# Joint Coordination and Muscle-Tendon Interaction Differ Depending on The Level of Jumping Performance

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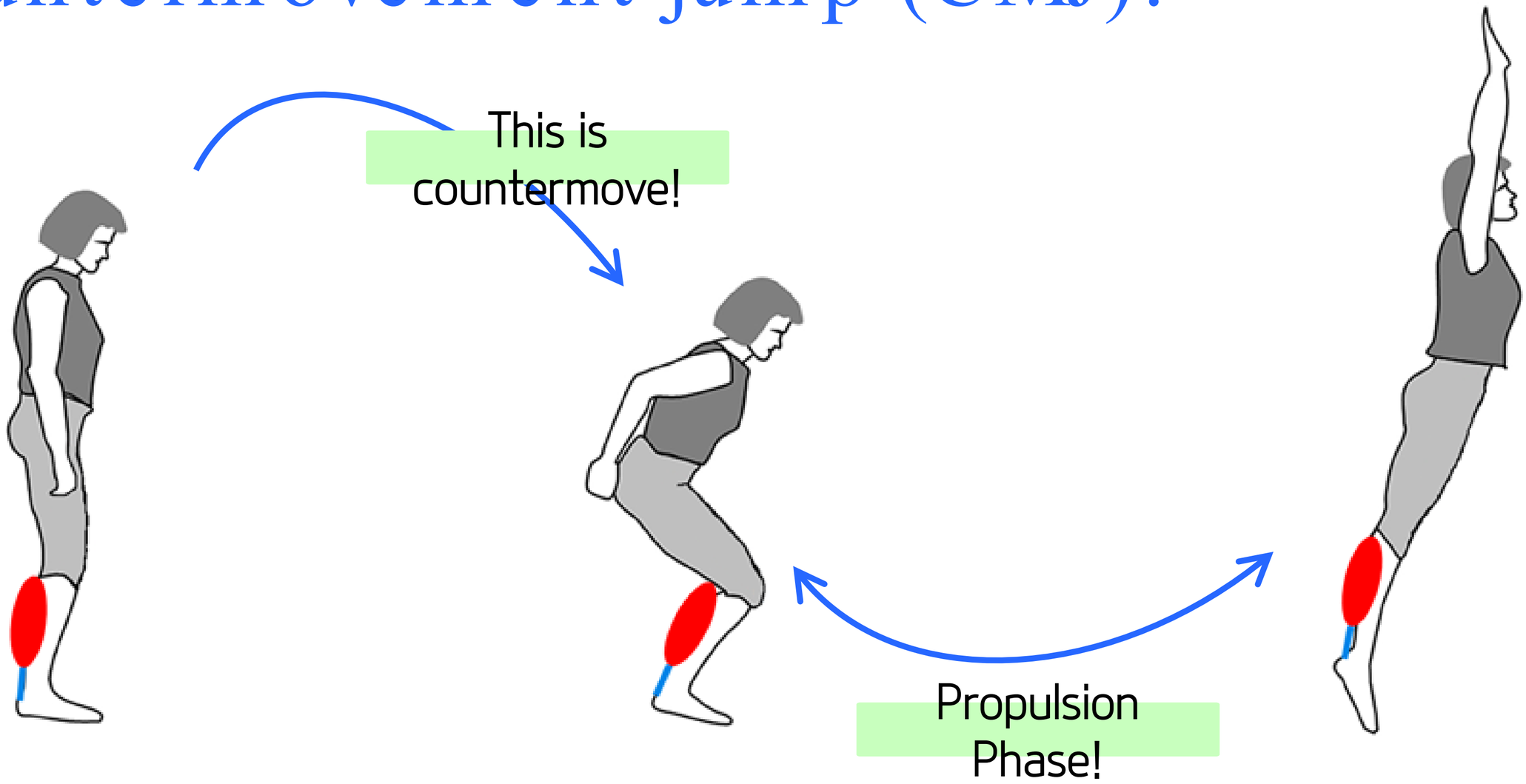
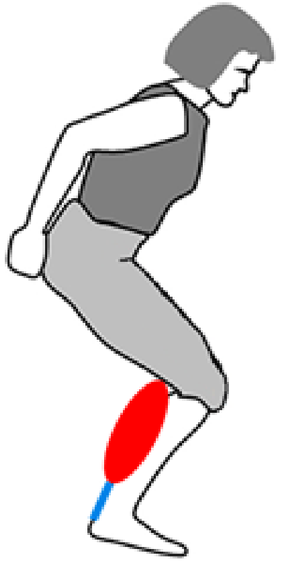
# What is the Countermovement jump (CMJ)?



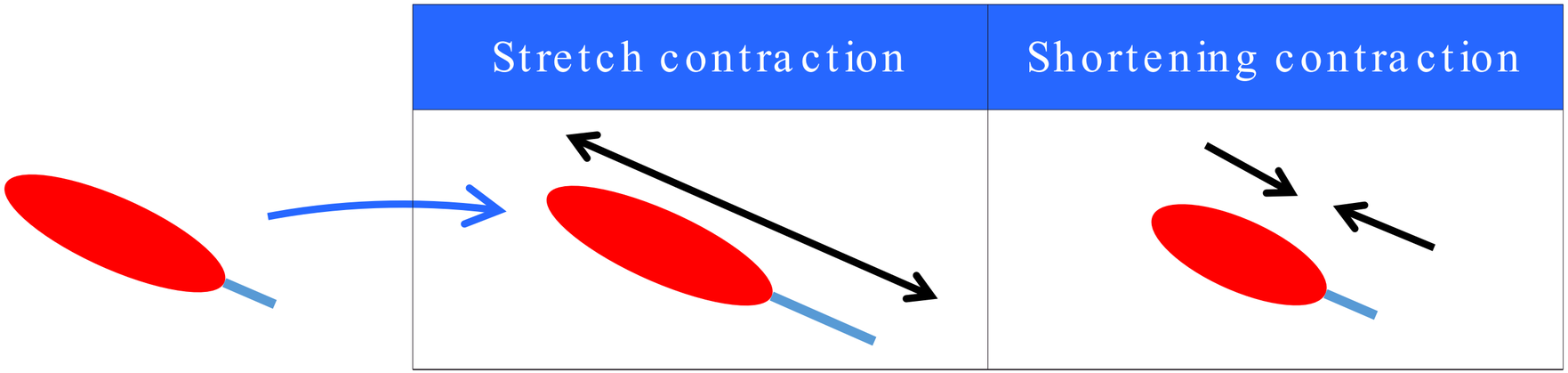
# What is the Stretch-shortening cycle (SSC)?

SSC = Stretching contraction (propulsion phase) following an shortening (countermovement phase) contraction occurs.

Muscle-tendon unit stretched

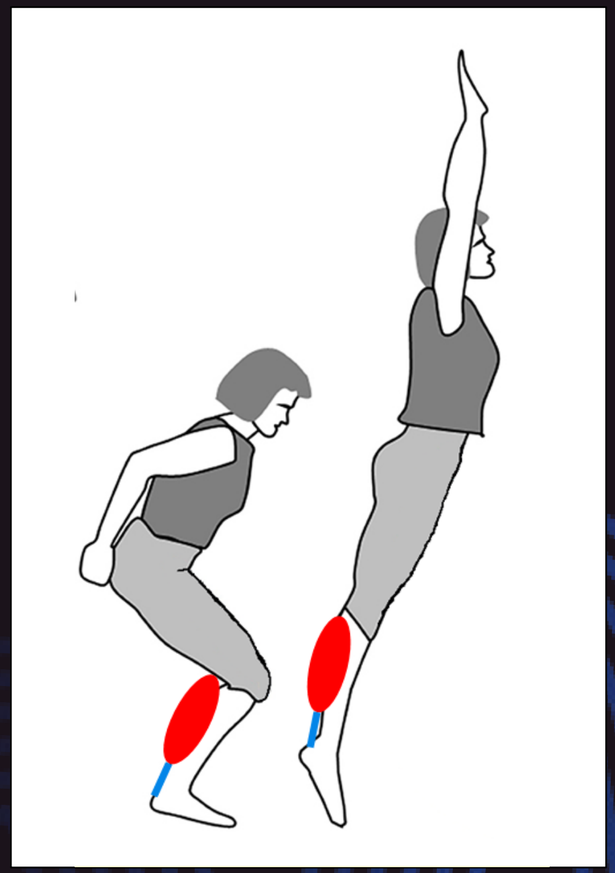


Shortening!



