Muscles and Swimming
By Santiago Bustos

Abstract

Despite much research on the contents of competitive swimming and training methods, we need more knowledge about the exercises outside of the water that can be done to improve your race. Through swimming physiology, we can better understand which major muscles are used in a swimming race and how we can improve such muscles. By dividing the contents of a sim race into three different sections, my research will better understand the muscles allocated to a different part of the race. t Muscles used at the start of the race consisting mainly of the glutes and hamstrings was found through research; meanwhile, muscles used during the underwaters of the race consist mainly of the erector spinae, and muscles during the breakout of the race consist mainly of the lats, triceps, deltoids, and traps. The fact that many muscles are used in just a tiny portion of the race implies that much can be done outside of the water in the form of exercise to hone these muscles and improve one's race.

Introduction

Figure 1
Tomoru Honda swimming the 200 fly in the 2020 Tokyo Olympics
Source:
https://www.japantimes.co.jp/sports/2024/02/15/more-sports/honda-gold-swimming-worlds/

In a competitive swim race, every milisecond counts. The little milliseconds of each action matter toward the end time of your race. A well-executed start can make the difference between winning and losing. In a swim race, you must consider the three aspects of your start: the dive, the underwaters, and the breakout. The dive is the launch of the swimmer off of a block and into the water. The underwater kicks, better known as “underwaters,” propel you through the water by using your momentum from the initial launch and additional kicks with your legs. Finally, the breakout is at the start of the race, where you start swimming on the water's surface. In this article, the muscles used in each action at the start of the race and how to train those muscles to your advantage will be reviewed.

How Does a Muscle Move

When a muscle moves, tiny signals are sent from the brain into your muscles through small connected pathways. The brain sends these connections to the muscles when a human wants to perform a particular action. The signals sent to the muscles are called action potentials. Action potentials are the voltage that travels across a membrane, causing muscle cells to move. The action potential threshold can go from -55 millivolts to -50 millivolts.

