Work Those Muscles

Kinesiology Lab Days

Presentation Notes

Introduction

Purpose and Description

Students will investigate...

- Skeletal muscle anatomy and contraction physiology
- Force production, moment of force, and moment arm
- Energy systems and muscle fatigue

Muscle Anatomy and Contraction Mechanisms

Roles of Muscles Within the Body

Before we dive into muscle anatomy, we should discuss the role of muscles within the body. The first is **Movement**. Muscles are activated by motor neurons to move the body; these movements can be something as large as a leap or as small as a finger twitch. The next role is **Support.** Muscles help to provide structural support and stability from the organs and bones within your body by surrounding them and acting as layers between them and external forces. The final role is **Protection.** Similar to support, muscles act to protect these internal components from external forces by being able to brace the body for impact and acting out relax responses as well as in a multitude of other ways. These are just three of the main roles of muscles within the body but there are many more.

Muscle Anatomy – Motor Unit

A Motor Neuron, as seen on the left, is a nerve cell that carries brain and spinal cord signals to the muscle fibre to produce movement. Skeletal muscle tissue is made of many muscle fibres. Each muscle fibre contains numerous sarcomeres, which are contractile units that allow for muscle contraction. If you were to zoom into a muscle and follow a single motor neuron, you'll see that it branches off and innervates several muscle fibres. The motor neuron and all the muscle fibres it supplies is called a **Motor Unit,** as seen on the right**.** A motor unit represents a functional part of the muscle and many motor units make up each skeletal muscle.

The Basics of Muscle Contraction

Muscle contraction arises as a result of electrical activity being relayed through our nervous system to muscle fibres. The control of movement first begins in the brain. The electrical signals from the brain are passed through the spinal cord and relayed through networks of motor neurons which connect directly to muscle fibres. Activation of the motor neurons is what causes the muscle to contract, produce force, and ultimately cause movement.

Muscle contraction does not produce the same force each time. The brain can send signals for varying amounts of force depending on what is needed for the task. What changes the amount of force production is the number of motor neurons that are activated from the original signal. Motor neuron activation is an all or nothing response, this means that a motor neuron is either fully activated or completely inactivated, therefore the amount of force produced is a function of how many motor neurons are activated.

The Basics of Force Production

We dive deeper into force production and look at cross sections of the spinal cord and muscle cell. In the image of the left it shows how the motor nerve leaves the spinal cord and connect to muscle fibres to activate them. These muscle fibres are colour coded to show which motor nerves connect to them. On the image on the top right, the different types of motor units are highlighted and then shown based on when they are recruited compared to force underneath. Now that we have covered the basics of force production, lets dive deeper and look at muscular contraction on a cellular level.

Muscle Contractile Proteins

Here we see a simplified drawing of a sarcomere. A **Sarcomere** is the basic contractile unit of muscle fibre. Each sarcomere is composed of two main protein filaments – actin and myosin – which are the active structure responsible for muscular contraction. The red lines are the actin, and the blue is myosin. When the muscle is relaxed, the actin filament is long and separated. When contracted, the sarcomere shortens, and the actin filaments slide across the myosin to move closer together. You will notice that the length of the myosin does not change, just the actin.

Muscle Contraction at a Cellular Level

You may have heard about the **"sliding filament theory"** – this explains the mechanism of how muscles contract. Contraction begins when the electrical signal from the brain arrives at the motor neuron attached to the muscle fibres. The motor neuron releases a neurotransmitter that initiates "**Excitation Contraction Coupling"** or more simply put, excitation of a muscle fibre evokes contraction. Cross bridges begin to form as the thick filament (myosin) binds with the thin filament (actin). This binding and crossbridge formation is facilitated by adenosine triphosphate (ATP). When ATP is broken down, the energy from this event helps myosin bind to actin and change shape. The shape change by myosin causes a "power stroke" which slides actin (thin filament) across myosin (thick filament). This sliding across each other leads to shortening of the sarcomere, resulting in muscle contraction.