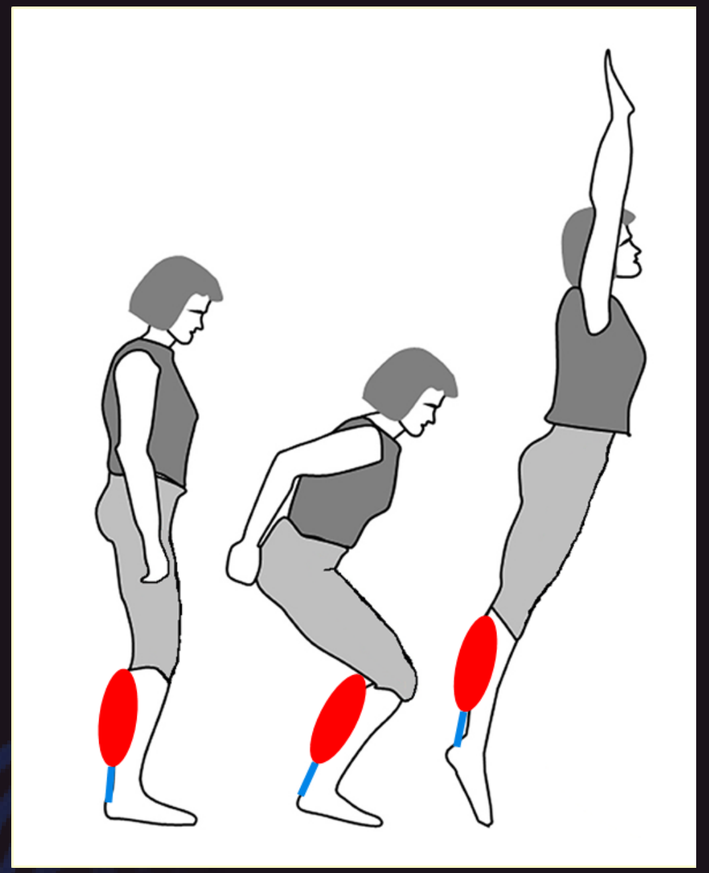

(Fukashiro and Komi, 1987)

# Compared to shortening contraction only…



Shortening contraction only

<



**Stretch -shortening cycle (SSC)**

Enhance muscle force/work
Greater jump height

↙

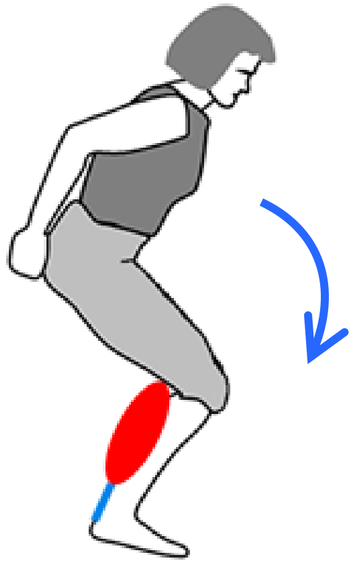
## “SSC effect”

(Bobbert and Casius, 2005, Cavagna et al., 1968)

# How to maximize the SSC effect?

(Cormie et al., 2009; McBride, 2021; Salles et al., 2011)

Tendon has elasticity!
Tendon stores and recoils elastic energy.

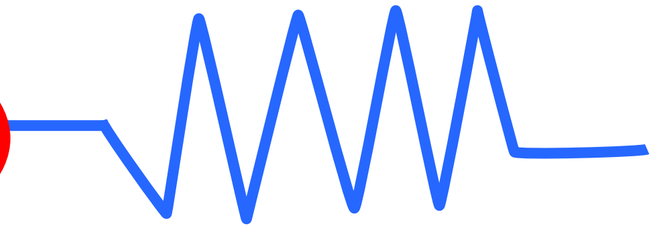


More countermove

+

Muscle

Tendon



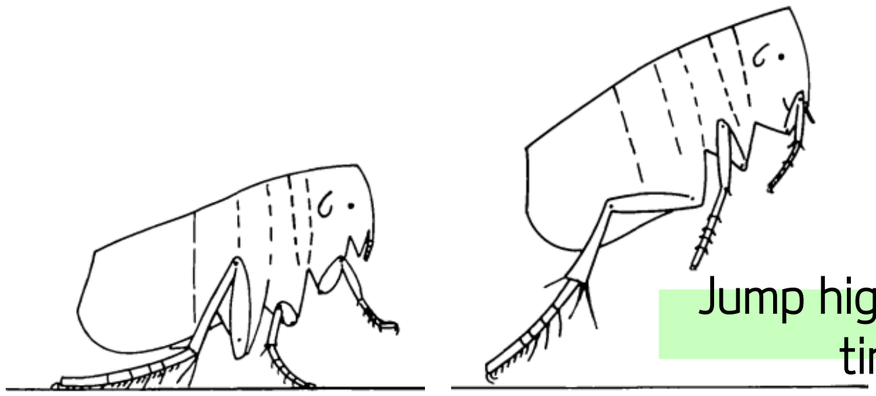
Increased tendon work

But, what it the difference between good and poor jumpers?

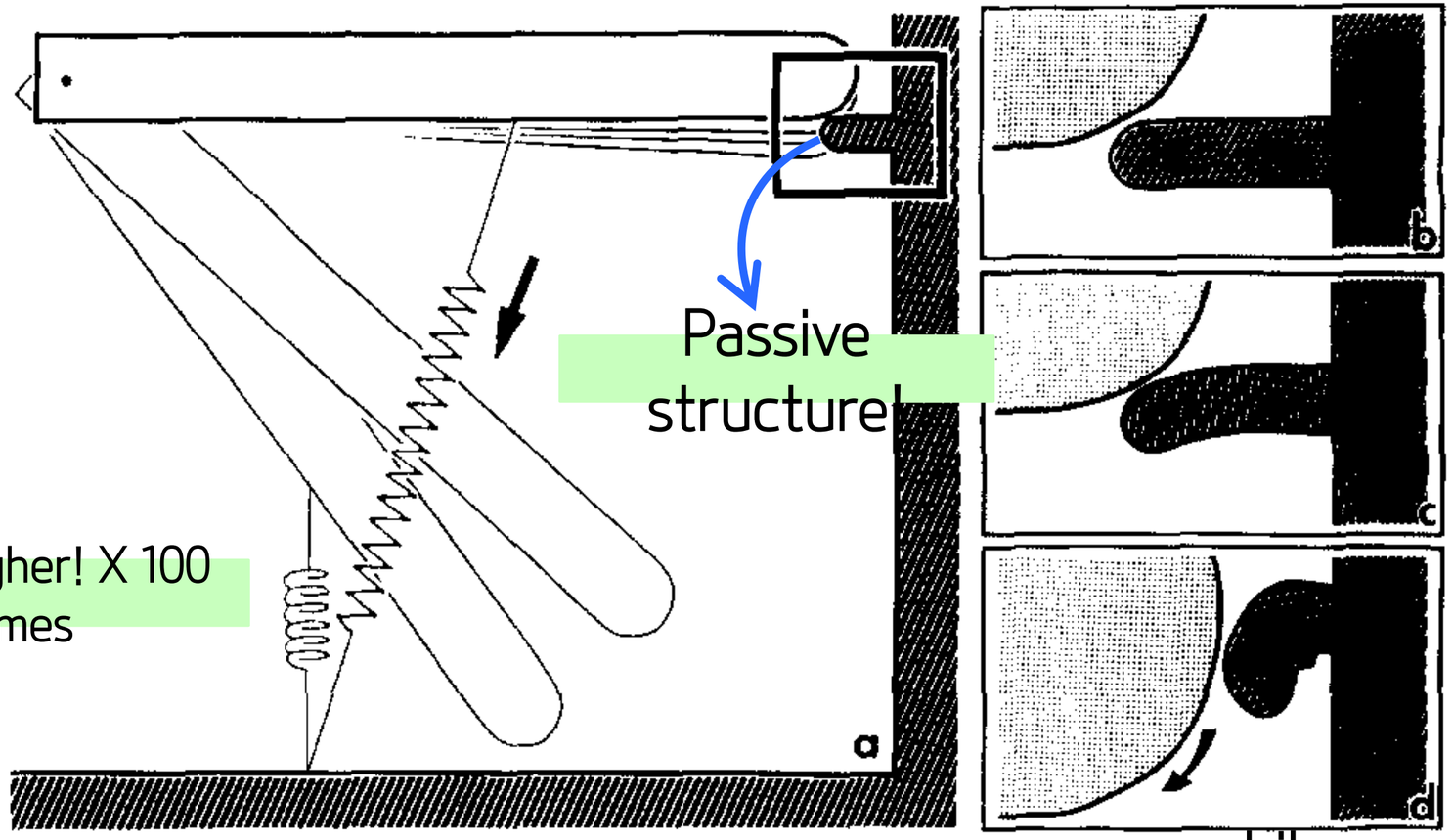
(Bennet-Clark, 1975)

