An Unmatched Analysis of The Elbow Joint & Its Surrounding Musculature Part I

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Abstract

The elbow complex is comprised of three distinct articulations: the humero-radial, humero-ulnar, and radio-ulnar joints. The hypertrophy athlete must be conscious of the detailed architecture on the arm and forearm, as well as the landmarks housed within them. This fact is only illuminated by various mechanical advantages distributed throughout the musculature via differing origin and insertion points. A muscle which originates on the radius will be effected in vastly dissimilar ways than one which finds its origin on the ulna.

To understand why, we turn to an in-depth breakdown of the brachium and forearm region. Articulations, movements, and key terms are highlighted herein. Moreover, aspects vital to growth will receive special attention. Our objective is to etch out all mechanical facts which can have a profound effect on the enhancement of hypertrophy in the biceps brachii, brachialis, pronator teres, brachioradialis, and the triceps brachii.

Introduction

How does one attack what has been attacked by so many? This is the task which I found myself entrenched in as I took on the project displayed before you. The arms have been discussed with an unmatched fervor, and have received more attention than any other body part; an almost mythical aura has been ascribed to them. As I sat and pondered how to give such magnificence its proper justice, an intriguing thought occurred to me: I would set out to provide you everything that can be offered concerning the topic at hand. This is no small task. Indeed, it may take numerous issues to relay. However, that is not all I intend to do. You see, though the following muscle groups have been written about quite frequently, they have never, in the world of hypertrophy, left the realm of the black box. Michael Behe defines such a concept as follows:

Black box is a whimsical term for a device that does something, but, whose inner workings are mysterious--sometimes because the workings can't be seen, and sometimes because they just aren't comprehensible. Computers are a good example of a black box. Most of us use these marvelous machines without the vaguest idea of how they work, processing words or plotting graphs or playing games in contented ignorance of what is going on underneath the outer case. Even if we were to remove the cover; though, few of us could make heads or tails of the jumble of pieces inside(4).

It is not enough to simply realize that your elbow can flex. That is an empty mentality. How does it flex, is there more to it than that? What other muscles act at the elbow besides the biceps? If perfection is the goal, then such questions must be answered. Curling a weight, while your mind cannot embrace the physiology behind it, will yield minimal results and will never lead you to your ultimate aspirations or coveted desires. You and I will therefore take a journey. Our goal is to open this black box. But it will not be a cake walk; of that I assure you. I can see questions already arising in your mind. Questions such as: "Can you target certain aspects of the biceps?" "Do all the muscles which act at the elbow joint do so in a purely synergistic format, or is there room for abstract training as well as abstract angular positioning during a particular lift?" Those are but a taste of what will be answered and, when the smoke clears, your arsenal will be boosted like never before. Indeed, your ability to add freak to the appendages will grow exponentially.

Overview of The Series:

Part 1 - Elbow joint.
Part 2 - Muscles which act to flex the elbow, supinate, and pronate the radio-ulnar joints.
Example: Biceps Brachii.
Part 3 - Muscles which act to extend the elbow joint.
Example: Triceps Brachii
Part 4 - Additional scientific insight from various literatures.
The goal here is to tie the former three articles together.

The first two phases of this project will be presented to the readers this month. The third and fourth, in the near future, in subsequent order.

Setting Our Parameters

How stable must the elbow joint be? To give you an idea, Dr. Amis, in the Journal of Medical Technology, calculated that the joint formed between the humerus (arm bone) and the ulna (medial forearm bone) sustained up to 720 pounds of "peak joint reaction forces," and up to 675 pounds between the humeroradial (the radius is the lateral forearm bone) joint (1). Such extreme forces call for extreme reinforcement, and yet still provide the user an ability to move the bones which act through the elbow articulation for several intricate tasks. We will analyze the structures involved in this system by first carefully distinguishing each bone. When complete, the bones and their architecture will be brought together. I want you to also note that if some of the information gets complicated, I will normally clarify as the article moves ahead. Therefore, information will be introduced and then expanded on.