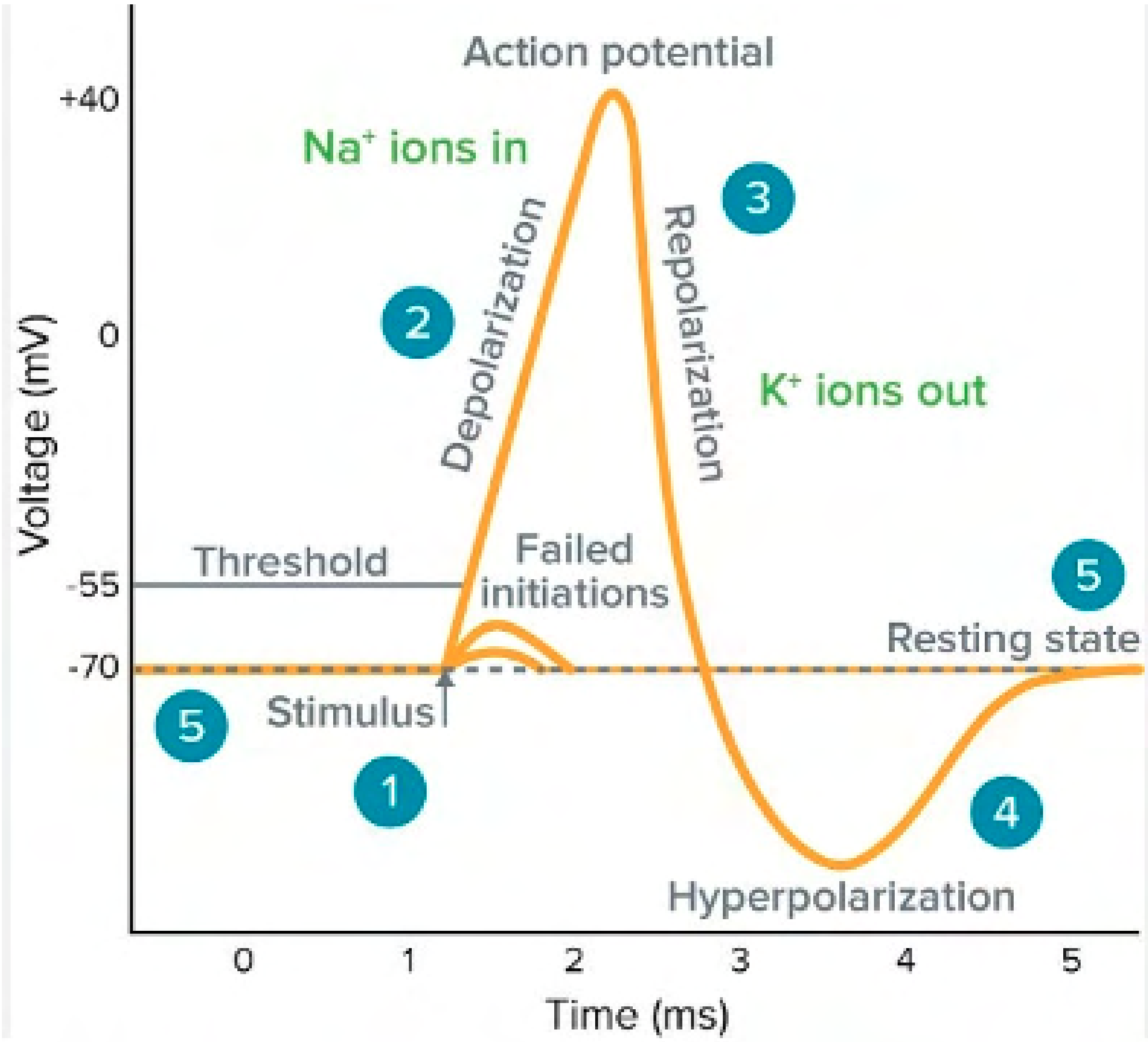

Figure 2
Source:
https://www.moleculardevices.com/applications/patch-clamp-electrophysiology/what-action-potential

1. The voltage of the muscle is below -55 until the stimulus is enacted and the voltage surpasses the threshold. 2. The voltage increases and goes through depolarization. 3. The action potential is reached and continues to repolarize. 4. The voltage reaches a state below the resting state at hyperpolarization. 5. The voltage returns to its resting state.

The brain sends the voltage of the action potential (see Figure 2) through the body's neurons. These voltage currents are called neurotransmitters, and they can travel through the neurons at different rates of speed. There are at least 100 neurotransmitters in the body, and more are to be discovered. A neurotransmitter is classified based on its chemical composition and where it acts in the body. Acetylcholine is the neurotransmitter that regulates muscle contractions.

The neuron contains a myelin sheath (see Figure 3) that allows the neurotransmitter from the brain to move faster throughout the body. Myelin is an insulating lipid layer surrounding the neuron, preventing action potentials from decaying. The myelin sheath also allows action potentials to move more quickly and efficiently than any un-myelinated neuron. There are spaces between the myelin sheath, which causes the action potential to slow down. These gaps are called nodes (Figure 3) and help the action potential by supplying it with sodium ions. The sodium ions protect the action potential from decaying. The action potential slows down at the nodes but speeds up in the myelin. Therefore, the action potential will move faster through the neuron if the myelin grows. If a muscle is trained correctly and consistently, the myelin sheath will grow enough to create automatic muscle responses to certain situations. Many call this phenomenon “muscle memory” because the muscle is trained sufficiently to memorize specific actions and perform them automatically.

