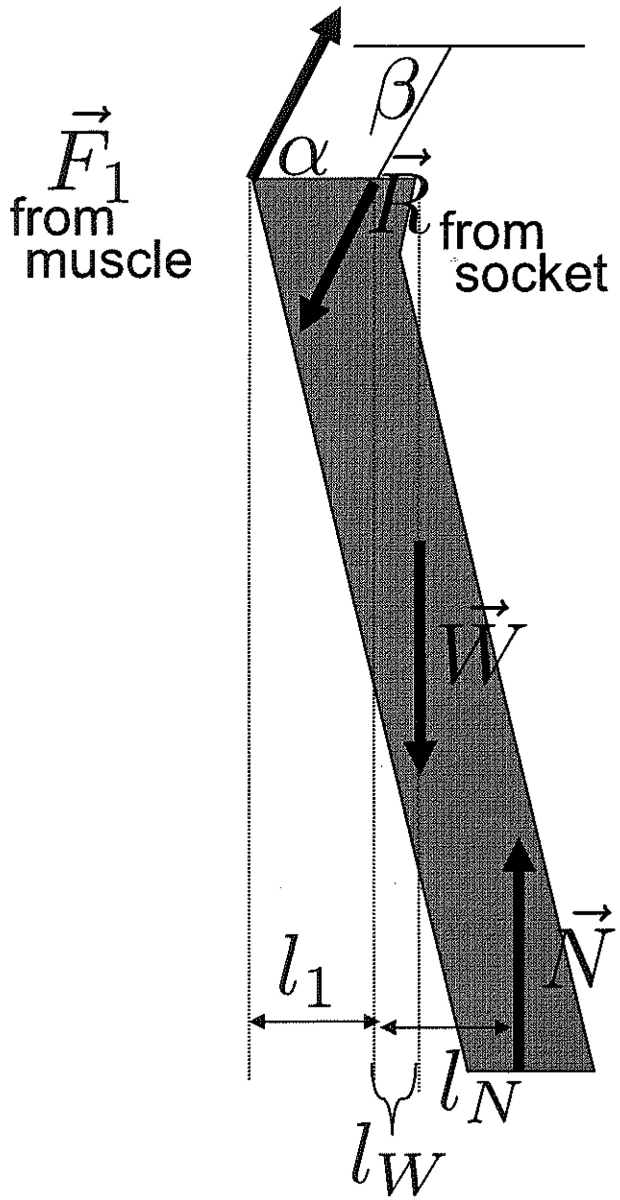
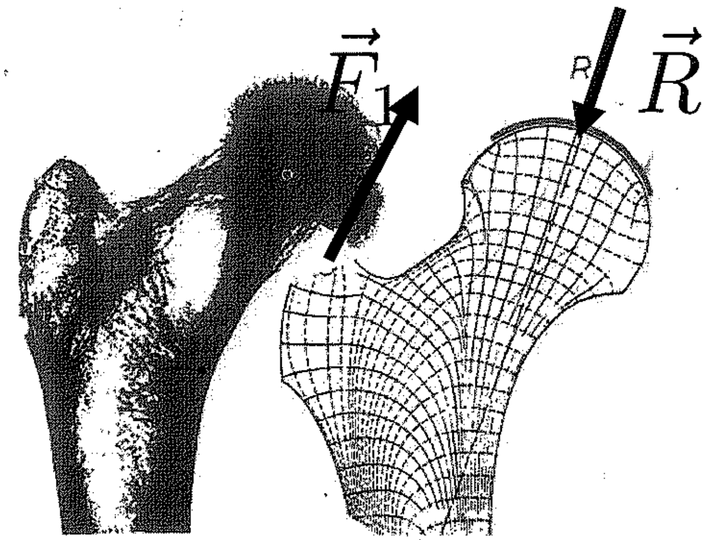
Example: human hip





From Benedek and Villars,
Physics with Illustrative Examples from Medicine and Biology: Mechanics

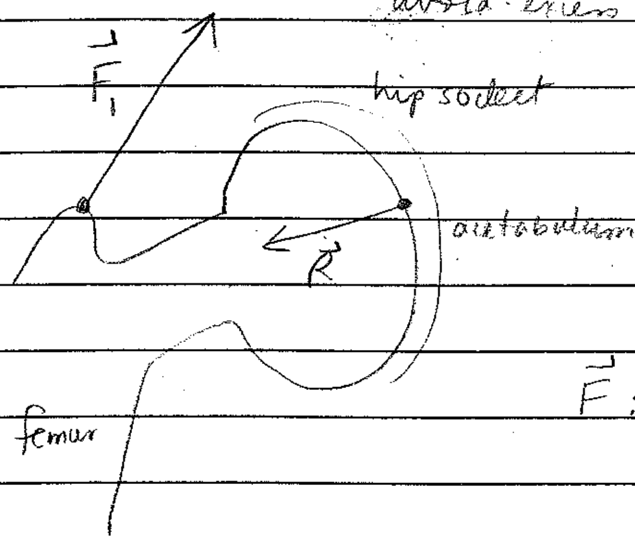
If you are balancing on one leg, what is the force on your hip from the socket?