The elbow is comprised by the distal (lower) end of the humerus, and the proximal (further up or, more technically, the aspect of a bone which is closer to the root of a limb than another point) ends of the radius and ulna. Three joints are formed within this parameter. As you know, there is one arm bone and two forearm bones. The arm bone, or humerus, forms one joint medially with the ulna, and one joint laterally with the radius. These are known as hinge joints (explained later--for now, this joint allows flexion and extension). Finally, the radius and ulna form joints between each other, which allow what you perceive as twisting motions at the forearm. The first two joints are separate units from the latter; however, all three are in close proximity and are additionally all held within the same "joint capsule." It is for this reason that one professional will strictly refer to the elbow as being simply the hinge joints mentioned, while another will refer to it as a "modified hinge joint;" meaning that if you view all three joints in conjunction, it is not just flexion and extension which are allowed, but also internal and external rotation of the forearm (also known here as pronation and supination respectively). It is important to therefore clarify what is meant when one discusses this region. I prefer the term: "elbow complex." Thus, you will understand that the joints are separate, yet I may refer to them as an encompassing unit. I do so because the musculature (within a single muscle, as well as muscles with similar function) which operate through these articulations are radically affected by movements at all three regions (22, 3, 6, 23, 25, 14, 24). Your ability to therefore target an elbow flexor or a certain aspect of the biceps is dependent on the entire complex.

The Distal Humerus

Our main concern is the lower, or distal, end of the arm bone. For further information on the proximal humerus, what actions take place there, as well as joints formed, click here. I will also briefly review these structures within this series.

The Distal Humerus has several functions within the elbow complex. It is designed to:

A. Handle the forces described above. To understand how bone handles such forces, I refer you to bone mechanics - Part One, Two and Three.

B. Articulate with the ulna and radius. Such a feat is accomplished by way of specialized condyles. A condyle is a rounded structure that is custom made to form a joint with another bone.

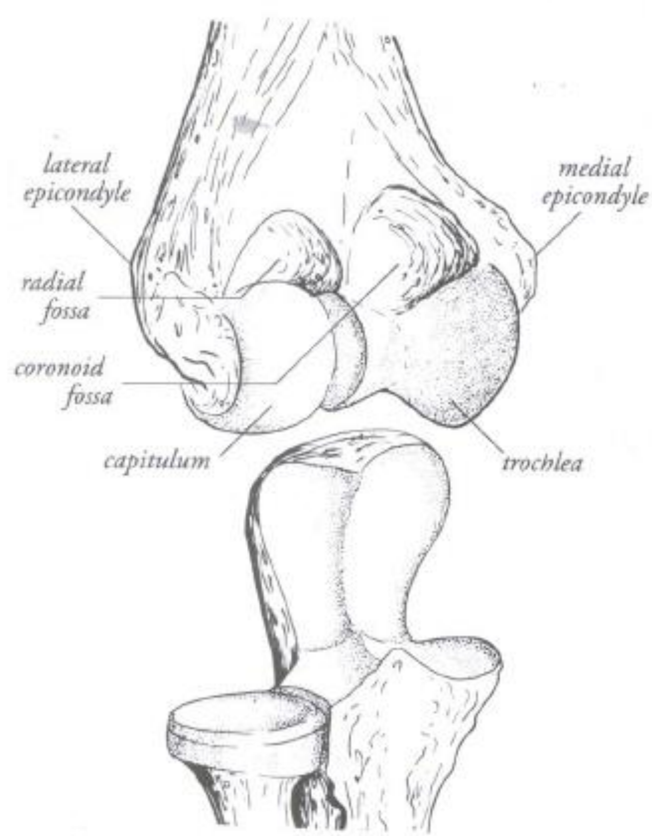
C. Have specialized depressions which allow protrusions of the forearm bones to not interfere with full range of motion during flexion and extension. These depressions are known in osteology terms as "fossa." They are dish like depressions which allow extra "space" for other bones during various movements. As you will see, there are three main fossa landmarks on the humerus.