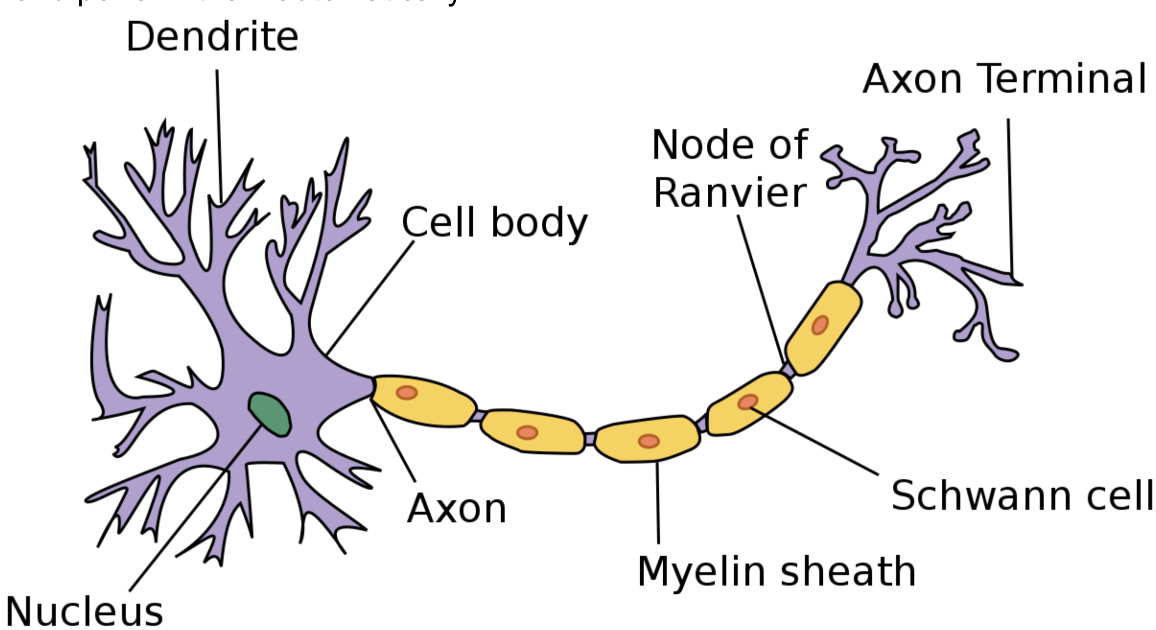

Figure 3
Source: https://en.wikipedia.org/wiki/Myelin

The neuron contains the myelin sheath, which transfers the action potentials throughout the body. The purple figure is the cell body, which connects the neuron to another neuron through the axon terminal. The green figure is the nucleus of the neuron. The yellow figure is the myelin sheath, which transfers the action potential. The orange figures are the Schwann cells in the myelin. The purple figures in between the myelin are the nodes that slow down the action potential.

When the signal is sent to the muscle, the striations or direction of the muscle's movement allow it to move in the direction its use is intended for. Training a muscle changes the striation angle, creating a more strict and powerful muscle motion. Highly trained muscles contain striations correctly angled in the muscle's contraction direction. In some cases, untrained muscles lose their striations and cannot move in a particular direction efficiently.

The muscles commonly trained in the body are called skeletal muscles. These muscles are connected to the skeletal structure and help move it. Inside the skeletal muscles is a connective tissue called the perimysium, which connects with the inner skeletal muscle fibers called fascicles. Multiple fascicles are contained in one skeletal muscle, and they run parallel. Inside the fascicles are the muscle cells, which can grow with training.

The Dive

Figure 4

Representation of the dive in a swimming race.
Source: https://swimswam.com/an-analysis-of-the-block-start-which-one-are-you/

The dive is the action at the beginning of the race, where the swimmer launches off a block and propels into the water. Multiple muscles are used in the dive, and mostly all are used in the lower body. We can divide the lower body muscles used in the dive into three sections: knee, ankle, and hip extensors. The knee extensors are the muscles used when the knee extends and contracts. The knee contracts in the dive before the start of the race, and when the race starts, the knee fully extends, using all of the major muscles in the quads. The four major muscles in the quads are the Sartorius, Vastus Lateralis, Rectus Femoris, and Vastus Medialis. The ankle extensors are the muscles used when the ankle moves, stretches, or contracts. The ankle extensor muscles are used in the dive when the swimmer points their toes forward as they enter the water. The hip extensors are the muscles used when the swimmer extends their hips. The glutes are the primary muscle of the hip extensors.

The recommended action is to do weighted squats to train the muscles mentioned from the extensors. The squat extends the hips and the knees, allowing for a range of motion similar to that of the motion in a dive. Repeating weighted squats builds the muscles and their explosiveness needed in the dive. Another basic workout for increasing the explosiveness of the hip and knee extensors is the Hang Clean Olympic lift. The Hang Clean Olympic lift, similar to the squat, flexes all the muscles in the knee and hip extensors, allowing for a more explosive form when diving. The one problem is that the squat does not work on the ankle extensors. Because ankle extensors are hard to train, there is no need to train them as much as the knee and hip extensors. Still, calf raises would be recommended if one wants to train the ankle extensors because they extend the ankle, using all the muscles in the ankle extensors.

