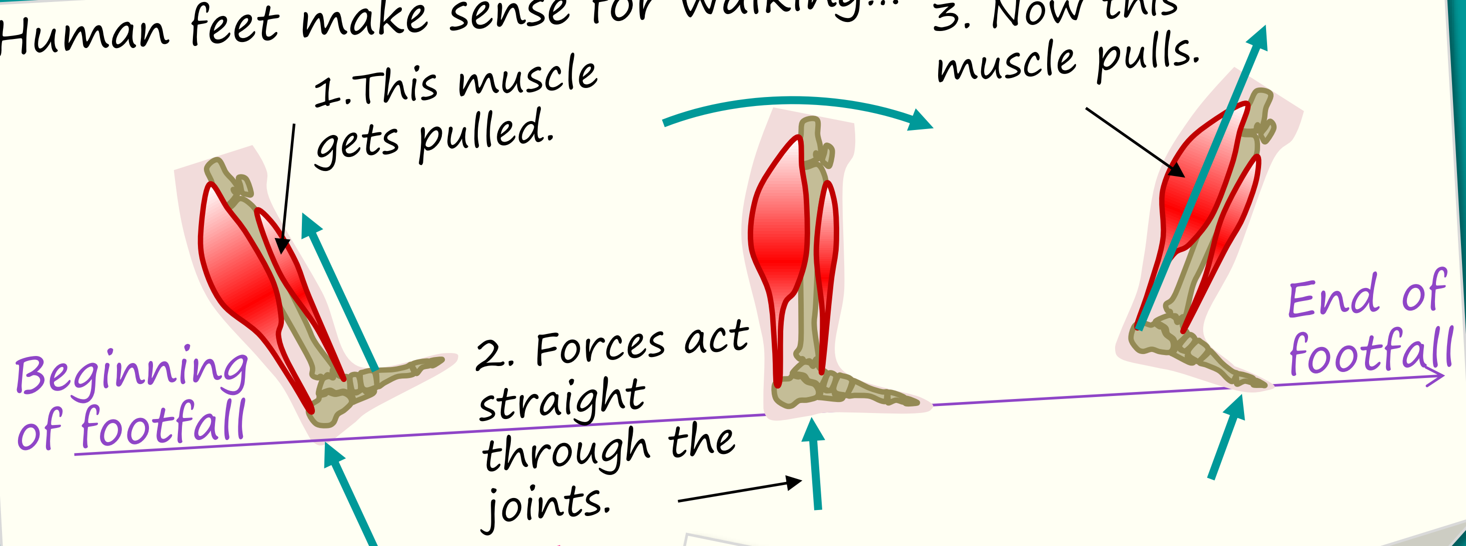


Vaulting does account for top speed, longest step (1.5 x leg length) and changes with incline.

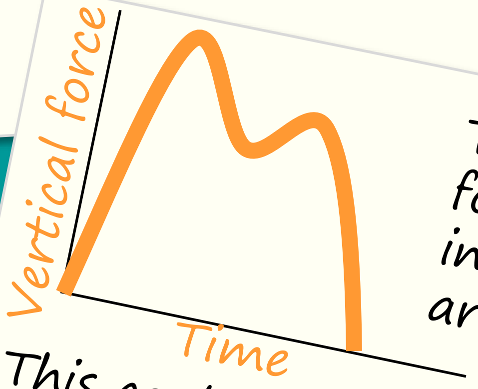
Vaulting does account for force in the middle of a footfall.



Human feet make sense for walking...



They allow for vaulting without muscle loading.



The vertical force traces in children are odd...

This could be to buy more time (more work by muscles but less power)...This is one of the things we're looking at today.

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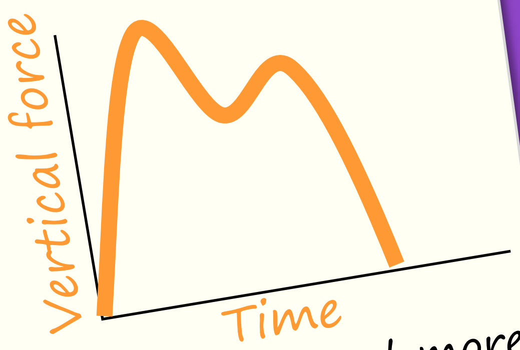
2. PRESENT

You can see from the information in MATHS, MECHANICS and MUSCLES that we have a pretty good idea about walking BUT…

How does variability in the population affect this? How good are our models really?