D. Provide attachment for ligaments and tendons

The upper humerus is rounded, almost like the handle of a baseball bat. However, the lower half differs quite a bit; it widens out side to side, or medially and laterally as it descends, and flattens from front to back as well. As this occurs, you will notice that medially and laterally, notable ridges are formed. These are called the supracondylar ridges. Supra refers to the fact that these are not only ridges but are, in fact, superior or above/higher than the condyles of the humerus. The two ridges lead into two prominent palpable (you can feel them) projections known as the epicondyles (small condyles). You can view these on the illustration of the humerus, but to further your understanding, I would suggest palpating them. Stick your arm out and extend it in front of you. Now, at the end of your arm, medially you should feel a large bump which corresponds to your medial epicondyle, and laterally you should feel a smaller bump which corresponds to the lateral epicondyle. These projections are in line with Wolff's Law, which states that the shape of a bone determines (in some way) its function, and that conversely, actions can alter a bones actual shape (26). The reason for the large protrusion of bone, on both the lateral and medial epicondyles (extensions of the supracondylar ridges), is due to the fact that ligaments, tendons, and the elbow joint capsule attach there. The tendons which attach to the medial epicondyle are the common flexors, which mainly act at the wrist joints and articulations which comprise the fingers. The medial epicondyle is larger because the common flexors which attach to them are larger, stronger, and cause more bone deposition to cope with the extreme forces (26, 27, 28). The ligaments and joint capsule will be discussed further into the article.

Also note that on the medial epicondyle, slightly posteriorly (to the rear), you should feel an indentation. This aspect of the bone caves in deeply and is then covered by a strong piece of connective tissue. The structure formed is therefore a tunnel, and is known as the cubital tunnel (9, 13, 18, 7). Each of you has no doubt heard of the funny bone. It is not actually a bone, but a nerve, known as the ulnar nerve which passes through the CT on the way to innervating structures like the medial hand. When you bang your elbow, this nerve is pressed up against the bone which causes an endless and very uncomfortable array of sensations. We now discuss the condyles of the humerus, pictured below.

As you can see, the condyles have particular shapes. First, let me explain that the elbow joint is designed to allow for fuller flexion. Thus, all the way distally, you will take care to note that the arm is curved inward on the anterior aspect. Such curvature allows the forearm bones more room for forward movement. The first condyle to analyze is the capitulum (pronounced ca-pitch-ul-um). It is "rounded" anteriorly and distally; it does not extend to the back of the arm. Further, you will see that the surface is meant to articulate (form a joint with) the head of the lateral forearm bone, known as the radius. More medially lies the trochlea, a term which literally means "pulley." It is wonderfully shaped and rounded anteriorly, distally, and posteriorly, such that the angle forms a near complete circle (not quite though; it extends 330 degrees, but allows for fantastic movement). The reason it has a fuller rounding is due to the fact that the humeroulnar joint is the main player in elbow flexion and extension. Consequently, the radius must have more freedom for rotating movements, described below, at the radioulnar joints. The rounded pulley-like trochlea fits perfectly with a notch on the ulna.



Note: Again, I will clarify all of these landmarks and they will make perfect sense as we discuss articulations below.

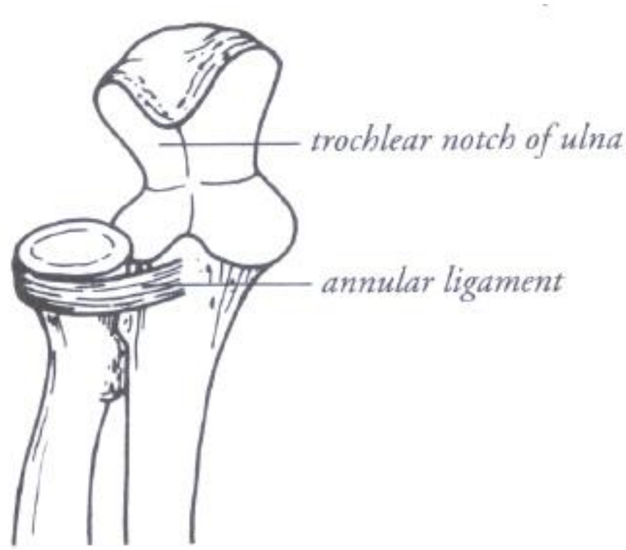
Finally, when studying the forearm bones, it will be seen that the head of the radius is wider than the neck, almost like the head of a screw. To accommodate for this protrusion, there is a depression just above the capitulum known as the radial fossa. This depression allows the head of the radius to fit snugly inside when flexation occurs. Medially you have a similar shallow depression known as the coronoid fossa. It is quite easy to remember, as the ulna has a protrusion named the coronoid process. It, like the head of the radius, fits nicely into its space on the humerus. Without such landmarks, you would not enjoy such freedom of motion. Likewise, on the distal and posterior aspect of the humerus lies another fossa. Bend your elbow and palpate the depression found right before the large bump on the forearm. That bump on the forearm is known as the olecranon process and, as you no doubt may have guessed, the depression is known as the olecranon fossa. Again, flex the elbow and place your finger into the olecranon fossa, and proceed to extend the forearm. Note that the depression disappears; this is what occurs as the olecronon process of the ulna fits into its respective fossa.