The Underwater

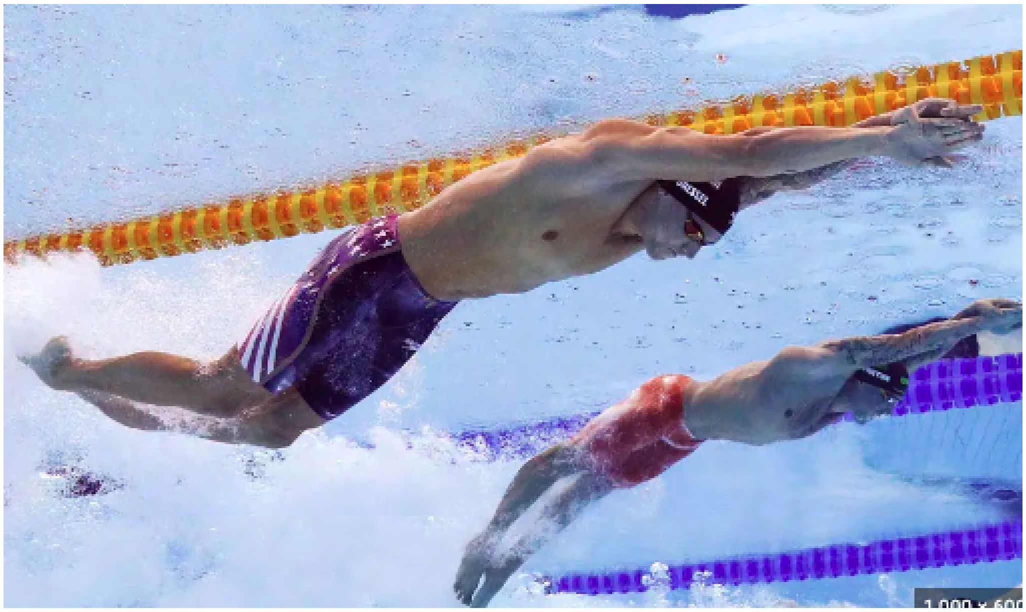

Figure 5
Representation of the “underwaters” is a swimming race.
Source:
https://ftw.usatoday.com/2021/07/olympics-swimming-caeleb-dressel-50-free-underwater-breathe

The “Underwater" is the action of undulating under the pool's surface and using the momentum of the dive to propel yourself farther. When performing an “underwater,” you must keep your arms above your head in a streamlined position to cut through the water. There are two muscle groups used in the underwater that need to be taken into consideration. Firstly, the back muscles used in the dive allow the swimmer to keep their body erect while they kick. Through the eccentric and concentric movement of the erector spinae, a swimmer can undulate their hips up and down to create fluid movement under the water. Through the isometric movement of the posterior deltoids, the swimmer can keep their arms above their head in a streamlined position. To help the posterior deltoids, the trapezius works through some concentric movement to bring the shoulders back. Secondly, the core muscles used in the dive allow the swimmer to move their hips up and down as well through concentric and eccentric movement of the core, specifically, the Rectus Abdominis.

To train the erector spinae, the recommended action is the weighted sit-up with the ball. This workout requires sit-ups with a ball behind your back to perform the concentric and eccentric muscle movements of the erector spinae, just as one does in the underwater of race. These sit-ups must be controlled to flex the erector spinae and not injure one's back. The recommended action is to do the reverse fly to train the posterior deltoid and the trapezius. This workout must also be controlled to practice the isometric movement of the deltoids and the trapezius, similar to the movement of the shoulders during the streamline.

The Breakout

Figure 6
The breakout of the swimming race.
Source:
https://swimswam.com/five-subtle-techniques-of-the-caeleb-dressel-50-freestyle-olympic-victory/

The breakout is the action at the beginning of the race when you complete your first stroke in the water. There are two parts of the stroke in the breakout that need to be taken into consideration: the catch and the recovery. The catch is the point in the race where your arm pushes through the water parallel to your body and in a 180-degree motion. The main muscles used in the catch are the triceps and latissimus dorsi. The triceps help the arm move backward during the catch. Roughly 20% of the entire stroke is focused mainly on the triceps. The triceps undergo a concentric movement as the elbow extends and contacts, causing the muscle to be used to create a greater force to move the swimmer forward. The latissimus dorsi contains the remaining 80% of the stroke. The latissimus dorsi is used during the downward movement of the arm. While the arm moves downward, the concentric movement of the latissimus creates the force to move the swimmer forward. After the catch comes the recovery, the part of the stroke in which the arm leaves the water and goes over the head of the swimmer. During this motion, the swimmer uses their anterior deltoid to move their arm over their head and in a forward movement. The deltoid exerts the main force in the recovery and is the only muscle being considered.

Training the muscles in the catch requires two different exercises. For the latissimus dorsi, the lat pulldown is a good action for practicing the pull motion of the catch and building strength on the lats. The tricep kickback is recommended for the triceps. The backward motion of the tricep during the catch is simulated in the backward motion of the kickback. To train the muscles in the recovery phase of the stroke, the recommended workout is the shoulder press, which exercises the anterior deltoid and simulates the overhead movement of the stroke during the recovery.

Breakdown of Muscle Actions

Every muscle either moves concentrically or eccentrically. For example, when the bicep contracts during a typical bicep flex, the bicep moves concentrically and “closes in.” When the bicep moves eccentrically, it stretches in the opposite direction of the concentric direction. Each muscle contains a counterpart muscle that moves in the opposite direction. For example, when the bicep contracts, the tricep moves eccentrically and vice versa. Therefore, a muscle never moves eccentrically unless you are concentrically moving another muscle.

Every muscle also contains a beginning and an end. For example, the bicep starts at the shoulder and finishes at the inner elbow. The beginning of the muscle is called the origin, and the end is called the insertion point. The muscle is associated with tissue called tendons, which connect the muscle at its origin and insertion point. In other words, These tendons connect the skeletal muscles to the skeleton.