Known: $\alpha=70^0$, m, l_W, l_N, l_1 , W=mg/7

Unknown: β, R, F_1

Human Hip : medical application

orthopaedic experts, physical therapists, biomed engineers, learn how to support the body → which muscles to strengthen, how to avoid pain, promote healing, avoid excess bone growth, etc



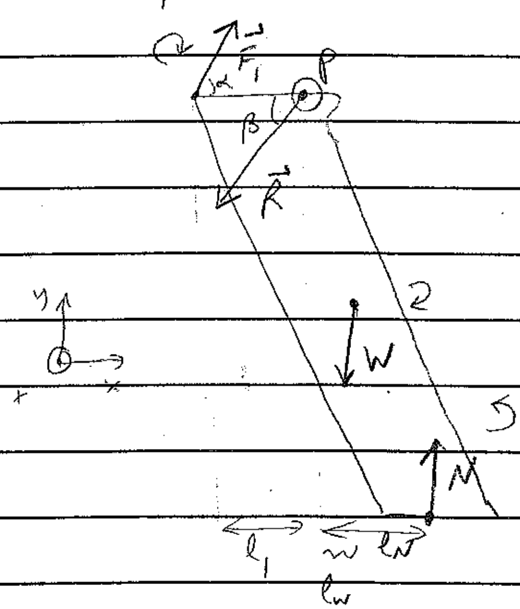
$\vec{R}$: force of acetabulum on femur, ⊥ to curved surface

$\vec{F}$: force from hip abductor muscle

Balancing on one leg (e.g. momentarily while walking) → what is $\vec{R}$

Simplified version of leg FBD

1) diagram
2) pivot
3) + dir
4) sense of rotation



Known: $\alpha = 70°$

m, l_1, l_w, l_N , $N = mg$

$W = mg/7$ since supporting whole body

These are all things one could measure for a person

Unknown β, R, F_1

5) Force balance on leg $\Sigma F_x = 0$

① $F_1 \cos\alpha - R\cos\beta = 0$

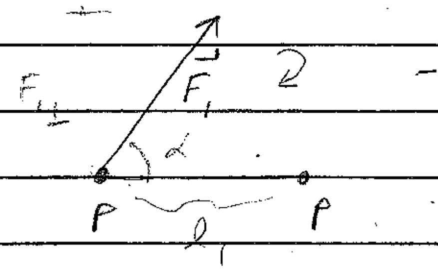
$$\Sigma F_y = 0$$

$$F_1 \sin\alpha + N - m_L g - R\sin\beta = 0 \quad (2)$$

6) Torque balance $\Sigma \vec{\tau} = 0$

τ_P due to $\vec{R} = 0$

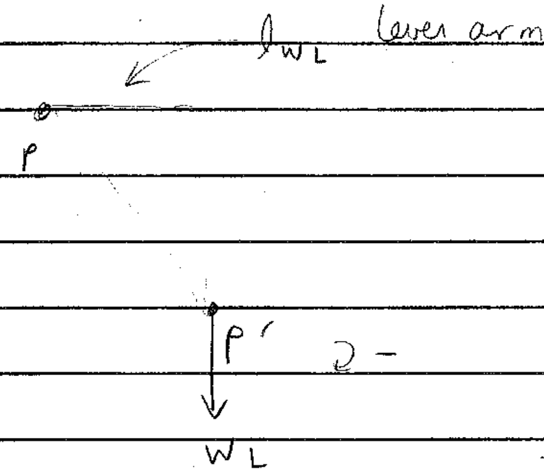
τ_P due to $\vec{F}_1$



Use ⊥ force method

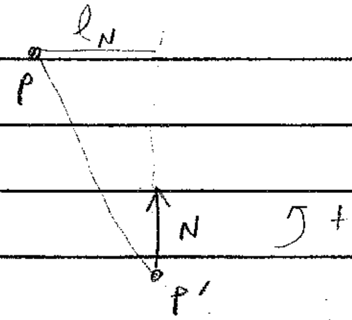
$$\tau_{PF_1} = -F_1 l_1 \sin\alpha$$

τ_P due to W_L



$$\tau_{PW_L} = -l_{W_L} W_L$$

τ_P due to N



$$\tau_{P_N} = +l_N N$$

N = mg if balancing

Sum $\Sigma\tau = \tau_{PF_1} + \tau_{PW} + \tau_{PN} = 0$

$\alpha = 70°$

$l_1 = 2.75''$

$l_W = 1.25''$

$l_N = 4.25°$

$$0 = -l_1 F_1 \sin\alpha - l_{W_L} m_L g + l_N N$$

$$(3) \quad F_1 = \frac{l_N mg - l_{W_L} m_L g}{l_1 \sin\alpha} = 1.6\, mg$$

quite a force! more than your weight

3 equs, 3 uk

② $\Rightarrow$ $R \sin\beta = F_1 \sin\alpha - m_L g + mg$

① $\Rightarrow$ $R \cos\beta = F_1 \cos\alpha$

Divide $\tan\beta = \tan\alpha + \dfrac{mg - m_L g}{F_1 \cos\alpha} = 4.3$

$\Rightarrow \beta = 77°$

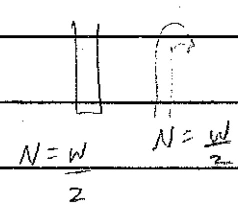
$|\vec{R}| = F_1 \dfrac{\cos\alpha}{\cos\beta} = 2.4\, mg$!

2.4 times your weight
in your hip socket when
you balance on one leg!
Hip injuries can be very painful
↳ orthopaedist can
use this knowledge

$F_1 = \dfrac{l_N mg - l_W m_L g}{l_1 \sin\alpha}$

→ Reduce l_N to reduce F → put foot directly under hip

Or, use cane
to support
weight



$l_N mg \rightarrow l_N \dfrac{mg}{2}$