Signals and Strength

Trace a muscle signal and design a test of motor recruitment.

HS-AP4-4 "Describe how a neuromuscular junction functions. Design an experiment to determine how motor recruitment influences the force and velocity of contraction."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Number the steps that carry a nerve signal across the neuromuscular junction to contraction, then underline the variable the research team changes and circle what they measure and keep constant.

From Nerve Signal to Muscle Motion

1. When a drummer snaps a stick upward, a signal must cross a tiny gap before a muscle fiber can pull. An electrical impulse reaches the end of a motor neuron, where calcium enters the nerve ending. This triggers the release of acetylcholine into the neuromuscular junction. Acetylcholine binds receptors on the muscle fiber, starting an electrical impulse that spreads along its membrane and into its interior. Calcium released inside the fiber lets protein filaments slide past one another, producing contraction. An enzyme breaks down acetylcholine, and calcium is pumped back into storage so the fiber can relax.

2. One motor neuron and all the muscle fibers it activates form a motor unit. A stronger effort usually recruits more motor units, so more fibers contribute to total force. Recruitment is not the same as firing a motor unit more often: both can change force, but they are different variables. Shortening velocity means how far a muscle shortens per unit time, not how quickly the nerve signal travels. At the same external load, activating more fibers may allow the muscle to shorten faster. If the muscle cannot shorten because it is held still, its shortening velocity is zero even while it produces force.

3. A research team tests an isolated muscle with its motor nerve intact. They raise the strength of brief electrical pulses to the nerve to activate different numbers of motor units, keeping pulse frequency and duration unchanged. In one set of trials, the muscle is held still and a sensor measures peak force. In another set, the muscle lifts the same load each time; a motion sensor measures distance shortened and elapsed time to calculate velocity. The team repeats each pulse strength, allows rest between trials, and compares results at matching strengths. Electrical stimulation recruits axons, but its recruitment order need not match voluntary movement.

2 ANSWER WITH EVIDENCE

Use the passage

1. Trace the steps from an impulse reaching the motor neuron ending to the muscle fiber contracting.

2. Why does the team keep pulse frequency unchanged while raising pulse strength?

3. Why does the team use held-still trials for peak force but lifting trials for shortening velocity?

4. How do using the same load and allowing rest between trials help the team test the effect of recruitment on shortening velocity?

3 YOUR TURN

Your own words

Design a follow-up test of whether a heavier load changes shortening velocity at the same level of motor-unit recruitment. In five or six sentences, explain how the neuromuscular junction starts contraction, how you will vary recruitment and load, how you will measure force and velocity, what you will keep constant, and what you predict.

Signals and Strength

PART 1 · READ AND MARK

Number the steps that carry a nerve signal across the neuromuscular junction to contraction, then underline the variable the research team changes and circle what they measure and keep constant. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	Trace the steps from an impulse reaching the motor neuron ending to the muscle fiber contracting.	**Calcium enters the nerve ending, causing acetylcholine release. Acetylcholine binds muscle receptors and starts an impulse in the fiber. Calcium released inside the fiber allows protein filaments to slide and the fiber to contract.**
2	Why does the team keep pulse frequency unchanged while raising pulse strength?	**Keeping frequency unchanged helps isolate motor-unit recruitment from changes caused by firing the activated units more often.**
3	Why does the team use held-still trials for peak force but lifting trials for shortening velocity?	**A held-still muscle can produce measurable force, but its shortening velocity is zero. Lifting trials let the team measure shortening distance over time.**
4	How do using the same load and allowing rest between trials help the team test the effect of recruitment on shortening velocity?	**The same load keeps resistance from changing between velocity trials. Rest reduces the chance that fatigue, rather than recruitment, changes the results.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

I would use an intact motor nerve and muscle and compare two loads the muscle can lift. At the neuromuscular junction, released acetylcholine starts a muscle impulse that leads to contraction. I would change pulse strength to recruit different numbers of motor units while keeping pulse frequency and duration constant. At each strength, I would measure peak force in held-still trials, then measure shortening distance and time during lifts of each load. I would give equal rest between repeated trials and calculate velocity as distance divided by time. At the same recruitment level, I predict the heavier load will produce a lower shortening velocity.

Accept plans that measure peak force and shortening velocity in separate trials and compare velocities at matched recruitment levels. Predictions should account for the effect of load, and controls should distinguish recruitment from pulse frequency or fatigue.