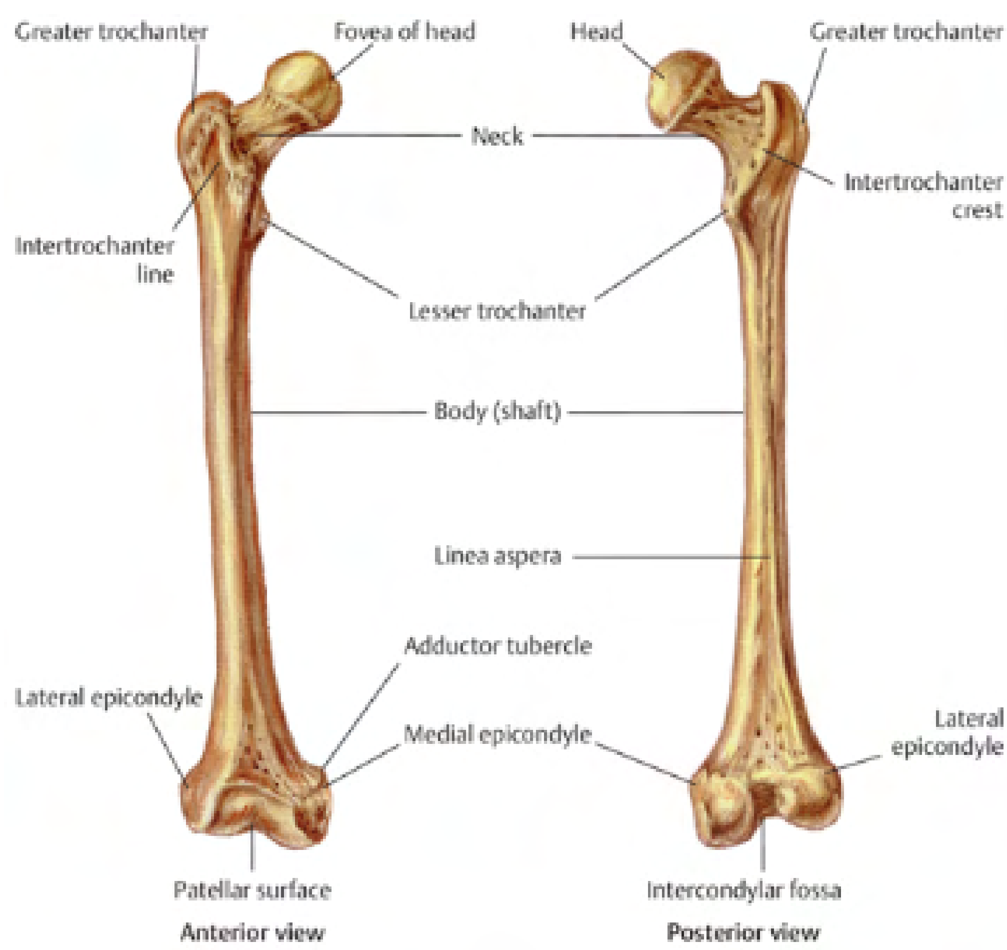

Figure 7
This is an image of the femur bone. The femur consists of the greater trochanter, the head, the neck, the intertrochanter line, the lesser trochanter, the body, the linea aspera, the adductor tubercle, the medial epicondyle, the lateral epicondyle, the intercondylar fossa, and the patellar surface. Most parts of the femur, such as the greater trochanter and linea aspera, attach to many muscles.
Source: https://www.ezmedlearning.com/blog/femur-bone-anatomy-labeled-diagram

Muscle Insertions and Origins

Understanding where each muscle originates and ends is essential to understanding how the muscle acts. The knee extensors move the quad muscles (Sartorius, Vastus Lateralis, Rectus Femoris, and Vastus Medialis) in a forward and backward kicking motion that extends the knee. The muscles originate near the femur bone's greater trochanter and linea aspera and are inserted near the patella (see Figure 7).