# Consider the invertebrate animals' jump

"Catapult mechanism"
Passive structure that deforms to store elastic energy and rapidly recoils maximizes the force and power generated by the muscle



Jump higher! X 100 times

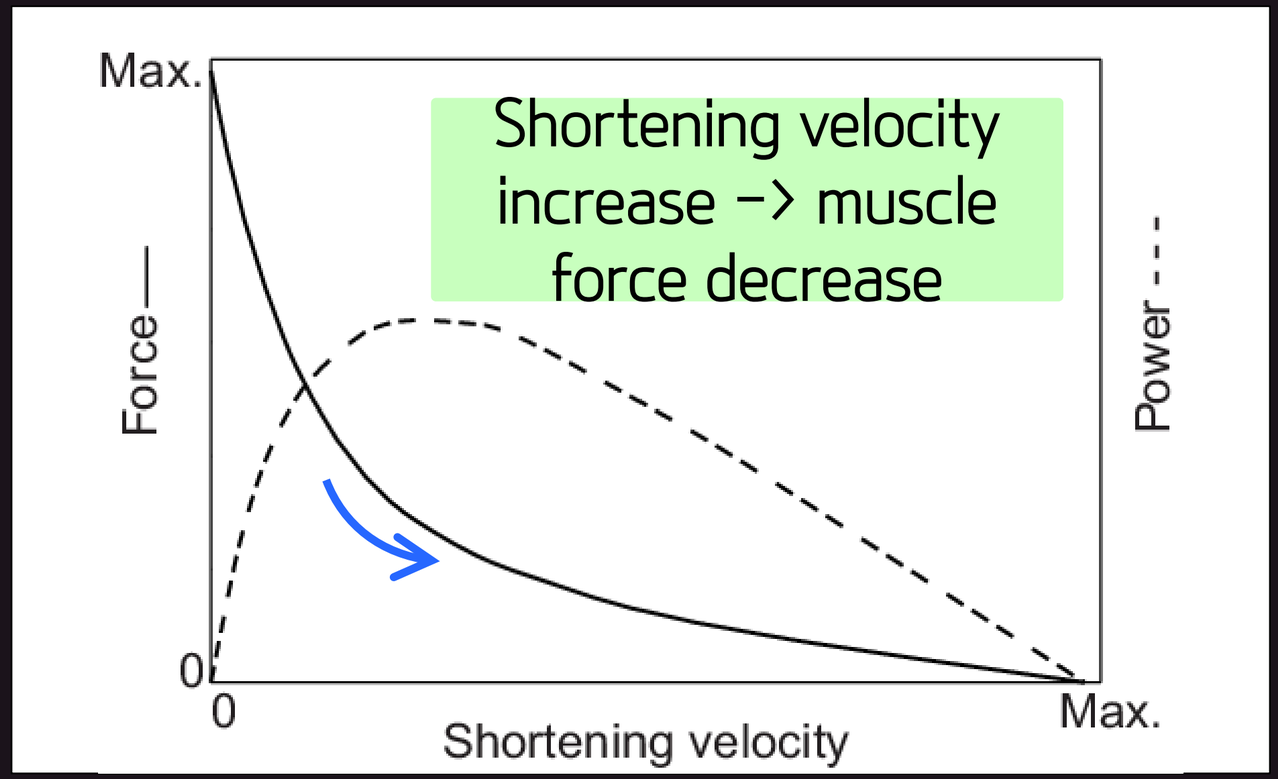


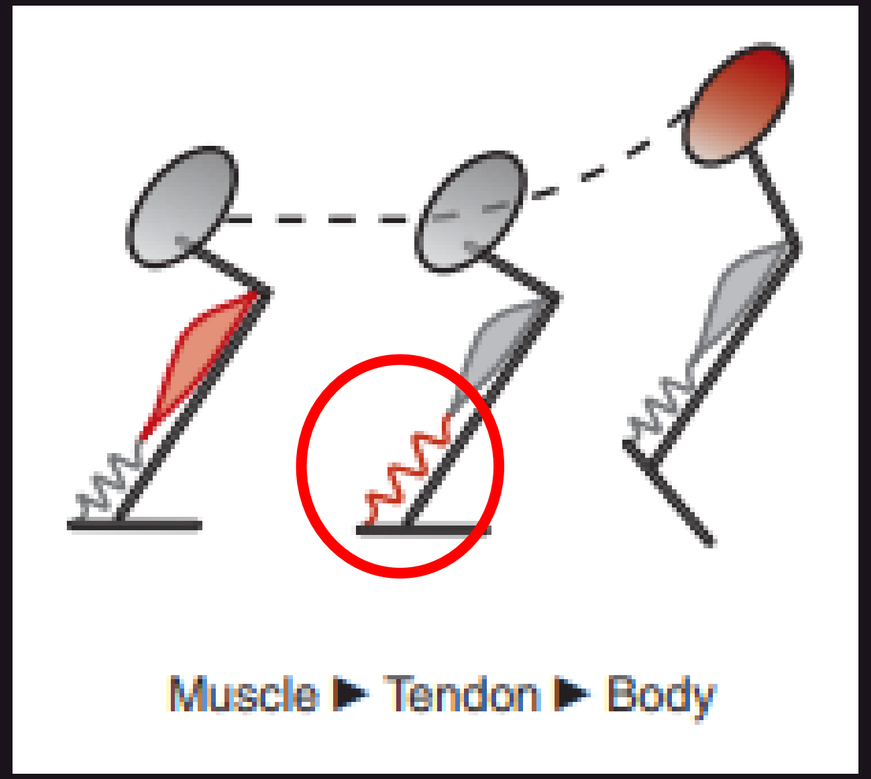

Like trigger!!!

But human do not have this passive structure. Instead…

# Muscle-tendon interaction

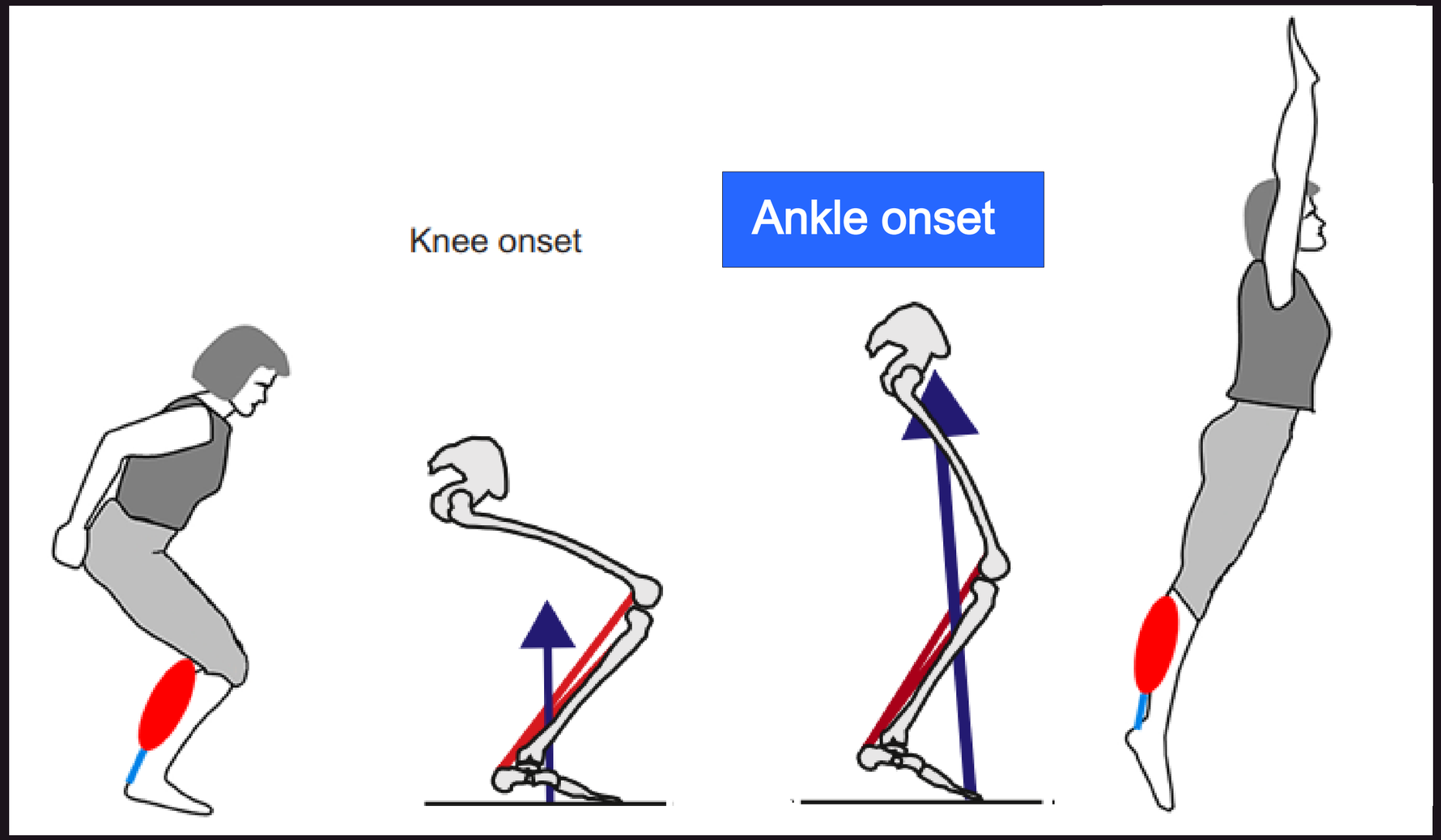
the tendon enabled the muscle to generate greater force at the optimal fascicle length states and amplified the power