Muscular Contraction vs. Relaxation

Muscular contraction, as we have been discussing is when the muscle fibres shorten to generate force and movement. An example of this is a bicep curl with a 10 lb weight. Muscular relaxation is when the muscle that was contracted returns to its resting length. An example would be once the bicep curl is finished and the weight is no longer held by the individual.

Discussion Questions:

Why is muscle contraction the focus as opposed to muscle relaxation

In what ways do you think the muscles of your body act as a protection mechanism?

The Core

Two Myths and a Fact About the Core

Here, we have listed some popular, common myths along with a fact about the core for you to think about. After reading through them, reflect on which of the three options you think are myths and which one is the fact! **(Click to reveal question boxes)**

Myth 1: While the core does include our abdominal muscles, they are only one layer of many that make up the core as you will see in the next few slides.

Myth 2: Crunches and sit-ups are some of the most popular core exercises, but they only focus on strengthening our abdominal muscles. Because the core is made of many groups of muscles that aren't being worked during these exercises, doing just situps and crunches neglects the rest of our core muscles. So, when you want to improve your core strength, don't forget to engage the entirety of your core!

Truth: Your core works to stabilize your body during the movement of your arms and legs. This means that your core is essentially always active in keeping you upright and stable during most daily activities like when you walk, run, kick a ball, reach with your hand to grab something, and many, many more movements!

Overview of the Core Muscles

Now that we've debunked some common myths about the core, we're ready to dive a bit deeper into its anatomy. This diagram shown gives us a brief overview of the layers and muscles that help make up our core!

Overview of the Core Muscles – Outer Layer

The first layer of the core that we will discuss is the outer layer. This layer is the one that is most noticeable on the exterior as it includes the rectus abdominis aka the "6 pack muscles", the external obliques, erector spinae and the gluteal region muscles. The erector spinae muscles help in supporting the spine while the external obliques help with flexion, rotation, and lateral bending of the trunk. Rectus Abdominis muscles are utilized when flexing the core. The gluteal region helps move the hip joints and stabilizes the pelvis.

Overview of the Core Muscles – Inner Layer

The inner layer of the core is comprised of the Internal Obliques, Transverse Abdominis, Multifidus, and Diaphragm muscles, along with the muscles of the pelvic floor. The internal obliques share a similar role and appearance to the outer layers' external obliques, but its muscle fibres run in the opposite direction. The transverse abdominis is the innermost of the abdominal muscles, and it plays an important role in stabilizing the lower spine and pelvis during movement.

Overview of the Core Muscles – Supporting Layer

The core's supporting layer includes the latissimus dorsi, or the "lats", which works to extend, internally rotate and adduct the shoulders, as well as support the trunk. When thinking about the lats function, think about performing pull-ups and/or lat pulldowns! Other muscles include the Quadratus Lumborum, which works to stabilize and extend the trunk, and the Psoas Muscles, which is responsible for the flexion of the trunk and hips. The Psoas muscles play roles in stabilization of both the hip and lower back.

The McGill Big 3

Dr Stuart McGill

Dr. Stuart McGill is a professor emeritus who completed 32 years as a professor at the University of Waterloo. He completed his PhD at the University of Waterloo and continued to conduct research in the spine biomechanics laboratory. His research focused on understanding how the low back functions, how the low back becomes injured, and how to apply this information to further investigate hypotheses related to prevention of injury and optimal rehabilitation of the injured back.

Dr. McGill has used his expertise to teach the proper form of exercises to Olympians and elite athletes to improve their spine health and performance. His research and publications on low back disorders and spine health have changed the way health professionals and athletes approach performance, injury prevention, and rehabilitation.

One of Dr. McGill's biggest contributions is the 'Big 3' which we will explore more throughout this workshop.

Building Core Strength

On this slide we will discuss building core strength! Core stabilization requires 3 components: neuromuscular, passive and active. The neuromuscular component helps with performing the correct motion, exercise and with patterns of muscle activation. The passive component helps with the good integrity of static tissues including vertebrae, intervertebral discs, ligaments and joints. The active component consists of the core musculature and provides dynamic stabilization.

