BIOMECHANICAL BASIS OF HUMAN MOVEMENT

Problem Title	Designing an Improved Multi-Joint Finger for a Humanoid Robot

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Learning Outcome(s)	
1	Describe a muscle's joint action(s) based on knowledge of its origin and insertion
2	Analyse the effects of the interactions between antagonistic muscles
3	Design a finger that can independently flex and extend its proximal and distal interphalangeal joints

Concepts / Competencies expected to engage with	• Muscle actions at joints • Agonists and antagonists • Intrinsic and extrinsic muscles

Course Level	Undergraduate, introductory biomechanics course

This problem involves data analysis	Yes	No X	Maybe

Approximate Length	30 mins

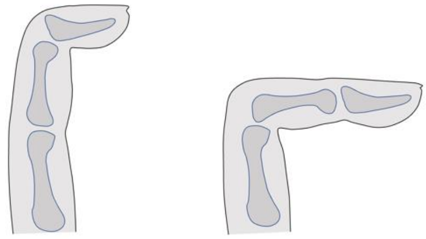
Class/ Group Size	3-5 per group; ideally no more than 30-40 students per facilitator

Useful References	• Floyd, R. T., & Thompson, C. W. (2020). *Manual of structural kinesiology* (Twenty-first edition). McGraw-Hill. • Park, J., Lee, C.-H., Choi, Y., Joo, I.-H., Lee, K.-H., & Kim, S. J. (2020). Extension mechanism of the proximal interphalangeal joint of the human phalanx: a cadaveric biomechanical study. Korean Society for Surgery of the Hand, Annual International Meeting 2019. *BioMed Research International*, 1–5. https://doi:10.1155/2020/7585976

Mode of Instruction	Synchronous or asynchronous

The Scenario:

You work for a company who build humanoid robots. The company want to design a new robot that is as realistic as possible – so joints will be moved using artificial tendons attaching to artificial bones etc. – but they also want to incorporate subtle improvements, one of which would permit the distal interphalangeal joint (DIP) to flex and extend independently of the proximal interphalangeal joint (PIP). The resultant increased adaptability of grip shape would, for example, allow the option for the fingers to remain in closer contact with an object while interacting with features on its surface (such as switches). In order to reduce manufacturing costs, you have been asked to identify the minimum number of tendons that would be needed and where they should insert. To keep the muscle actuators away from the hand, where they would be more likely to be damaged, only extrinsic "muscles" should be included (with a pull being applied to each tendon by a muscle actuator located proximal to the hand).



The Questions:

1. What is the minimum number of tendons needed to meet the design requirements?
2. For each of these tendons, where should they insert and which joint actions at the PIP and/or DIP would they produce if the associated muscle were to be activated in isolation?
3. Which of the attached muscles need to be activated to cause isolated flexion and extension at each of the two joints?

Expected Outcomes:

Working in small groups, students should complete these tasks:

<u>Tendons and Their Insertions (essential):</u> Students are asked to identify how many tendons – to be pulled on by extrinsic muscles – are needed to allow each joint to flex and extend independently, and where each tendon should insert. [Q1, Q2]

<u>Active Muscles (essential):</u> Students should complete a table to show which of the attached muscles need to be activated to produce each of the four isolated joint rotations (PIP flexion, PIP extension, DIP flexion and DIP extension). [Q2, Q3]

<u>The Human Design (optional):</u> Once students have their optimal design, they can research the insertions of the three extrinsic muscles we actually have that run to all four fingers (flexor digitorum profundus, flexor digitorum superficialis and extensor digitorum) and use this knowledge to explain our incomplete range of joint actions!

Groups could be asked to complete a written worksheet and/or feed their ideas back to the larger group.

Guided Questions (Hints):

1. Which side of a joint – palmar or dorsal – should a tendon pass in order to flex or extend, respectively, that joint?
2. If a tendon inserts on the most distal of the three finger segments, at which joint(s) can it cause movement?
3. If a tendon inserts on the middle of the three finger segments, at which joint(s) can it cause movement?
4. What would happen at a particular joint if tendons passing across its palmar and dorsal aspects were pulled at the same time? Why?

Students could use a table with the following columns to support their analysis:

Tendon number (or name, if preferred)	Segment on which it inserts (proximal, middle or distal)	Aspect of the finger (palmar or dorsal)	Action at the PIP joint (if any)	Action at the DIP joint (if any)

Note: The tendon locations and insertions needed to produce flexion and extension of the metacarpophalangeal joint could be explained/discussed, to illustrate the principles required in solving the task.

Follow-up topics, if needed:

1. What internal and external forces should be accounted for in analysing the motion of the robotic hand?
2. Considering all of the possible tasks the robotic hand might be involved in, discuss the accuracy of assigning the names “origin” and “insertion” to the attachments.