(Farris et al., 2016; Kawakami et al., 2002; Roberts and Azizi, 2011)

# Joint coordination




Joint strategy

Delayed ankle onset

⇣

Store and recoil elastic energy ↑

(Farris, Dominic James, et al., 2016)

Altered joint coordination and increased MTU and tendon velocity after training

(Cormie et al., 2009; B. W. Hoffman et al., 2022)

Cooperation between joint kinematics and MTU interaction is the key to a jump mechanism

(Robertson et al., 2018)

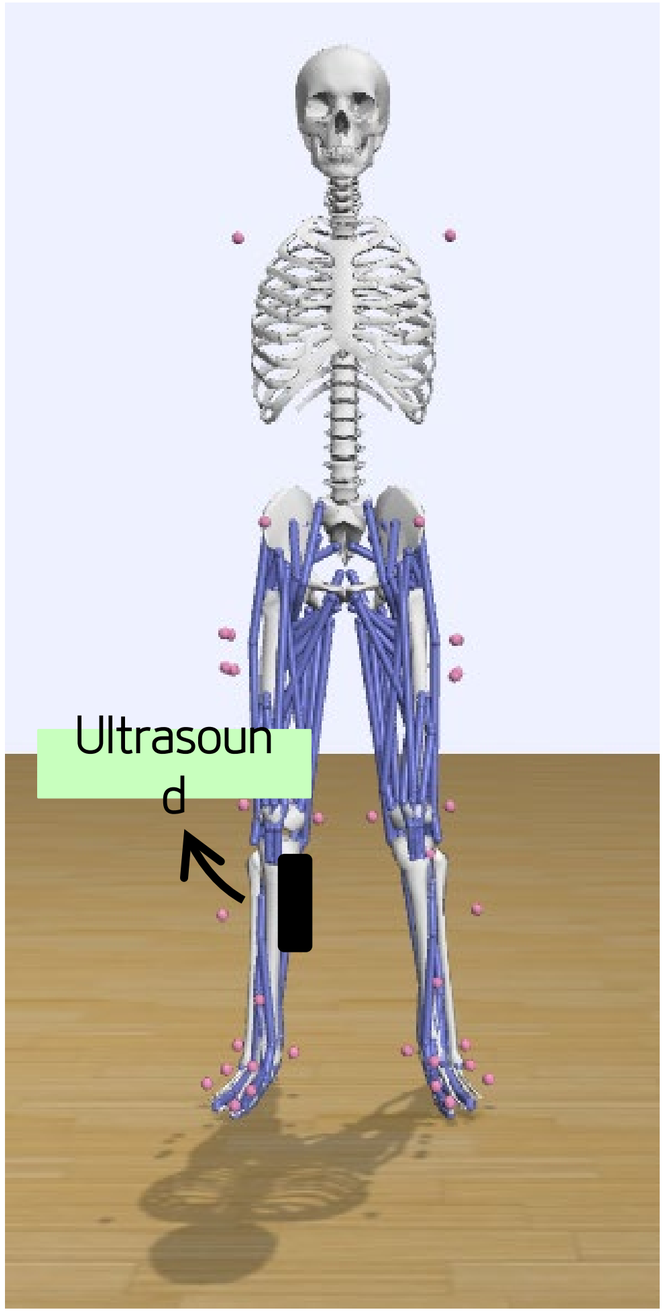
Purpose of this study!

Therefore, this investigation aimed to determine whether the joint coordination and MTU interaction differ based on the level of jump skill and jump height during a CMJ.

# Participants and tasks

| | UG | TG |
|---|---|---|
| Age | 25.1 ± 1.5 years | 25.1 ± 1.9 years |
| Height | 174.4 ± 5.9 cm | 178.6 ± 3.5 cm |
| Weight | 75.8 ± 10.2 kg | 78.1 ± 6.1kg |
| Maximal jump height | < 50 cm | > 50 cm |

a jump to 20% of their height ($CMJ_{20}$)
and the maximum effort jump ($CMJ_{Max}$)



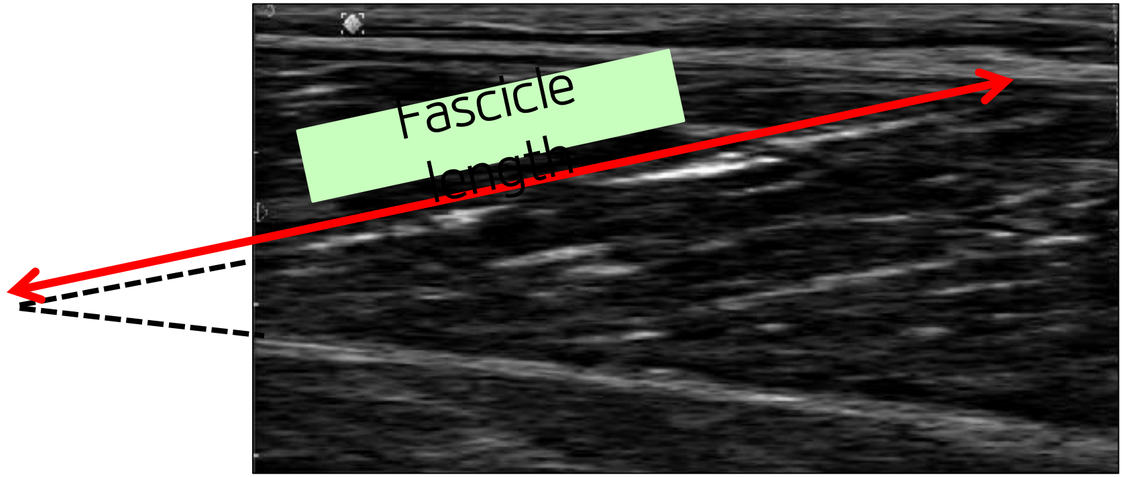

# Methodology

## Joint kinematics & kinetics

3D motion capture cameras & Force plates

Muscular modeling program ( Opensim 4.1)

(Arnold, Hamner, Seth, Millard, & Delp, 2013, Thelen, Chumanov, Best, Swanson, & Heiderscheit, 2005)