In summary:

1. The humerus is round at the top half, but lower it is wider as well as flatter.
2. The distal aspect of the humerus curves inward anteriorly, to accommodate flexion.
3. There are two condyles on the humerus which articulate with the radius and ulna.
4. On the outside of the condyles lie the epicondyles, landmarks which have important attachments,
   thus reflecting their shape.
5. To allow for full flexion and extension, two fossae are found distally and anteriorly on the humerus,
   as well as one which is found on the posterior aspect of the bone.

The Ulna

The Ulna is the medial bone of the forearm region. Again, we are concerned with its top or proximal end. When looking at it, you are struck immediately by a hook like landmark, which is called the "trochlear notch." Note that it is the notch which fits fantastically with the trochlea of the humerus. The notch is formed as the top end of the ulna curves in anteriorly. The top and posterior aspects of the ulna are a part of the olecranon process. Note the bump on the back of your elbow joint that is the Olecronon. Most martial artists, and even non-martial artists, recognize its potential to do damage, and many use it as a sort of platform when leaning on a counter.



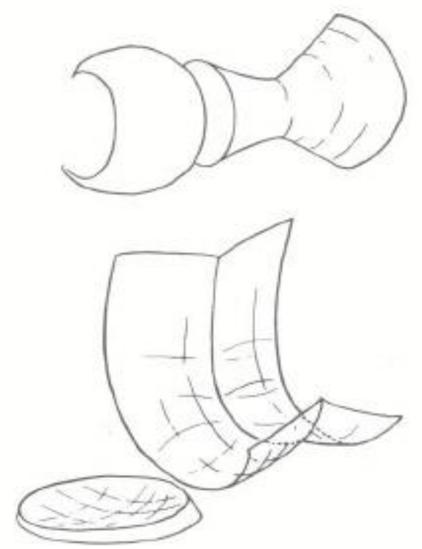
A protrusion, at the floor or bottom of the notch is called the coronoid process. Thus, the olecronon process makes up the top of the trochlear notch as the ulna curves inwards anteriorly, and the coronoid forms the bottom half. Note also that the two processes meet in the middle of the notch. If you want a very crude representation of how the trochlear notch articulates with the trochlea, make a fist with one hand, and a claw with your other. Now cusp the fist and move it forward and backwards to mimic extension and flexion. As mentioned previously, the olecronon process fits into the olecronon fossa when the forearm is extended, and the coronoid process fits into the coronoid fossa anteriorly when the forearm is flexed.

Finally, on the outside or lateral aspect of the proximal radius, you will see a notch. This is known as the radial notch and fits beautifully with the head of the radius. It is absolutely spectacular for supination and pronation, as will be seen! Below the radial notch lies a protrusion known as the ulnar tuberocity, an insertion point for the brachialis.

Radius

A very easy illustration of the proximal radius is, again, to imagine a screw. It has a disk shaped head and a more narrow neck. The disk shape of the head acts as a wheel of sorts, as it rotates around the radial notch on the ulna. Further, the top of the head has an incredible round depression, which makes it a perfect fit with the capitulum (9, 13, 18)! A tad bit lower, or distally on the medial aspect of the bone, you will find a protrusion, and this is of great interest to the bodybuilder. Named the radial tuberocity, this landmark serves as the insertion point of the coveted biceps brachii. As you will later see, such an insertion provides for interesting and applicable discussion on mechanical advantages during the process of flexion of the elbow joint.