Bracing the Core

Before starting a core exercise, it is essential to brace our core and keep it braced throughout the exercise. Bracing helps to engage our core and protect our spine.

There are several ways to explain how to brace our core, but a good example to think about is to pretend someone is going to punch you in the stomach. In anticipation of being hit, you would tighten and contract your muscles, (i.e., brace them). In fact, your core naturally braces when you cough or sneeze to protect your spine.

Another point would be to imagine the core as a jelly cube and when you train all the muscles on 4 sides, contract all your core muscles to develop a "brick wall" which will allow transmission of force as you perform exercises. When bracing your muscles, you want to make sure you are not over-contracting to the point where you suck your belly button to your spine. This decreases spine stiffness, and thus compromises spine stability.

Anatomical Planes

To orient ourselves in any kinesiology-based conversation, we must first identify which plane of view we are observing! Sagittal divides the body into left and right sections. Transverse divides the body into upper and lower sections. And frontal divides the body into front and back halves.

McGill "Big 3" – Fundamental Core Exercises

The McGill Big 3 consists of three fundamental core exercises. In addition, Dr. McGill includes a warmup of the spine before completing the exercises.

To perform the cat camel warm up, you will get on an all-4's position, meaning on your hands and knees. To get into the cat position, slowly arch your back so you are in a rounded position. While arching, inhale a deep breath. At the end of this movement, your head will be looking down towards the ground. Pause for a few seconds before moving into the camel position. While exhaling, slowly extend your back from its rounded position until you end the movement with your head facing straight forward. This exercise is intended to be a motion exercise and not a stretch, therefore focus on the motion and not reaching the end ranges of flexion and extension movements.

Perform this cat camel 5-6 times to complete your warmup.
The Big 3 fundamental core exercises include the half curl up, bird dog, and a side bridge.

Introduction to the Half Curl Up

The half curl up is a great exercise because:

1. it places minimal stress on the spine due to the neutral position
2. It activates rectus abdominis, transverse abdominis, and internal/external obliques.

This movement works in the sagittal plane.

Activity 1A – How to Perform a Half Curl Up

This is the first exercise of the McGill Big 3, a half curl up. Follow the instructions on the slide to perform this exercise. On the slide you will see 2 images showing correct form for step 1 and step 2. The third image is incorrect form of step 2, you will notice that the individuals head is raised off of the ground too high and there is no lumbar support from their hands.

Introduction to the Side Bridge

The side bridge is an important exercise that improves force transmission from the lower body to the upper body. It activates the obliques, transverse abdominis, and the gluteal muscles. The side bridge occurs in the frontal plane.

Activity 1B – How to Perform a Side Bridge

This is the second exercise of the Mcgill Big 3, the side bridge. Follow the instructions on the slide to perform this exercise. On the slide you can see two images showing correct form of step 1 and step 2. You will notice in the correct form of step 2; the individual's body is in a completely straight line. The third picture is showing incorrect form of step 2, where the individuals' hips are out of alignment with the rest of their body.

Introduction to the Bird Dog

The bird dog is great for building low back function; it engages the core and back.
The bird dog activates the erector spinae, rectus abdominis, transverse abdominis, and the glutes. This movement occurs in the sagittal plane.

Activity 1C – How to Perform the Bird Dog

This is the third exercise of the McGill Big 3, the bird dog. Follow the instructions on the slide to perform this exercise. On the slide there are images of proper form of Steps 1 and 2. In step 2 you will notice the individual is in a completely straight line, whereas in the third picture it is showing improper form of step 2 with the individual unlevel.

Discussion Questions Continued

Why do you think Dr. McGill chose these exercises as the "Big 3"?
How would having a weak supporting core layer affect your daily life?

Energy Systems and Muscle Fatigue

How do muscles get the energy they need?

ATP is the primary energy source used by muscles and it is required for muscle contractions to occur. When oxygen is present and can be readily transported to the muscle cell, aerobic cellular respiration is used. Oxygen is used as an electron acceptor in the oxidative phosphorylation pathway where ATP is then produced at a high rate.