Today we're collecting force traces from LOTS of people to see how walking changes with:

AGE: Do children and old people walk differently from everyone else? Are their muscles different?



Want to understand more about the biased traces in children…? Maybe: shorter legs = quicker steps = less time => high power requirement?

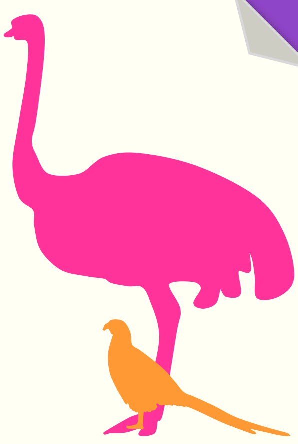
SEX: Do males and females walk differently?

Do we need to use a slightly different model to account for this?

LEG LENGTH: Is the wonky force trace we see in children to do with age (possibly different muscle) or is it simply that they have shorter legs?

In humans, to look at a good size range, we have to include children and adults but this includes 2 of our factors: size and age.

So, we also look at how animals walk so we can look at a bigger size range.



Is there anything else you think would affect walking? Talk to us about it!

3. POTENTIAL

Basic Science: This work helps us to answer key questions like "why do we get tired walking, even downhill?". It also helps us to understand walking in terms of forces, power, work and muscles.

Medicine: Understanding how young, tall, old and short people walk can help in informing rehabilitation techniques when people need to learn how to walk again after a brain or spinal injury.

Prostheses: Understanding the detailed mechanics of walking and the demands on the musculoskeletal system can feed into the design of prostheses that behave more like real human legs.

Caputo, J. M., Collins, S. H. (2014)

Photo credit: Roberto Quesada

Collins, S. H., Wiggin, M. B., Sawicki, G. S. (2015)

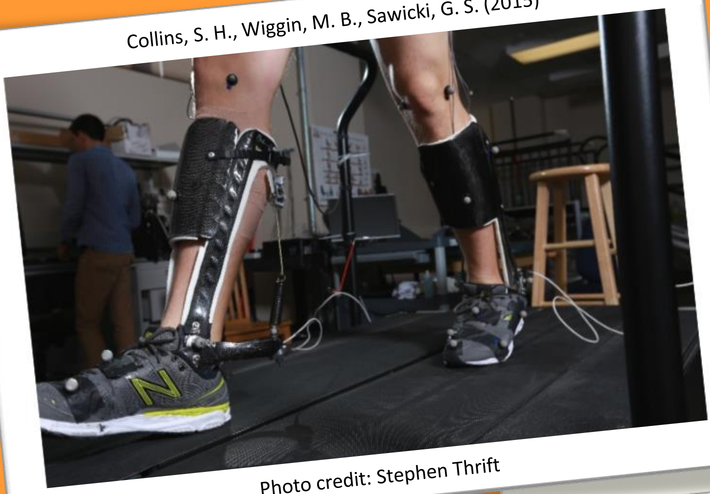
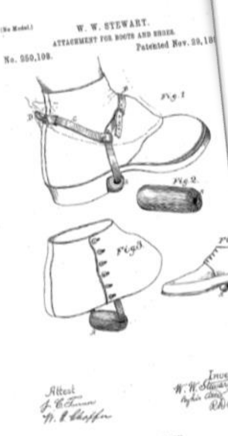


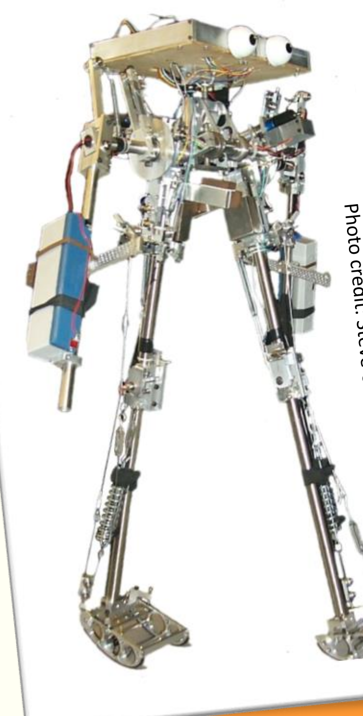
Photo credit: Stephen Thrift



Making walking easier!
We are at a stage where we can make walking 'easier' on the muscles through advanced exoskeletons and footwear.