Humero-radial and Humero-ulnar Joints

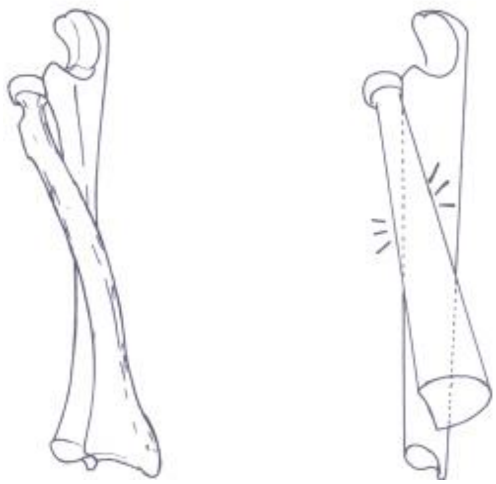


Once you understand the landmarks of the bones discussed, and their shapes, it is easy to picture the articulations between them. The Humeroulnar joint is formed on the more medial trochlea of the humerus and the trochlear notch, which raps around the trochlea with a near perfect fit. There is, however, a slight space between the two bones (7). As weight is born by the joint, the space becomes smaller and can absorb shock. The humero-radial joint is formed by the rounded capitulum and the concavity or depression on top of the radial head.

The articular surfaces of the bones (capitulum, trochlea, trochlear notch, and head of the radius) are coated with a smooth, almost frictionless cartilage. It is known as hyaline cartilage. The Greeks named it as such for its glassy appearance, and you recognize it when eating foods such as chicken. Furthermore, the entire joints discussed are covered in what is known as a joint capsule.

A joint capsule is a fantastic contraption. Think of it as a protective sleeve made of tough, connective tissue. The elbow joint capsule attaches anteriorly, directly above the coronoid and radial fossa; it then extends laterally and attaches above the olecronon fossa. Distally, to complete the sleeve, it attaches on the coronoid process, and olecronon, the medial aspect of the ulna and the neck of the radius. Its purpose is to encapsulate the joints discussed and keep fluid inside of the joint spaces. You see, inside of the capsule is a membrane which secretes what is known as synovial fluid (classified as a synovial joint). As oil lubricates a machine, so too synovial fluid provides a virtually frictionless environment to the encapsulated articulations. You can test it out right now by flexing and extending the elbow quickly. Such movements are so smooth due to the fantastic fit of the bones (which also provides stability), the hyaline, and finally the lubricating fluid.

Movements Reviewed



The final joint to be discussed is the radio-ulnar joint, formed by the head of the radius with the ulnar notch. Both the ulna and radius have a fantastic inward (concave) curvature anteriorly. When the radius rotates around the ulna, an extreme amount of rotation is allowed due to this fact. If it was not present, you would have very little movement in this region.

Movements between the hinge joints are as follows:

1. Flexion - This is allowed between the hinge joints formed between the humerus, radius, and ulna. It can be defined as follows: The lessening of an angle between two bones. Or, in this case, as the forearm is brought closer to the arm, flexion is occurring. From my review of several studies on the subject, I found that the elbow could flex from 135 degrees at the lower end of the spectrum to as much as 150 degrees at the higher end (10, 11, 21, 20).

2. Extension - Such a movement again occurs at the hinge joints discussed and is the opposite of flexion. That is, extension straightens an angle out. When moving past full straightening, the movement is called hyperextension. Hyperextension from those same studies was not very notable and, for the most part, did not occur. However, Steindler et. al showed as much as 20 degrees of hyperextension, but also reviewed abnormal conditions (20). For the most part, extension is the furthest you will get. There was zero hyperextension seen in studies performed by The Us Army and Air force, as well as by Gerhart et al. (10, 5).

3. The ulna is relatively unmovable (although it can move as discussed below), while the radius can rotate around this bone at the notch. In order to understand joint movements, you need to realize that bones rotate around an axis, which is opposite the movement (see bone mechanics and look to a future article on arthrology and its implications in BB). When the head of the radius rotates internally or toward the middle of the body, the movement is called pronation. When it rotates back out laterally, the movement is known as supination. Try it. Stick your arm out so that its palm faces upwards. Your forearm is in a " Supine " position. Now turn your palm downward; you just pronated the radio-ulnar joint. Note that slight rotation occurs in the distal radio-ulnar joints as well, but this is a future article. As stated, it used to be believed that the ulna was stagnant and did not move; however, further studies have shown ever so slight deviations in the bone during the above torques (8, 15, 29). Both pronation and supination can take place through approximately 70-80 degrees of movement (21, 20, 5).