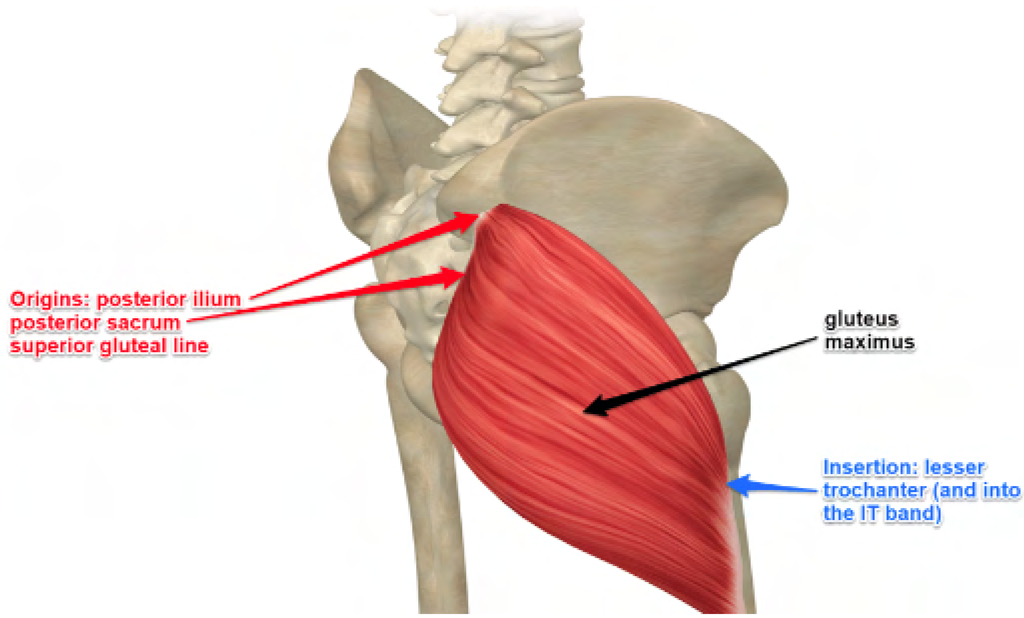

Figure 8
Image of the origin and insertion of the gluteus maximus.
Source: https://www.yoganatomy.com/gluteus-maximus-muscle/

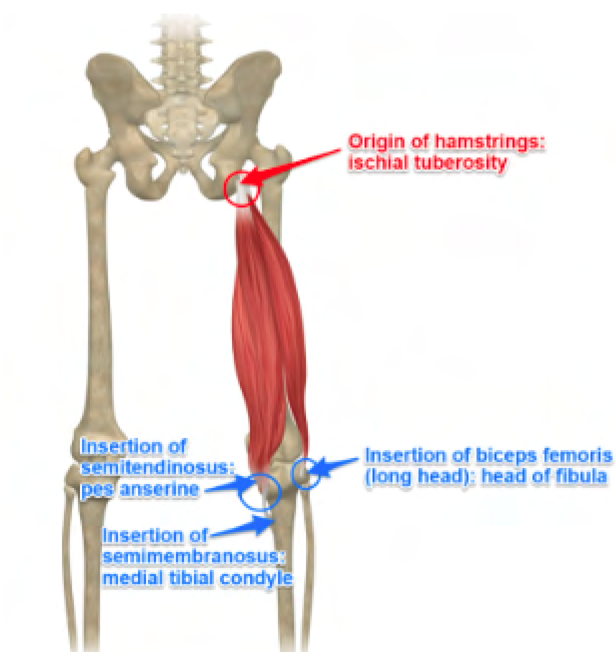

Figure 9

Image of the origin and insertion of the hamstrings (biceps femoris, semitendinosus, and semimembranosus).
Source: https://www.yoganatomy.com/hamstrings-group-muscles-yoga-anatomy/