This can also guide the design of **sports** equipment like trainers.

Robotics: Ideas from studies on walking humans and animals can help make more economical 'bio-inspired' robots. The robot on the right walks using less energy per unit distance per unit weight than any other walking robot to date – similar energy consumption to a human!



Collins, S. H., Ruina, A. L., Tedrake, R., Wisse, M. (2005)
Photo credit: Steve Collins

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VITAL STATISTICS

DR JIM USHERWOOD

A levels: *Biology, Physics, Maths, Chemistry.*
Degree: *BSc. Zoology, Uni. of Oxford.*
Master's: *MRes. Biology & Engineering, Manchester Uni.*
PhD: *Zoology, Cambridge Uni.*
Post-Docs: *Florida State Uni., Harvard Uni., RVC.*
Current job: *Reader & Wellcome Research Fellow.*

DR ZOE SELF

A levels: *Biology, Chemistry, Physics, Maths (AS Level).*
Degree: *BSc. Equine Science, Bristol Uni.*
Master's: *Didn't do one.*
PhD: *Biomechanics (athletic performance in racehorses), RVC.*
First job: *Lecturer in Sports Biomechanics.*
Current job: *Post-Doc in Locomotor Biomechanics.*

DR GRZEGORZ SOBOTA

Degree: *M.Sc.Eng Biomechanics & Biomedical Engineering, Silesian Uni. of Technology, Poland.*
PhD: *Biomechanics, Jerzy Kukuczka Academy of Physical Education, Poland.*
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DR BEN SMITH

A levels: *Maths, Further Maths, Physics, Computing.*
Degree: *Electronics & Satellite Engineering, Uni. of Surrey.*
Master's: *Space Technology & Planetary Exploration, Uni.Surrey.*
PhD: *Bio-inspired Robotics, Uni. of Surrey.*
First job: *This one! Post-Doc in biomechanics of terrestrial locomotion, working with mice.*

EMILY SPARKES

A levels: *Biology, Chemistry, Physics.*
Degree: *Sport and Exercise Science, Manchester Metropolitan*
Master's: *Biomechanics , Manchester Metropolitan Uni.*
First job: *Head Biomechanist, Great Britain Water polo.*
Current job: *Senior Technician in Structure and Motion Laboratory.*

DR JEFFREY RANKIN

A levels (US equivalent): *Physics, Maths, Biology, History.*
Degree: *BSc. Mechanical Engineering, Brigham Young Uni. (USA)*
Master's: *MSc. Mechanical Engineering, Uni. of Texas (USA)*
PhD: *Mechanical Engineering (Biomechanics), Uni. Texas. (USA)*
First job/ Current job: *Research Fellow.*
Next role: *Lecturer/Uni. Professor.*

DR TATJANA HUBEL

Intermediate Diploma (BSc): *Biology, Saarland Uni. (Germany)*
Diploma (MSc): *Biology, Saarland Uni. (Germany)*
PhD: *Zoology (bird flight), Darmstadt Uni. (Germany)*
First job: *Research Assistant, Darmstadt Uni. (Germany)*
First Post-Doc: *Engineering dept., Brown Uni. (USA)*
Current job: *Post-Doc looking at cheetah locomotion.*

DR LAUREN SUMNER-ROONEY

A levels: *Biology, Chemistry, French , History, Maths (AS Level).*
Degree: *Biological Sciences, Uni. of Oxford.*
Master's: *Didn't do one.*
PhD: *Biological Sciences , Queen's Uni. Belfast.*
First job: *This one! Research technician and science communicator.*

"What can I expect from a career in science?" – Ask us!
"But what about the money..?"

Bachelor's Degree: Typically around 3 years and costs about £9000 per year.
Master's Degree: More 'optional' than other qualifications. These can vary in cost, duration and type of training (research vs. taught). Some master's can cost up to £9000 a year or you could get funded.
PhD: Typically, you will receive a 'stipend' which is a tax-free payment of around £12,000-£18,000 per year. A PhD generally takes 3-4 years full-time and you can do one almost anywhere in the world. Then you can call yourself a Dr!
First job: You can expect to earn around £30k in your first post-doctoral role, and again, you could find yourself working anywhere!
Professor (late academic career): Earn £60-80k (ish) – better than most expect from science!