On one final note, the trochlea extends distally slightly more medially than laterally. Thus, the forearm is angled outwards as much as 15 degrees (12). The carrying angle allows objects to be strutted away form the body at the same angle caused by the distal location of the medial aspect of the trochlea.

How the is Elbow Joint Protected

Three aspects are involved in stability of a joint:

1. The Bony Fit - The fit between the humeral-forearm joints is fantastic, especially with the trochlea and trochlear notch; thus, stability is enforced nicely.

2. The Joint Capsule provides tensile force around the entire joint.

3. Medially, there is a ligament known as the "MCL" or medial collateral ligament. It is also known as the Ulnar ligament, as the ulna is the medial bone of the forearm. This ligament is comprised of three parts. One is anterior, one is posterior, and one lies in a horizontal or side-to-side plane. Thus, it can protect against hazards in several directions. Ligaments are composed of parallel collagenous fibers, which are comparable to steel in tensile strength! In simple terms, these aspects attach proximally on the distal end of the medial humerus, and distally on the proximal end of the medial ulna. In more technical lingo, all sections of the ligament attach on the humerus at the medial epicondyle (again you can palpate this). The anterior aspect attaches downward on the coronoid process, the horizontal aspect attaches on the trochlear notch and, finally, the posterior aspect attaches to the olecronon on the ulna. If the elbow joint is yanked to the outside, the ulnar ligament will protect it quite nicely.

4. Laterally lies the LCL. Once again, this ligament can be divided into three parts. The main thing I want you to know is that proximally it attaches to the lateral epicondyle, and distally it attaches to the annular ligament (discussed shortly) and the olecronon. Two portions attach to the annular and one on the olecronon.

5. The head of the radius does not have as supporting a fit with the radial notch as do the hinge joints mentioned above; it therefore relies more heavily on the annular ligament. This is a u-shaped ligament which wraps around the neck of the radius and attaches on the ulna as pictured below. This ligament protects the radius from being dislocated laterally and distally. You can now appreciate why your forearm is not ripped off of your body when performing deadlifts! I like to imagine the process quite vividly.

6. Muscles which cross the elbow joint also provide much stability. The elbow flexors and the muscles of the forearm cross this joint. Their musculature, as well as the tendons which they are connected to, provide stability.

7. Between the radius and ulna lies obliquely situated connective tissue throughout the length of the bones. This serves several purposes:

A. It binds the two bones together (9, 13, 18).

B. It serves to separate the anterior forearm from the posterior into functional "compartments." These are actual computerized compartments, if you will. The forearm flexors innervation by the nervous system is thus separated from the forearm extensors innervation.

C. According to Birkbeck et al. in the journal of Hand Surgery, there is another incredible purpose served by the interosseous membrane. They state the following:

The role of the interosseous membrane in load sharing was defined by simultaneously quantitating loads in the distal radius and ulna and in the proximal radius and ulna with an axial load to the wrist, before and after transecting the interosseous membrane. With the interosseous membrane intact, the load at the proximal ulna was greater than at the distal ulna and the load at the proximal radius was less than at the distal radius, suggesting that force was transferred from the radius distally to the ulna proximally (2).

Allow me to translate what was just said. The radius is the main bone which articulates with the wrist or carpal bones of the hand. This is why the hand moves with the radius as it rotates around the ulna. The ulna is relatively stagnant (non-moving), which is important, namely when we discuss muscle actions. Stand up and place your hand on the desk and lean into it. Your weight is transferred from the hand, directly into the radius. Without the interosseous membrane, the force would be transferred directly to the distal and lateral aspect of the humerus. As you know, pressure = force over area. Well, as the force moves up the radius, the bone moves upwards towards the humerus. As this occurs, it tugs on the interosseous membrane which, in turn, pulls the ulna and the ulna moves up as well toward the humerus, and with it distributes the load! This increases the area to which force is applied and, therefore, lowers the overall pressure (2, 17, 16)! Other functions have been found as well, which further distribute forces (19).

Conclusion

My intentions within these pages were to equip readers with the ability to more clearly understand how various muscles work through the elbow joint. Without these concepts, one can never fully grasp what will be revealed in parts II and III of this series.

Yours In Sport

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