## Architecture of Medial gastrocnemius

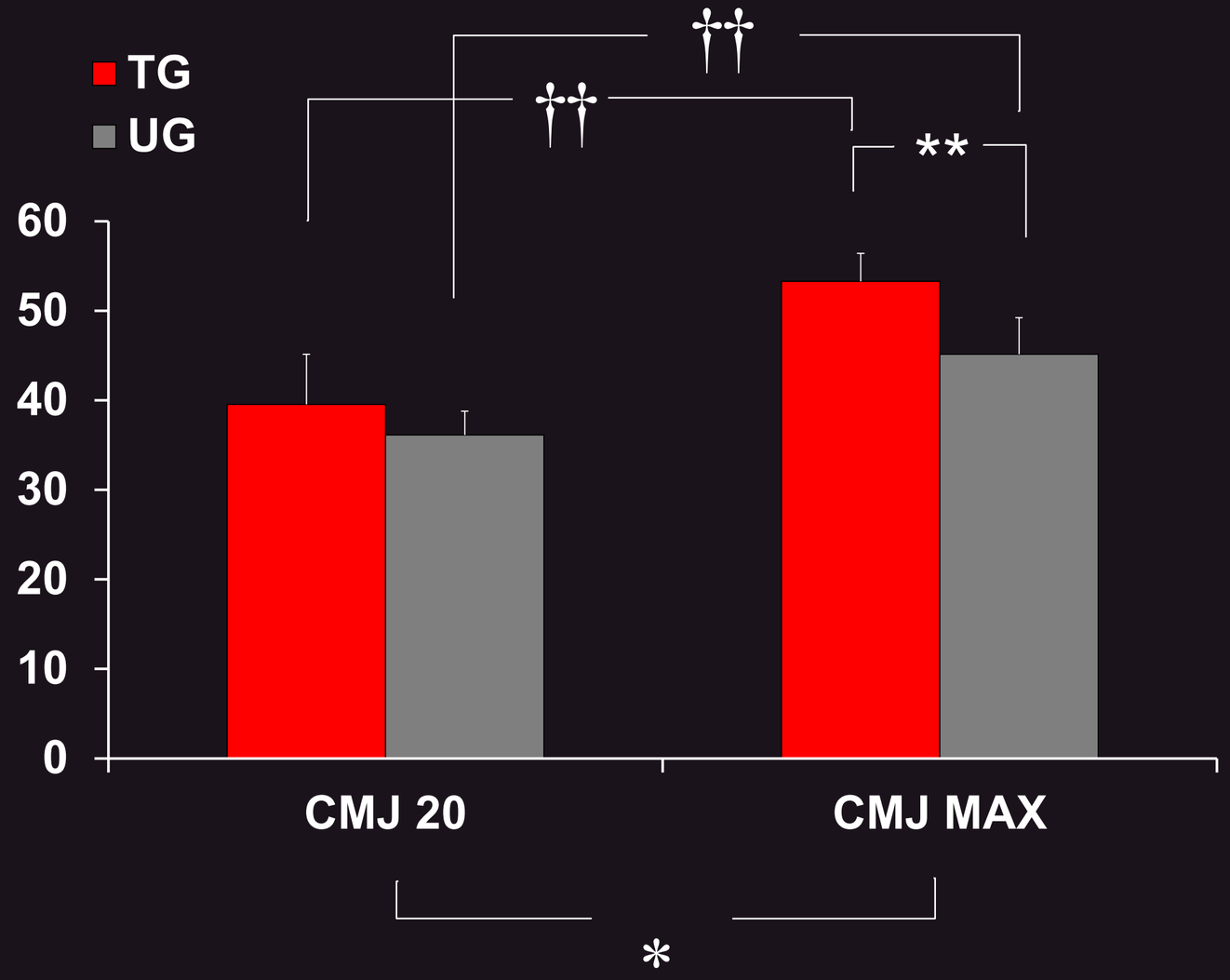
B-mode realtime ultrasound

# Statistics

| Repeated measures ANOVA | A reliability method |
| --- | --- |
| to verify the effect of interaction between the group and the task ( $p$ <.05) | intra -class correlation coefficients for days [ICC]<br>0.835–0.997 for $CMJ_{20}$<br>0.945-0.998 for $CMJ_{MAX}$ |

# Jump height (cm)

| Tasks | CMJ 20 < CMJ MAX |
|---|---|
| CMJ 20 | TG = UG |
| CMJ MAX | TG > UG |

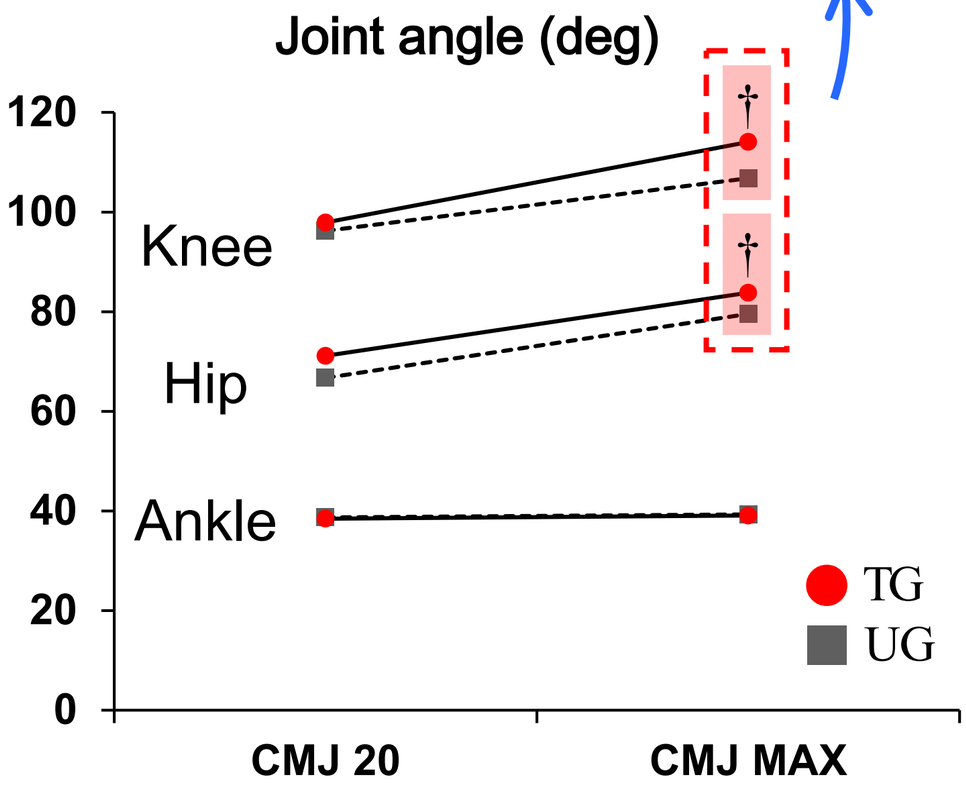



*TG vs UG regardless of tasks. † $CMJ_{20}$ vs $CMJ_{Max}$ regardless of groups.

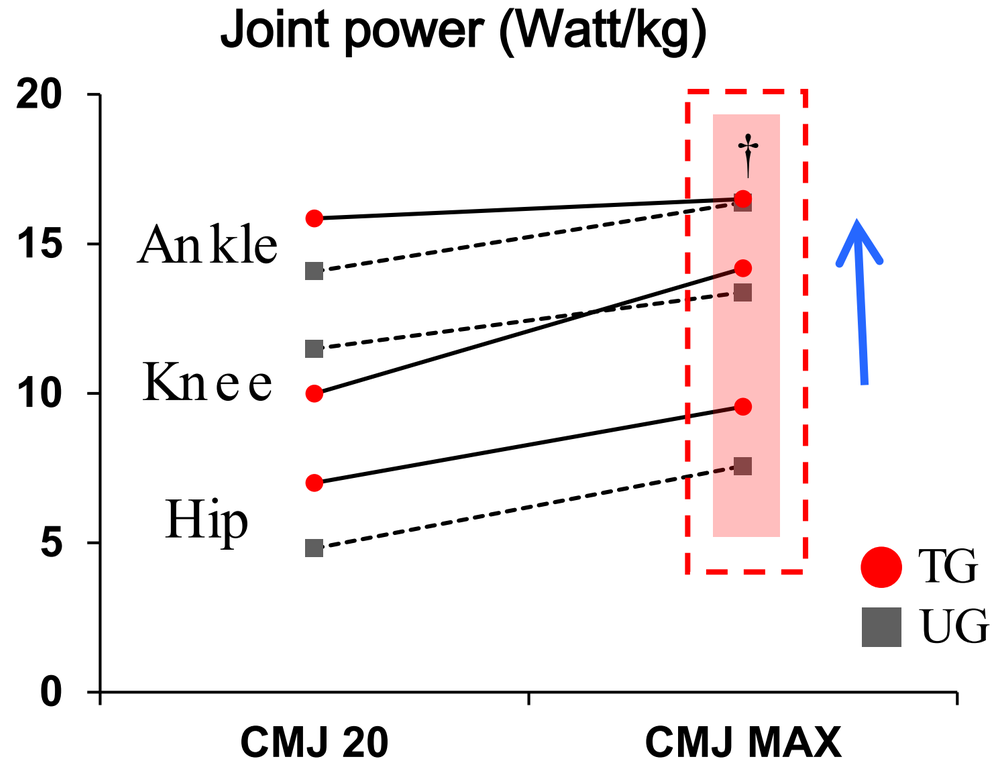
**TG vs UG in $CMJ_{20}$ or $CMJ_{Max}$. ††TG or UG in $CMJ_{20}$ vs $CMJ_{Max}$.

