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Purpose

The purpose of this paper is to introduce the concepts of accessible strength and strength ceiling and its relationship with muscular force in regards to both the structural and neurological properties of a muscle.

Motor Unit Recruitment and Accessible Strength

Muscular force is the summation of contractile properties, firing rates, and number of motor units recruited. The force of this contraction determined by the firing rate of the innervating neuron and the type of fiber that is being innervated. Together the system of a neuron and its innervated fibers are called a motor unit. A muscle is comprised of many different motor units.

The amount of force you could theoretically produce if all available motor units that you could normally stimulate (~65% of all motor units in a given muscle) are activated and fired at 100% is called **Accessible Strength (AS)**. **NOTE:** Even if 100% of your motor units were activated, this doesn't mean all of those neurons are firing at 100% capacity. It is possible that an active motor unit may be firing at a sub-maximal level, thus limiting force output. This is important because **AS** is the summation of the number of motor units firing and their firing rates firing rates. When **AS** is at 100% this means that ALL motor units are firing at 100%. In applicable terms, **AS** is the amount of force you can produce in an ordinary situation. However, there can be extraordinary situations that may cause a greater stimulus and recruit more neurons to fire faster. This can be noted in the story where the little old grandma lifted a car to save a child. This is obviously not an ordinary situation. In an ordinary situation it has been shown that in a muscle the average human can only access 65% of these motor units (8). This would lead to the belief that you are only accessing 65% of that muscle's potential force. However, this belief is incorrect. It actually means you are using less than 65%. This is because the harder to stimulate motor units innervate Type II muscle fibers (4). These muscle fibers will be able to produce more force than the easier to activate Type I fibers (7). They are also larger in size, meaning there are more muscle fibers per motor unit in the higher threshold fibers. The remaining 35% of inactive motor units may contribute much more than 35% of the body's potential remaining strength.

AS is the summation of motor units firing and their firing rates and therefore its relationship with strength will not be linear. This is due to the fact the harder to stimulate motor units create more force, so the curve for force on a graph would curve upward moving positively (left to right) from easy to activate to hard to activate motor units. This means that the jump from 65% of motor units activated to 75% motor unit activated and a jump from 50% motor units activated to 60% motor units activated do not equate to the same amount of strength gains even though the increase in total motor units activated for both situations is 10%. The jump from 65% to 75% may lead to a much greater strength gain because the motor units that are activated above 65% may be predominately more powerful type II motor units. While the jump from 50% to 60% may involve the activation of more type I fibers or less powerful two II fibers. It is important to note that the muscle fibers in a type II motor unit not only intrinsically produce more force; the type II motor unit itself consists of larger amounts total muscle fibers than type I.

	<u>Muscle Fibers</u>	<u>Motor Unit Size</u>
Type I Motor Unit	Slow, low force	Small
Type II Motor Unit	Fast, high force	Large

**** Type II motor units have more powerful muscle fibers and larger quantities of muscle fibers per motor unit.

T I (low force)→ T I (moderate force)→ T II (strong force)→ T II (Strongest force)

Easiest to activate→ Easy to activate → Hard to activate → Hardest to activate

Smallest size → medium size → Large size → Largest size

**** T: Type of motor unit

Unlike the motor units, the relationship for motor unit <u>firing rates</u> would most likely be linear, moving from 0% firing rate to 100% firing rate. This is because a motor unit will innervate the same fibers regardless of firing rate. The rate of firing simply determines the level of contraction of a specific motor unit.

The complexity of this situation is taken one step further when we realize the muscle is made up of many motor units. So, in order to find **AS** of a muscle, you would have to take each individual motor unit, determine its force potential via contractile properties and potential neural firing rates and then give it a numerical value. This process would need to be repeated for all motor units in that particular muscle and then summated to find the **AS** of the muscle. This complexity is one of the main reasons why neural contributions to muscular force are not completely understood.

