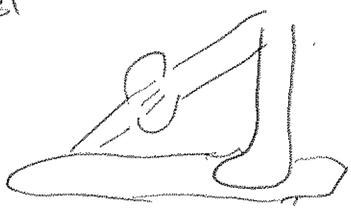
Lecture 11

Last lecture:

Started single joint control : next few lectures.

Single muscle can almost control one joint

- assuming gravity, etc.

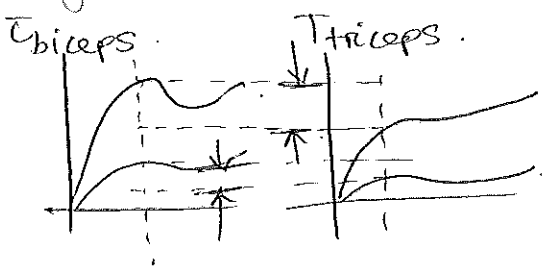


- But need atleast 2 to work under all conditions

Usually more than 2 for stability (∵ most joints have more than 1 DOF).

2 different ways to change angles.

- reciprocal innervation
- co-contraction



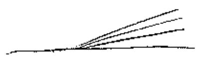
$$T_{b_1} - T_{t_1} = T_{b_2} - T_{t_2}$$

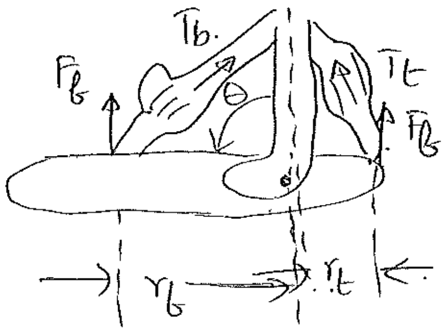
same movement.

So $T_{biceps} - T_{triceps} \neq 0$ creates τ @ the joint.

So what is τ @ the joint equal to?

F & τ have complex relationship w/ tendon insertion shape.





For many muscles, $r_b \ll L_b$

Thus assumption $F_b \simeq T_b$. $\cos\phi = 1$ for small ϕ

$$\therefore \quad \tau = F_t r_t - F_b r_b = T_t r_t - T_b r_b = I\alpha.$$

I ↑ inertia; α ↖ angular accln

$$= I\frac{d^2\theta}{dt^2} = I\ddot{\theta}$$

For a thin rod, $I = \frac{ML^2}{3}$.

$$\Rightarrow \quad \frac{ML^2}{3}\ddot{\theta} = T_t r_t - T_b r_b$$

In reality $$\frac{ML^2}{3}\ddot{\theta} = T_t r_t - T_b r_b + \underbrace{\tau_{ext}}_{\text{gravity}}$$

$$\tau_{grav} = mgh \sin\beta \sin\theta$$

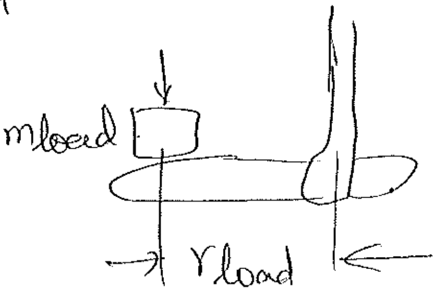
h = dist. from COM to joint center

β = ∠ between floor & plane of motion

θ = angle of joint

m = mass of arm

Another τ_{ext} is due to external loads



$$\tau_{load} = m_{load}\, g\, r_{load} \sin\beta \sin\theta .$$

$$I\ddot{\theta} = T_t r_t - T_b r_b + (m_{arm} h + m_{load} r_{load}) g \sin\beta \sin\theta$$

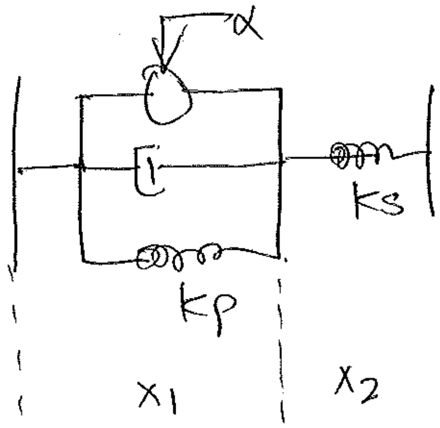
~~des~~ also changed w/ m_{load}

will come back to this & how to control the τ for dynamic mvto

but lets first talk about effect of co-contraction on a joint

co-contraction $\rightarrow$ does not affect τ_{joint}.

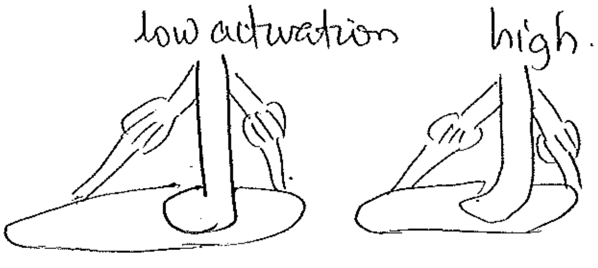
But we covered that stiffness changes.