# Results ($CMJ_{20}$ vs. $CMJ_{MAX}$)

Increased angle of proximal joints

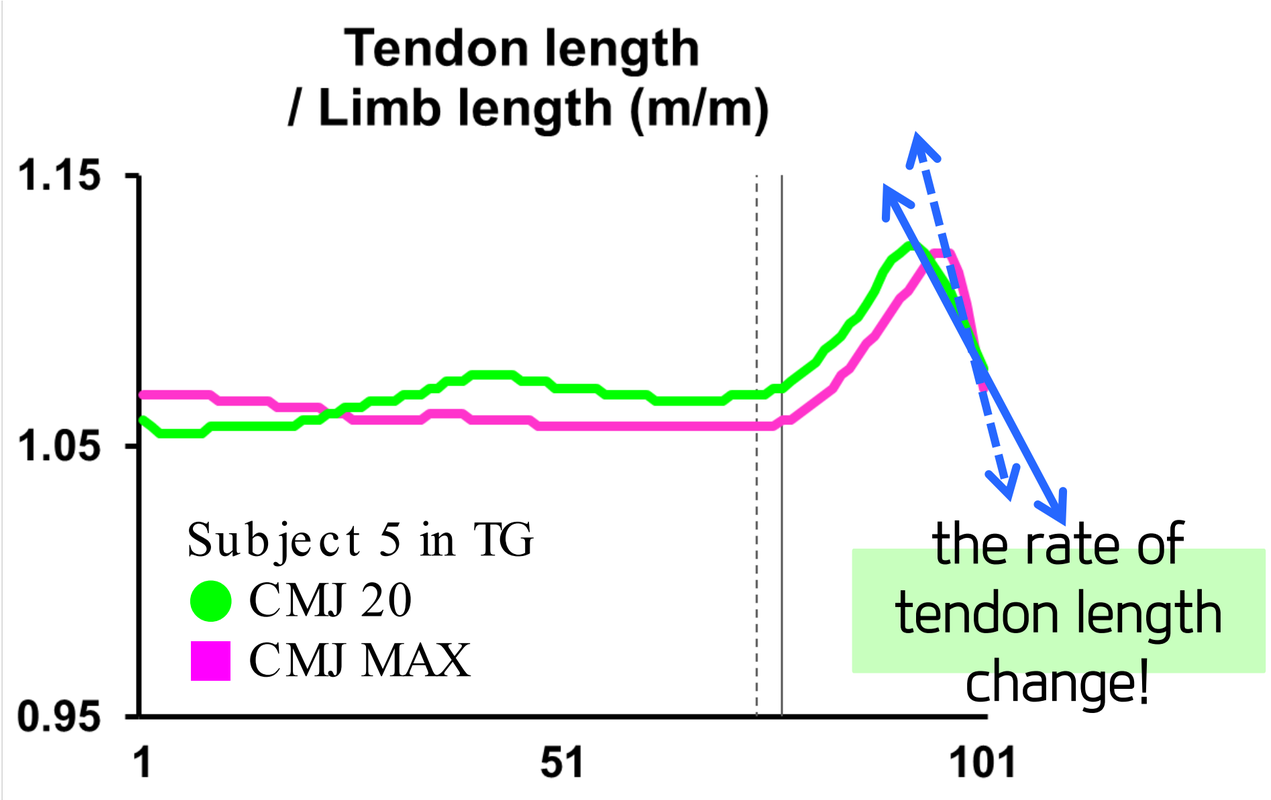



Increased velocity and power of all lower extremities joints

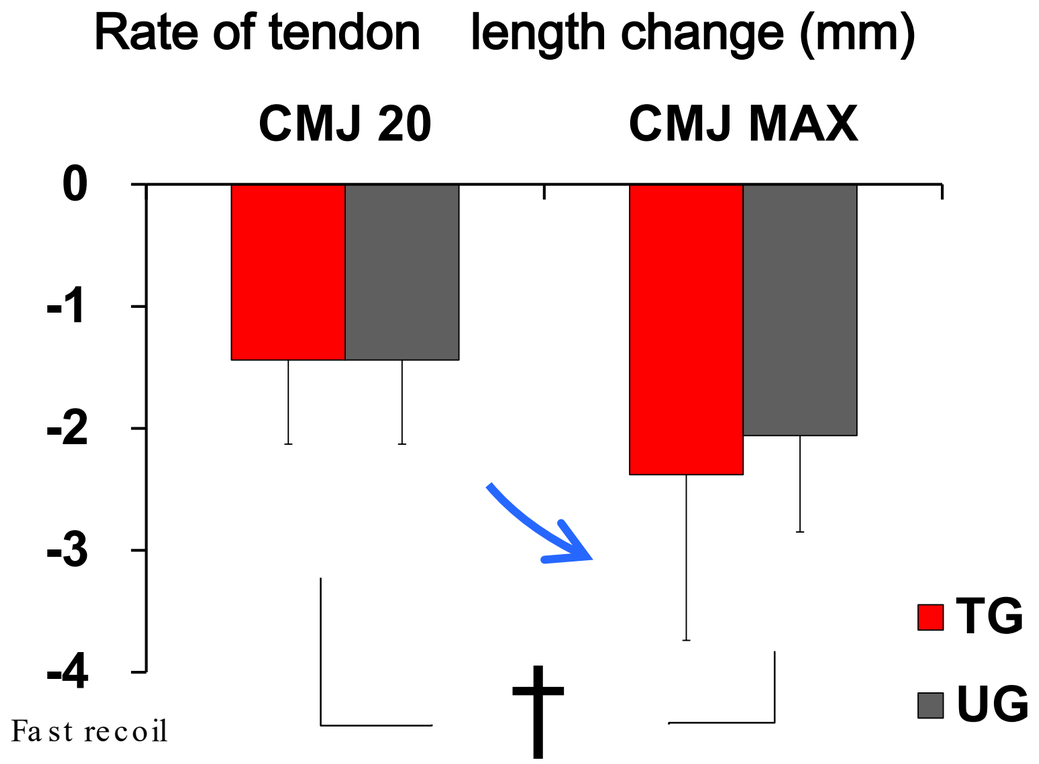



† $CMJ_{20}$ vs $CMJ_{Max}$ regardless of groups.

# Results ($CMJ_{20}$ vs. $CMJ_{MAX}$)




the rate of tendon length change!




Increased the rate of tendon length change after the peak MG tendon length

† $CMJ_{20}$ vs $CMJ_{Max}$ regardless of groups.

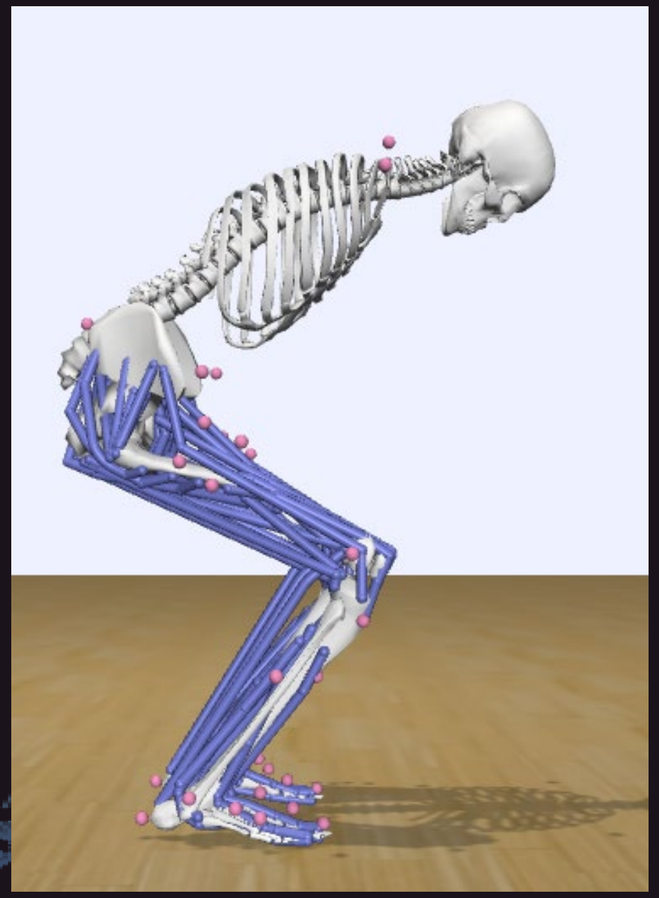
# Jump strategy to enhance jump height regardless of groups