When the demand for ATP is high, but the supply from oxidative phosphorylation is low, the muscle must gain ATP from other sources, such as through anaerobic respiration, glycolysis. In this process, glucose is the only substrate used to produce ATP. However, this process causes a buildup of lactic acid as it is a by-product of anaerobic glycolysis. As lactic acid builds up it increases the acidity inside the muscle cell which can interfere with some biochemical reactions necessary for contraction and relaxation.

Types of Muscle Fibres

As briefly touched on in earlier slides, there are 2 broad categories of muscle fibre types: slow twitch and fast twitch. Slow twitch muscle fibres are smaller and allow for fine and precise movements, such as writing with a pen. They rely on aerobic respiration which uses oxygen, so these fibre types fatigue slower. Therefore, these fibres are good for maintaining your posture (e.g., standing) and endurance activities.

Fast twitch muscle fibres tend to be larger and are used for quick bursts of power, such as weightlifting or sprinting. They have a large capacity to produce ATP anaerobically, thus leading to a faster fatigue. Due to these characteristics, smaller fibres (slow twitch) tend to be activated first, followed by larger (fast twitch).

For example, muscles in the hand are made of mainly fast twitch muscle fibres. This is why you are unable to write a long essay on paper continuously without your hand feeling tired. The fast twitch fibres in your hand fatigue faster and can't sustain contraction for long periods of time. Whereas postural muscles, such as muscles in the back and legs, are made of mainly slow twitch fibres. This is why we can stand and move very stabilized for extended periods of time. The postural muscles fatigue slowly due to the slow twitch muscle fibres allowing us to keep our posture all day.

The picture on the right depicts the amount of muscle fibres activated during 3 types of running: Long distance, middle distance, and sprinting. As you can see, the long-distance runner has more slow twitch fibres activated, because they are more fatigue resistant. As you get into shorter and faster running, like the sprinter, you can see it has more fast twitch muscle fibres which are for quick bursts of energy, but fatigue faster.

Muscle Fatigue

Muscle fatigue is a decline of muscle performance during activity. After prolonged exercise, muscles become slower and weaker, therefore reducing the amount of force the muscle can produce. One of the reasons muscle fatigue occurs is when there is a reduction in the energy production that the muscle needs in order to contract and produce force. Another reason is the metabolic breakdown products associated with muscle contraction – we generalize these as "metabolites". Let's use the example of performing squats, eventually you cannot perform anymore repetitions. Your muscles become fatigued, and this may be due to the metabolites and/or a lack of ATP.

Applied Muscular Function

Now let's look at the big picture. Why do we care to look at fatigue in our muscles? We care because muscle fatigue affects our overall muscular function. You may wonder why it is important to assess muscular function? It's important because:

- We can use it as an aid in screening to determine the extent of muscle weakness and or imbalance which could make an individual more prone to injury
- As a guide to rehabilitation after an injury or accident where there has been loss of function
- For exercise prescription – both athletes and fitness participants need programs based on their performance capabilities
- To aid in selection of the best exercises for working on specific problems

Collection sheet for endurance time

In the next experiment you will be testing your muscular endurance through core exercises. We chose to test the muscular endurance of the core because it makes the rest of the body more capable and having a strong core allows you to radiate strength peripherally to distant regions of the body.

Please record your endurance times in Table 1 of the recording sheet which will be provided.

Activity 2: Testing Muscular Endurance Part 1: Left and Right-Side Bridge Test

- This is Activity 2
- You will be testing your muscular endurance.
- There are two tests to the experiment, this is test number 1.
- Follow the instructions on the slide to start the experiment.
- Remember to record your results in the recording sheet.

If students performed Activity 2 at home ahead of time, please skip to slide 38

You should end the test when...

•When should you end the test? The test should end when the subject breaks proper form.

•As you can see in the image on this slide the subject is not maintaining proper form for a side bridge. This mean that shoulders have rolled inwards, head is no longer in line with the spine, hips are sagging, and your calf is touching the mat. These indicate that the subject is starting to fatigue, and that is when the timer should be stopped.