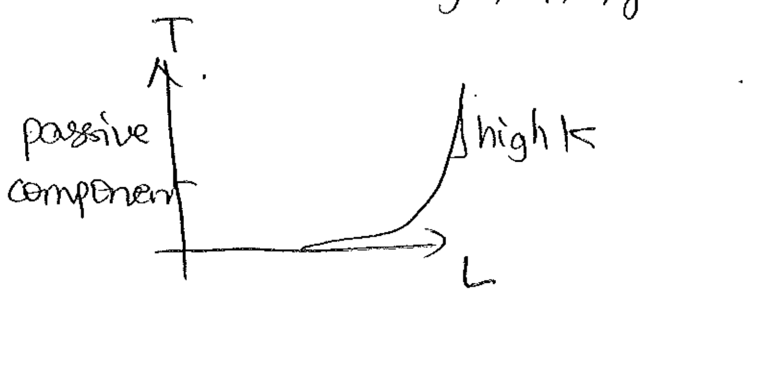
$\alpha \uparrow$

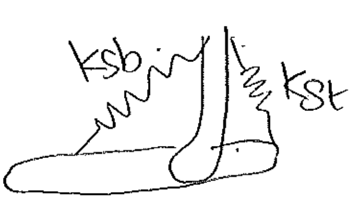
$x_1 \downarrow$

$x_2 \uparrow$



No length change.





Less effect of τ_{ext} w/ higher co-contraction

When do we want to reject Text ?.

Rejecting Text → Tgrav → balancing → postural control.

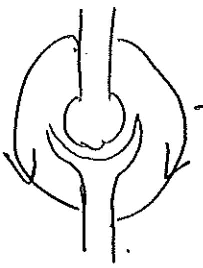
Which posture? upright

We are an upside down pendulum.

@ perfect balance → all F = 0. 

but that's never the case.

Consequence → HUGE joint load.

Tfl.  Text

joint load = Σ all muscle + weight on top

ex. Back to elbow :

Realistics #s : Forearm + hand weigh ~ 2.5 kg

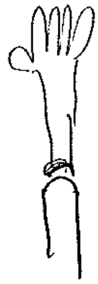
Arm length ~ 0.4 m

CoM ~ 0.2 m

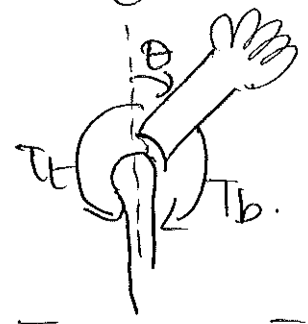
Biceps moment arm ~ 0.05 m.

Triceps " " ~ 0.02 m

Upside pendulum-like arm.



Think of a case.



$\theta = 30°$.

Then τ ?

isometric

$$\tau = 0 = T_b r_b - T_t r_t + mgh \sin\beta \sin\theta.$$

Assume no co-contraction $\Rightarrow T_b = 0$

T_t = active

For simplicity $\beta = 90°$.

$$\Rightarrow \quad 0 = -T_t(0.02) + 2.5 \times 9.8 \times 0.2 \times 1 \times 0.5$$

$$T_t = 125\,N \simeq 25\,lbs$$

@ joint load $= \Sigma T$ + weight

$$= 125N + \underset{\substack{\uparrow \\ 2.5}}{m}\underset{\substack{\uparrow \\ 9.8}}{g} \simeq 150N = 30 lbs$$

Now, imagine the arm is straight up & isometric.

If everything is balanced & muscle activation = 0

then load = mg = $2.5 \times 9.8 = 25N \simeq 5 lb$

But then the arm will flop over for any tiny perturbation

Assume a case that the arm can reject external perturbation up to 30° perturbation

Require $T_t = 125$

Then need to co-contract for balance

$$\tau = 0 = T_b r_b - T_t r_t - mgh \sin\beta \sin\theta$$

$$= T_b(0.05) - 125\,(0.02).$$

$$T_b = 50N$$

$\therefore$ joint load $= \underbrace{T_b}_{50} + \underbrace{T_t + mg}_{150} = 200N \cong 40 lb$

And this is just to reject 30° perturbation

Typically in this posn, $T_t \sim 250N$ ~~twice as much~~

$T_b = 100N$.

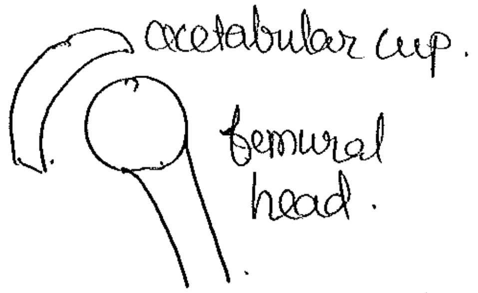
$\Rightarrow 250 + 100N + 25 = 375N \simeq 75 lbs.$

This is just the elbow w/ no load.

Imagine a joint like the hip, which is always under stabilization

What is the load on the hip?

During hip surgery, some volunteered to get a pressure sensor installed.



A quick overview of hip replacement.

↳ a new acetabular cup

→ prosthetic femural joint

Sensors on the prosthetic surface.

Measured in pressure. → in Pascal Pa.

$1\,Pa = 1\,N/m^2$ $\quad 1\,atm = 1.01 \times 10^5\,Pa = 10^4\,kg/m^2$

$= 0.1\,MPa \quad = 10\,tons/m^2$

Pressure recorded from hip

Standing still: 0.7 – 3.2 MPa.

Resisted contraction: 3.5 – 5.0 MPa

Walking 2.4 ~ 5.5 MPa.

Running 7.3.

Jumping 7.7

Stair climbing 10.2 MPa

Why more than jumping? Joints go thru' almost unstable postures

Rising from a chair ~ 18.0 MPa.

||

midsize car on a postage stamp!

H. U. G. E.

Thus in biomechanics studies of joints/tendons, they apply large/unrealistic amt of forces to test things.

Next time: controlling the reject perturbation