Use proximal joints and increased joints velocity

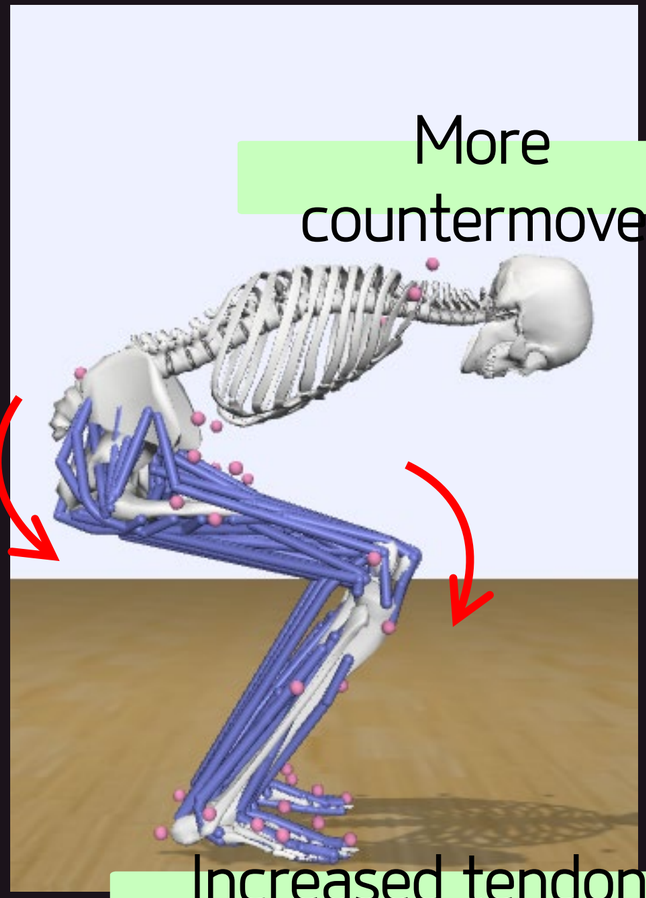
The faster recoil velocity

**Elastic energy Usage ↑**

## CMJ 20



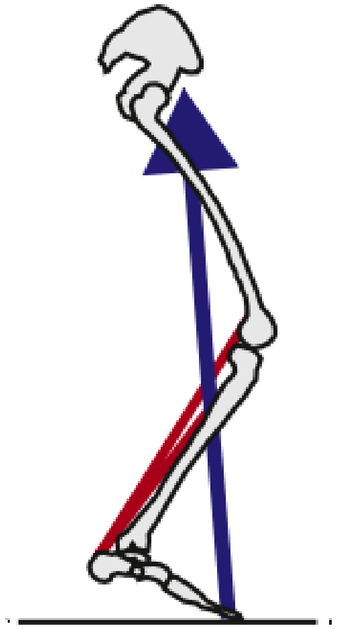
## CMJ MAX

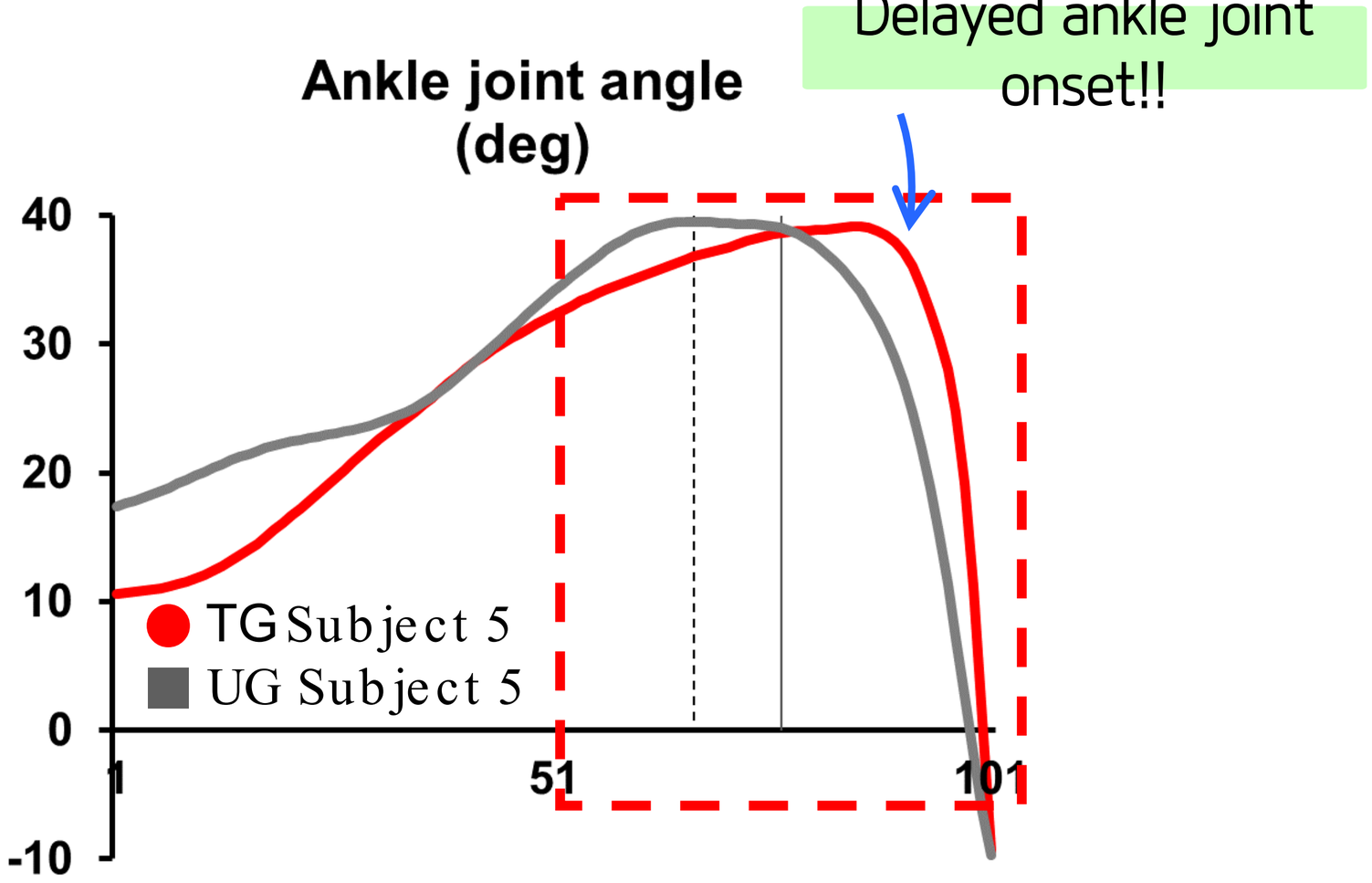


# Results (TG vs. UG)

No difference in joint kinematics and kinetics
But, different joint coordination was shown in TG