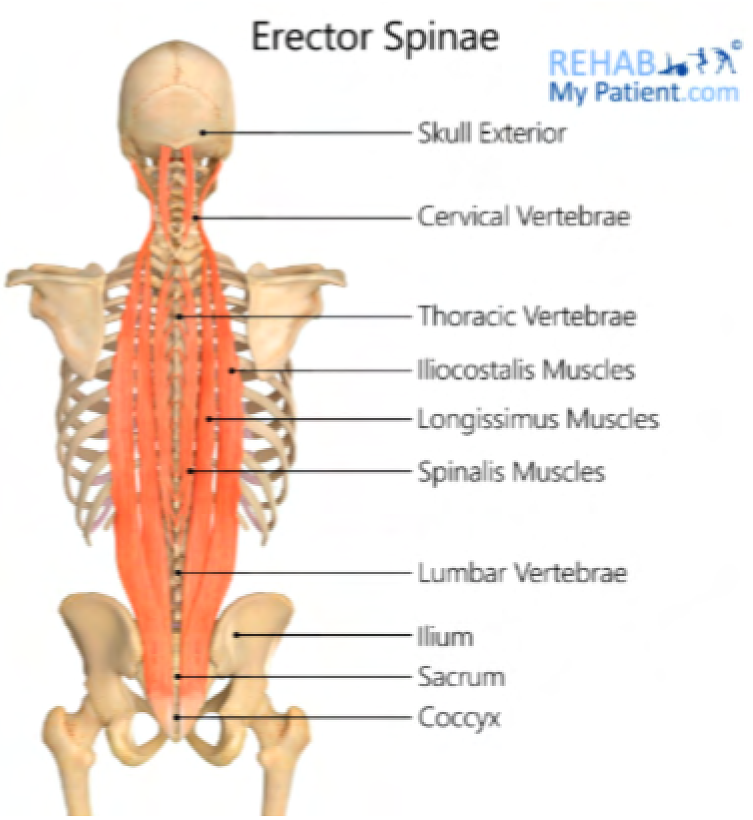

Figure 10
Parts of the erector spinae. Erector spinae has multiple origins and insertions throughout the lower and upper vertebrae.
Source: https://www.rehabmypatient.com/thoracic-spine/erector-spinae

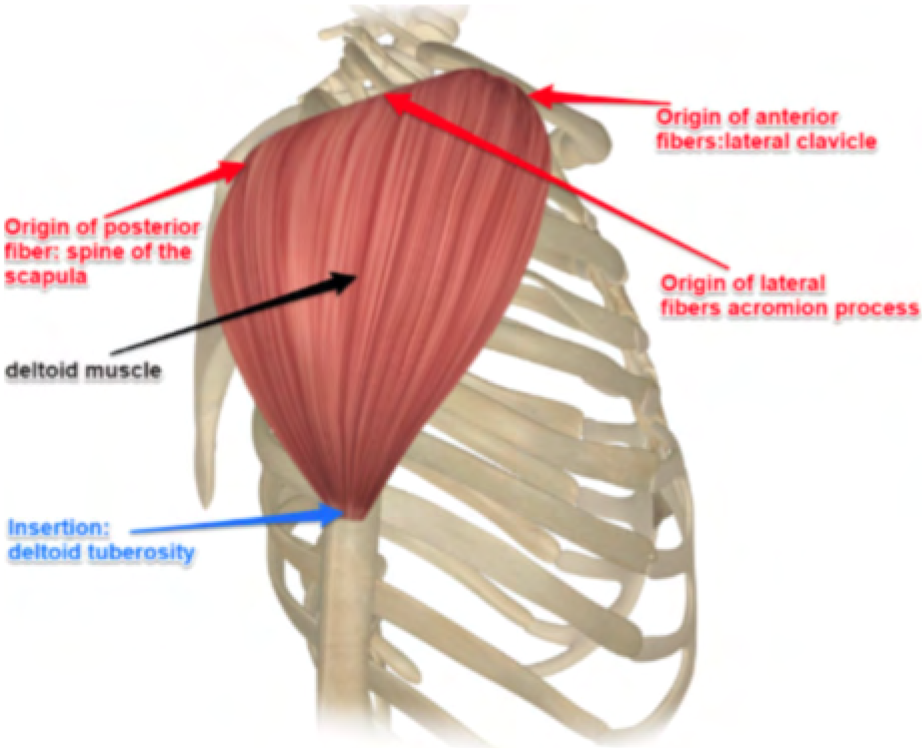

Figure 11
Origin and insertion of the posterior, anterior, and lateral deltoids.
Source: https://www.yoganatomy.com/the-deltoid-muscle-of-month-yoga-anatomy/