Expected Results: Muscle Fatigue

As the number of repetitions of the movement increases, the rate of muscle fatigue will increase. As previously mentioned, Muscle fatigue is a decline in the ability for the muscle to generate force. A decrease in force generation will cause a decrease in number of repetitions as successive trials are performed. In the lab we can use a bio amplifier to display a biological signal from muscular contractions, much like the image provided here for us to examine.

Activity 2: Testing Muscular Endurance (continued)

•This is experiment Part 2 of Activity 2

•Where you will be testing your muscular endurance by performing a front plank test.

•Follow the instructions on the slide to start the experiment.

•Remember to record your results in the recording sheet.

Incorrect Form of a Front Plank

•Make sure your spine is at level, having your hips too high or too low is incorrect form, which will affect your endurance time.

Things to keep in mind…

It is important that each exercise is performed by each student, to calculate the endurance ratio for the side plank and record it on the recording sheet and to ensure you are maintaining proper posture.

Normative Data (Side Bridge)

Now that you have your results, compare your endurance time to these mean endurance values for both right and left side bridge. Do you meet the norm?

Now look at table 2. If the ratio is less than 1.05 and greater 0.96, this means that the balance between your muscles is good. Does your ratio meet the criteria?

Normative Data (Front Plank)

Now that you have your results from the front plank test compare your endurance time to these normative values. Determine what percentile you fall under.

Discussion Questions Continued

What metabolic system was likely more active near the end of the planking exercises?

Which plank did you find more challenging? Why do you think this might be?

Conclusion

Questions?

In this workshop, we reviewed muscle anatomy and contraction physiology, discussed force production, moment of force, and moment arms, and examined energy systems in relation to muscle fatigue. All of these things go together to explain how our muscles allow us to move each day. There are so many processes going on in our body with each step we take, and that is why it is so important to learn more about it. At the University of Waterloo, we pride ourselves on a multidisciplinary look at muscles, including physiology and biomechanics. We hope that in this workshop you have gained a new understanding to how to 'Work Those Muscles'.

END OF PRESENTATION

Excel Data Collection File

- **Excel data collection file** – to be shared as a collaborative file with students either during the presentation or after.
- This file contains tables and graphs that will automatically update as data is inputted. The students will input their own results.

- Please send the provided summary table to klabdays@uwaterloo.ca. Class averages will be displayed on the Work Those Muscles! data dashboard and each school will be represented by a single average number. Averaging will maintain the anonymity of the data.

Discussion Questions (10 minutes):

1. **Why is muscle contraction the focus as opposed to muscle relaxation?**
   A: Muscle contractions are generated by the signals from the motor neuron and is how we move our bodies; muscle contraction can result in something as big as a leap and as small as a finger twitch.

2. **In what ways do you think the muscles of your body act as a protection mechanism?**
   A: They help your joints to reduce shock absorption, they allow you to brace your body for any type of impact or expected force, fast twitch muscles help you to move out of the way or to catch yourself in potentially dangerous situations. There are many other examples as well!

3. **Why do you think Dr. McGill chose these exercises as the "Big 3"?**
   A: They primarily challenge core stability and utilize a variety of different core muscles while being safe exercises that protect the spine. For example, the side bridge heavily relies on the obliques while the half curl up relies mostly on the rectus abdominis

4. **Why would having a weak supporting core layer affect your daily life?**
   A: Having a weak supporting core layer could put more strain on the low back and result in postural compensations that impede on one's day to day life.

5. **What metabolic system was likely more active near the end of the planking exercises?**
   A: Anaerobic metabolism was likely used near the end of the exercise. This is because this movement required lots of ATP and the demand was higher than the supply from aerobic sources. Therefore, the muscles had to resort to anaerobic metabolism, like glycolysis.

6. **Which plank did you find more challenging? Why do you think this might be?**
   A: Think the primary muscles involved in the side plank vs the front plank (obliques vs rectus abdominis) and which ones would be stronger based on day-to-day life and different sport groups.