Another important aspect regarding force output is **Strength Ceiling (SC)**. The **SC** is the amount of force you could theoretically produce if <u>ALL</u> motor units (100% in that muscle) were recruited and firing at 100%. This obviously does not happen in a normal situation. The difference between the amount of motor units being recruited and their firing rates is **AS.** The deficit in motor unit recruitment and firing rate is known as the **Motor Unit Recruitment Deficit (MURD).** This is the percentage of motor units not being recruited and not being fired at full speed. **AS** and **MURD** have an inverse relationship.

****Motor unit deficit and Accessible strength are percentages of strength ceiling. This means when strength ceiling's numerical value changes so do the numerical values of motor unit recruitment deficit and accessible strength. However, their percentages will not change unless specified.

SC (100%) = MURD (% of SC) + AS (% of SC)

Strength ceiling is independent of **AS** and **MURD.** If the strength ceiling is increased then the numerical value of **AS** will increase, but the percentages of **AS** and **MURD** will remain the same (**AS** and **MURD** percentages can change, but that will be discussed later). The number of motor units in the human body does not change nor does the theoretical potential firing rate of that motor unit. This means **SC**'s numerical value is only determined by cross-sectional/contractile properties of the muscle. It is not affected by the percent of motor unit recruitment or the percent firing rate, because they are assumed to be 100% at the **SC**. This leads to the conclusion that **SC** can only be affected by the increase or decrease in contractile properties (1,2). So as an example lets say an athlete has a **SC** of 500 lbs, a **MURD** of 35% and an **AS** of 65%.

500 (100% **SC**) **=** 325 **AS** (65%) **+** 175 **MURD** (35%)

Now lets say you pushed the strength ceiling up to 1000lbs. The percentages remain the same, but the numbers change

1000 (100% **SC**) **=** 650 **AS** (65%) **+** 350 **MURD** (35%)

Conceptually this seems nice, but you are leaving a lot on the table if you just focus on raising the strength ceiling. It is imperative to increase the **AS**, which in turns decreases the **MURD**. Lets say we raise our **AS** to 90% (90% is a representation of the summation between potential firing rates and motor unit activation).

1000 (100% **SC**) **=** 900 **AS** (90%) **+** 100 **MURD** (10%)

Now instead of being able to lift 650lbs, we can lift 900lbs by simply increasing our **AS.** This is where the importance of maximal efforts and dynamic efforts come into play. The **SC** is increased through hypertrophy during hypertrophy work and the **AS** is increased with the Dynamic Effort (DE) and Max Effort (ME) works. It has been shown that both DE and ME are the effective at increasing power (possibly motor unit recruitment and firing rates) and type II fiber development (2,6). This will be discussed in greater detail later.

****You could argue that the repeated effort method to failure (going to complete muscular fatigue) recruits higher threshold motor units as well, which is does. But, due to the large accumulation of volume and the recovery time required after a repeated effort to failure, the method might be too demanding for constant use.

Determining the SC of a movement

Motor unit firing and recruitment are two different concepts and they should both be addressed. Motor unit firing and recruitment is what **AS** and **MURD** are comprised of**.** Just because someone is recruiting all of their motor units does not mean they are firing all of them at the fastest rate they can be. Faster firing means greater contraction. **AS** is the summation of both firing rate and total number of active motor units.

**** **MURD** is the inverse of **AS**.

The equation **SC (100%) = AS (% of SC) + MURD (% of SC)** is used to describe an individual movement. To better understand the **SC, AS,** and **MURD** of the movement the equation needs to be broken down into the muscle groups of the movement. Take the deadlift for example, the total movement equation may look exactly the same. However, we know the deadlift is comprised of many different muscles firing in sequence to perform the action. For the sake of simplicity, lets just say the Gluteus, Hamstrings, and Lower Back are the only muscles involved. The deadlift equation would look something like this:

Deadlift → SC (100%) = AS (% of SC) + MURD (% of SC)

**** Now, if you breakdown the deadlift movement into the muscle groups working (hamstrings, gluteus, and low back) you get an equation that looks like this:

Gluteus→ SC (100%) = AS (% of SC) + MURD (% of SC)

Hamstrings→ SC (100%) = AS (% of SC) + MURD (% of SC)

Low Back→ SC (100%) = AS (% of SC) + MURD (% of SC)

**** The deadlift movement is a summation of all of the other working muscles that create that movement.

Deadlift = Gluteus + Hamstrings + Low Back

**** If you want the extended version of the equation here it is.

Deadlift (SC (100%) = AS (% of SC) + MURD (% of SC) **= Gluteus** (SC (100%) = AS (% of SC) + MURD (% of SC))**+ Hamstrings** (SC (100%) = AS (% of SC) + MURD (% of SC))**+Low Back** (SC (100%) = AS (% of SC) + MURD (% of SC))

In simple, as one muscle group either increases it's **SC** or **AS** so will the movement's (deadlift) respective **SC** or **AS** will increase.

Max Efforts and Dynamic Efforts and Rotation of Exercises

It has been noted that rotating exercises is imperative to avoid neural accommodation. By rotating exercises you are able to train the body with new stimuli, which in turn may activate new motor units. This is why it is essential to change exercises. It is science that high threshold motor units are harder to activate compared to low threshold and high threshold motor units innervate Type II fibers (7). These are the fiber types that produce the most force (5). Maximal efforts are extremely effective at recruiting higher threshold motor units. But, to avoid accommodation the exercises that are being performed at a maximal effort needs to be rotated often. Performing movements with maximal intent (dynamic effort) can elicit similar results. The use of bands and accelerated eccentrics can help aid in decreasing the amount of deceleration that occurs and increase the stretch shortening cycle. This exemplified in a study looking at power development and the efficacy of bands (3). The bands contributed to greater power outputs and possible greater neural drive from the increase in movement intent and stretch shortening cycle.

Optimization of the **AS**

The best way to optimize the **AS** is to perform a combination of selective hypertrophy work, maximal effort movements, and dynamic (maximal intent) movement. A combination of these exercises will lead to the greatest results in muscular force. The selective hypertrophy will allow for an increase in the **SC'**s numerical value, which in turn will lead to an increases in **AS'**s numerical value. Performing maximal effort movement and dynamic movements will increase the motor unit recruitment and firing rate. It is important to note that maximal movements and dynamic movements need to be performed in a minimally fatigued state. This will optimize the motor unit recruit and firing rates of the muscle. It is necessary constantly change exercises for the maximal effort and dynamic efforts. This is because one exercise may increase the **AS** of one muscle more than the other. An example of this would be changing from a rack pull to a deficit deadlift. The rack pull may emphasize the **AS** of the gluteus while the deficit deadlift may emphasize the **AS** of the hamstrings. If you were to only perform one of these exercises then there is a possibility that one of these muscle groups may be under stimulated.

If you want to run fast or have a strong deadlift, all muscles performing that movement need to be optimized. By raising the percentage of the **AS** and the numerical value of the **SC** you can elicit the greatest training effect.

Not completely related to athletic performance and power

This does paper does not cover the topic of how power and rate of force production are related. Its inaccurate to assume the stronger athlete is always the faster athlete.

"The stronger athlete is able to generate greater maximal power output and improved power output throughout the loading spectrum.[9,19,20,22,24,41,56,74] These observations hold true for relatively weak individuals or those with a low training age and are driven by increases in myofibrillar CSA especially of type II muscle fibres, maximal neural drive and RFD capabilities.[27,56,62,74,89,123] Changes to maximal power following such training in strong, experienced athletes are of a much smaller, non-statistically significant magnitude.[29-32]" - Cormie, P., Mcguigan, M. R., & Newton, R. U. (2011). Developing Maximal Neuromuscular. *Sports Medicine*, *41*(1), 17–39. http://doi.org/0112-1642/11/0001-0017

The stronger you are the more important it becomes to focus on specific areas of the force-velocity curve to increase performance

Citations

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