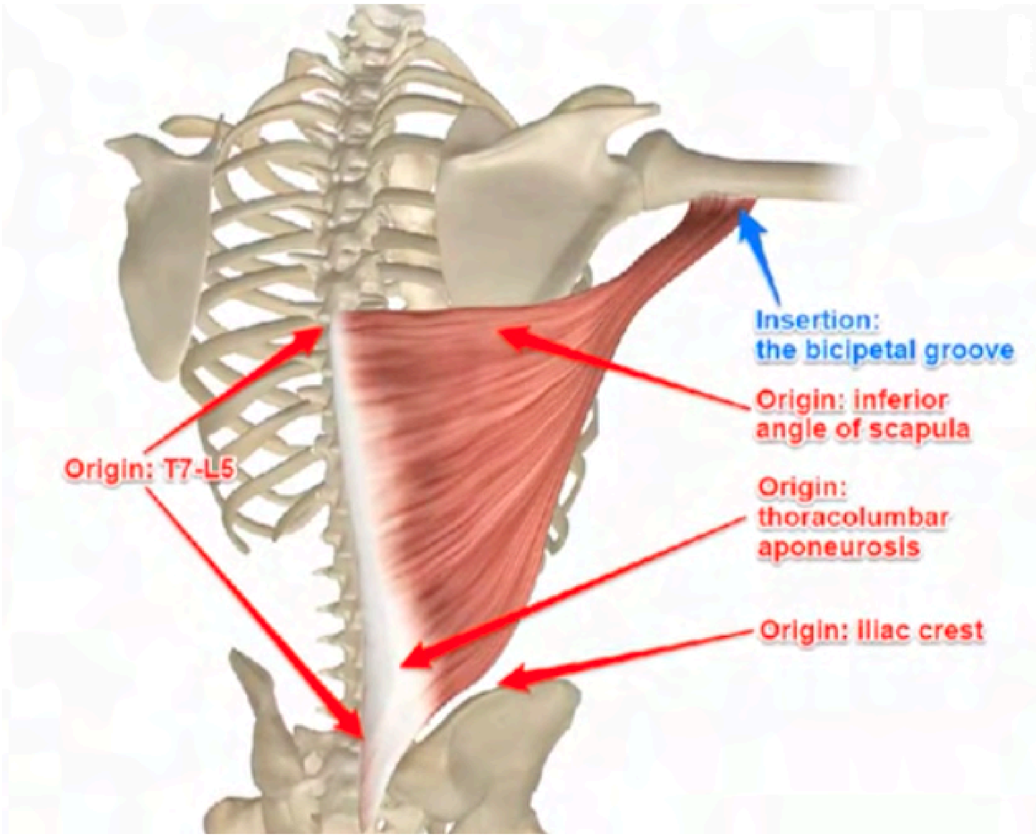

Figure 12
Origin and insertion of the lats. The lats contain multiple origins along the vertebrae, but only one insertion.
Source: https://parallelcoaching.co.uk/latissimus-dorsi-origin-and-insertion

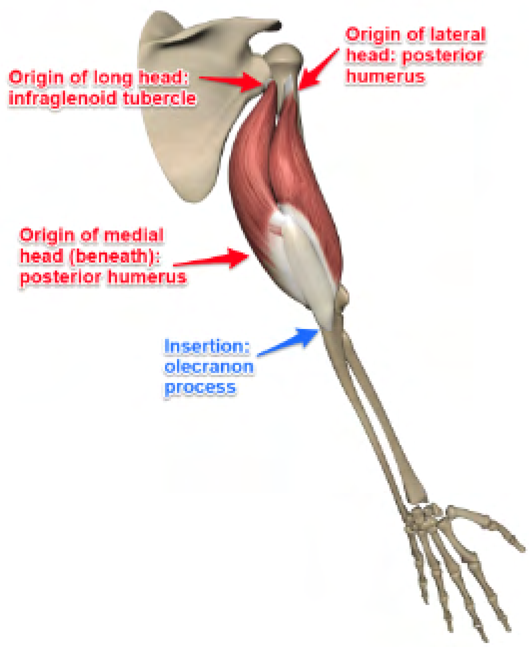

Figure 13
Origin and insertion of the triceps. The triceps only have one insertion.
Source: https://www.yoganatomy.com/triceps-brachii-muscle/

The hip extensors consist mainly of the gluteus maximus and the hamstrings (biceps femoris, the semitendinosus, and the semimembranosus). The gluteus maximus originates at the posterior ilium, posterior sacrum, and superior gluteal line and is inserted at the lesser trochanter (see Figure 8). All the muscles of the hamstring originate at the Ischial tuberosity, but the long-head bicep femoris inserts at the head of the fibula, the short-head bicep femoris inserts at the linea aspera, the semitendinosus inserts at the head of the tibia, and the semimembranosus inserts at the medial tibial condyle (see Figure 9). The erector spinae is a back muscle that allows for the upward and downward motion of the hips. Its origin is at the pelvic vertebrae (lower-middle back), and they are inserted on the vertebral and rib bones closer to the neck area (see Figure 10). When someone arches their back, they use the erector spinae to move their hips out and thrust their chest forward. The trapezius muscles move the shoulders and lats backward and forward. The trapezius originates at the thoracic vertebrae, and the insertion is near the shoulders (acromion and spine of the scapula) (see Figures 10 and 11). The posterior and anterior deltoids can move the arms up and down and side to side**.** Both parts of the deltoid insert at the deltoid tuberosity, but the anterior deltoid originates at the lateral clavicle, and the posterior deltoid originates at the spine of the scapula. The latissimus dorsi causes the upward and downward movement of the arm. The latissimus dorsi originates from the inferior angle of the scapula, thoracolumbar aponeurosis, and the iliac crest. All parts of the latissimus dorsi are inserted at the biceps groove. The triceps (lateral head, medial head, and long head) cause the forward and backward movement of the arm. The lateral and medial head originate at the posterior humorous, and the long head originates at the infraglenoid tubercle. All three heads are inserted at the olecranon process.

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