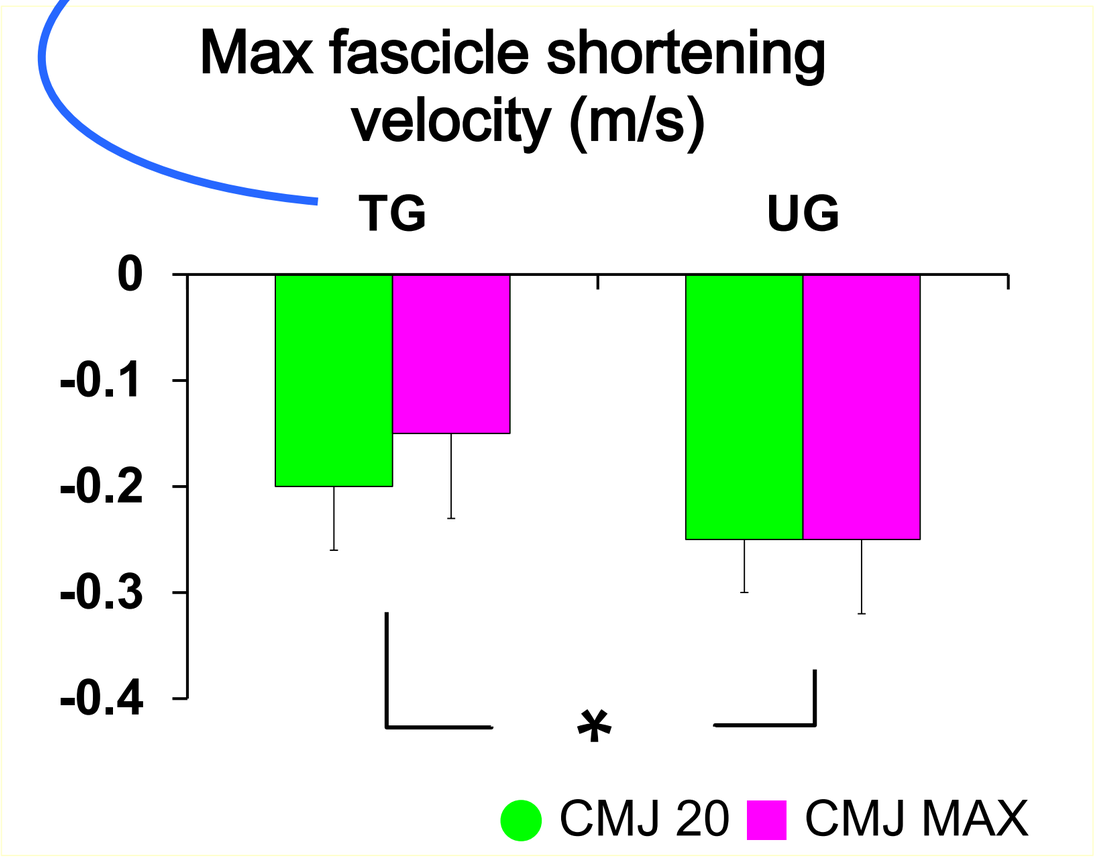
Ankle onset



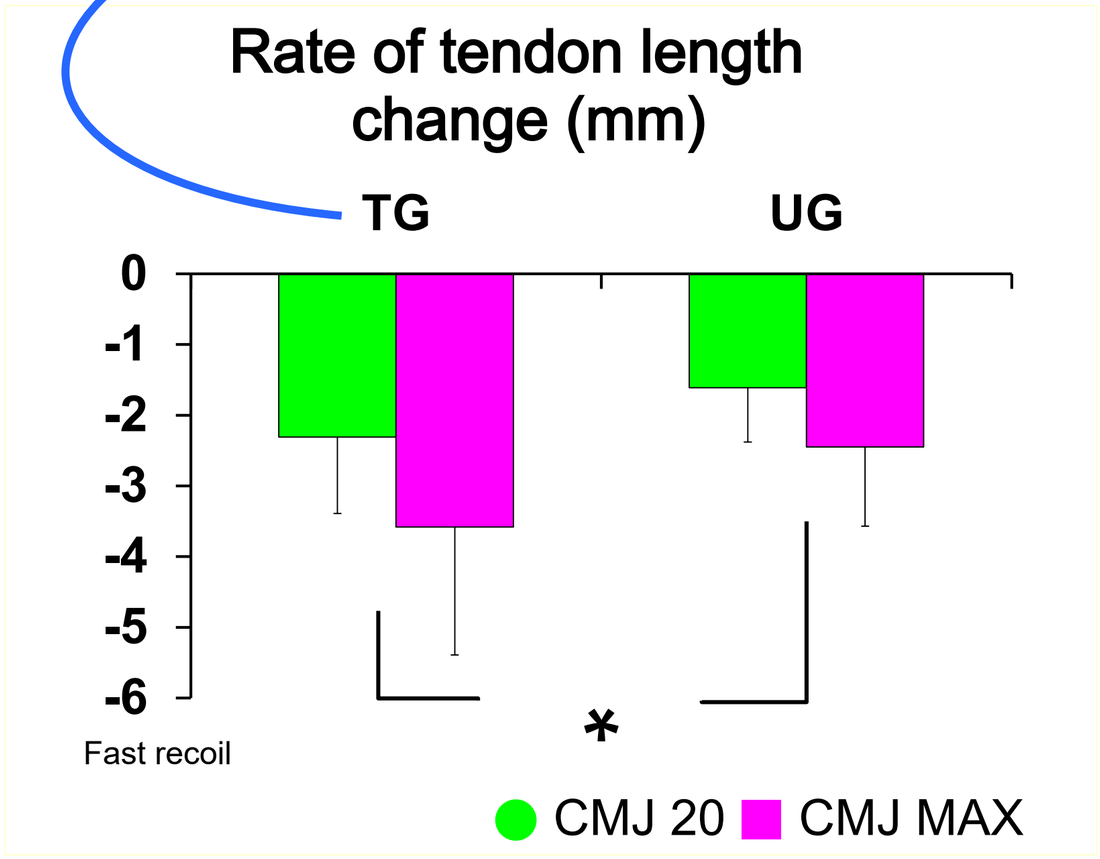


# Results (TG vs. UG)

Less fascicle shortening velocity




Greater the rate of tendon length change after the peak MG tendon length

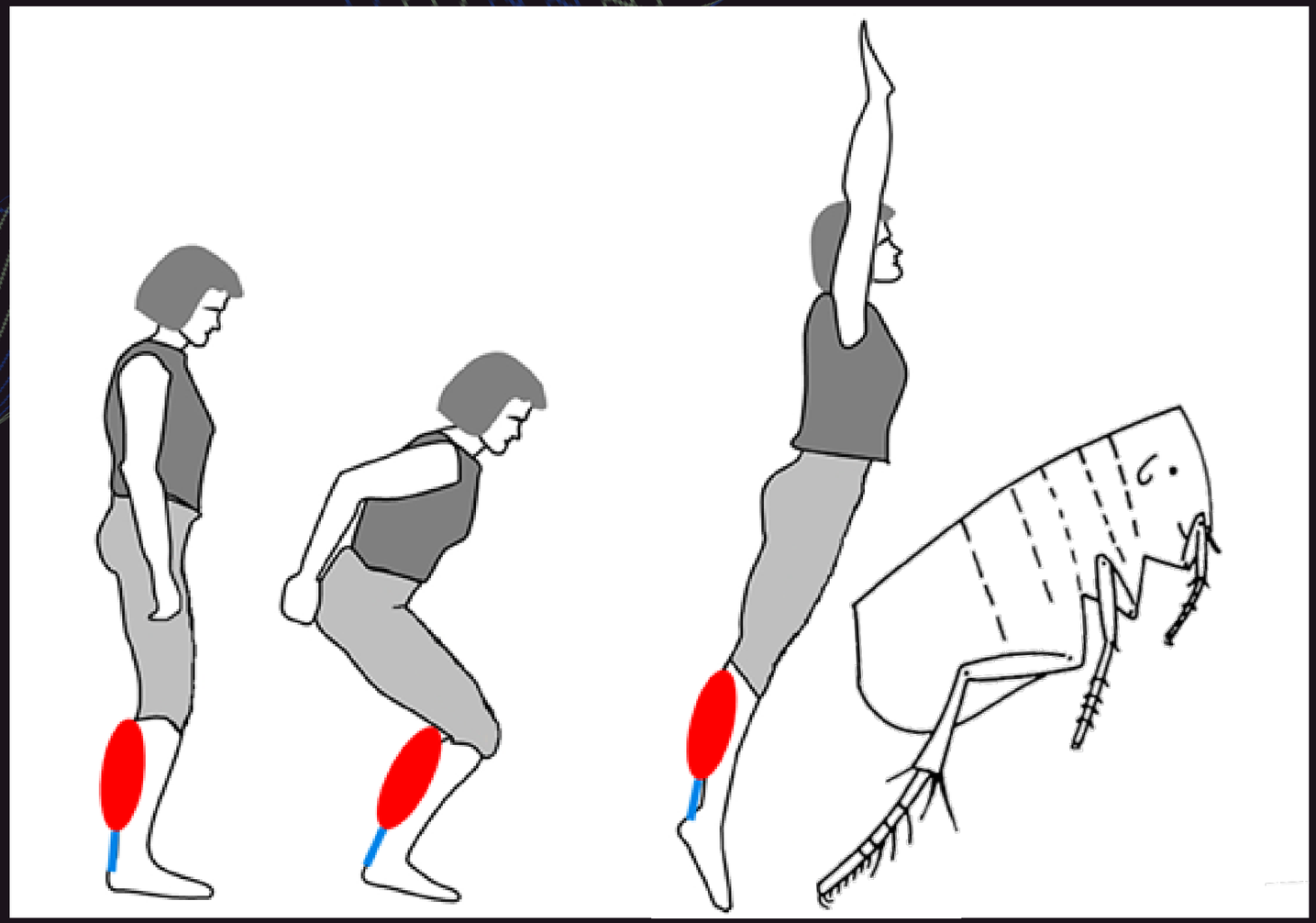



the tendon enabled the muscle to generate greater force at the optimal fascicle length states and amplified the power

# The catapult-like jumping mechanism in higher jumping group

delayed ankle joint extension and instantaneous recoiled elastic energy

They used jump strategy like a catapult mechanism



# Take home Message

Key points

As jump intensity increases, the kinematics and kinetics of the lower extremity enhance as expected, regardless of jumping skill level.

But, the higher jumping group seems to utilize the dynamic catapult-like mechanism better.

When analyzing jump performance, muscle-tendon interaction, in addition to joint coordination, should be considered an essential factor.