# Determining a better way to calculate the amount of tension on a muscle: A case study.

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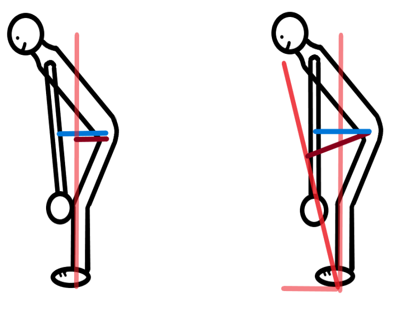
This unofficial case study tried to find a better approach to measure how much tension is being applied to a muscle. There are currently two ways to measure the quantity of mechanical tension on a muscle. Either the distance from the tension to the joint that is moving multiplied by the weight. The other way is the distance between the resultant of forces from friction under your feet and from a perpendicular line in the middle of a foot because every force (from gravity or from another resistance) will be expressed by your feet, multiplied by the weight. Based on my finding, tension was in correlation with the first example.

## Background and context

Mechanical tension, which is the amount of tension applied on a muscle, seems to be the main driver of muscle hypertrophy.[1,2] Even with metabolic stress, which is another driver of hypertrophy, you need to apply a certain amount of tension on a muscle to have an accumulation of metabolites and attain hypoxic and ischemic condition.[3] Therefore, being able to understand how much tension an exercise puts on the muscle you want to train would be useful, no matter if mechanotransduction, reactive oxygen species or lactate accumulation or muscle fiber recruitment is your goal.

As of right now, I am aware of two ways to try to determine the amount of tension on a specific muscle. The first one (Blue line) is to measure the distance parallel to the floor if the tension comes from gravity or perpendicular to the tension if you use cable for example, to the joint that is moving multiplied by the weight. The second way (Red lines) is the distance between the resultant of forces from friction under your feet, if there's any, and from a perpendicular line in the middle of a foot multiplied by the weight. The thinking behind that theory is that every force (from gravity or from another resistance) will be expressed on the floor or other surface with your feet.



When the goal is to find the amount of tension on a muscle from the upper body, everyone seems to utilize the first way. However, when some people want to find the amount of tension applied on a lower body muscle, they will use the second way.

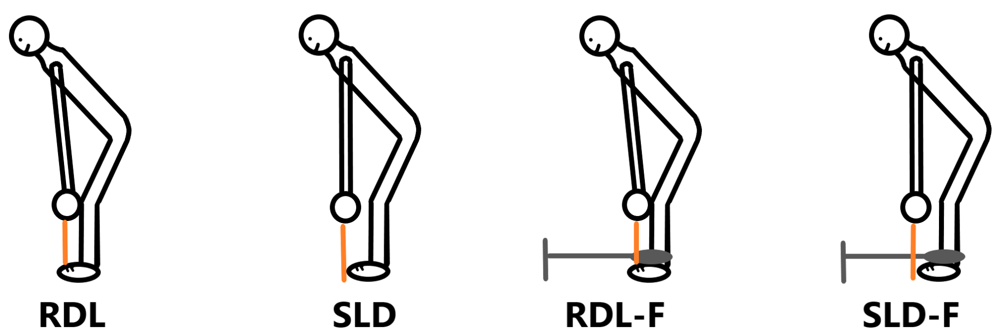
Based on other science fields, a theory, for it to be great, should be able to answer its question every time. The famous saying "The exception that proves the rule” actually means that, when something seems like an exception, a rule or a theory should still be able to work. If it does, the theory “works”, until proven otherwise. If we translate that to the situation at hand, I think that the exception, or what seems to be, is when we try to calculate the tension applied on a lower body muscle. Everyone seems to agree that the first way is applicable with the upper body but some people think it doesn’t work on the lower body due to the role of friction, and the second way would be more appropriate. The same people also think that you shouldn’t measure from the weight to the moving joint but from the middle of the feet to the moving joint, probably because the weight is expressed on the floor under your feet. If you want to prove it, just step on a scale and measure your weight. Step again but try to move your center of mass by bending at the hips. You could also try with a weight in your hand, and then with the same weight but far from your body like with a shoulder flexion. You will see that the weight on the scale stays the same.

## Methods

The study was done on two subjects. Both participants were highly trained individuals. One of them was myself, and the person taking the results was not aware of the goal of the study. The other subject that participated was not aware of the goal of the study, but the person taking the results was myself. Due to the Covid-19 pandemic, I was only able to get these two persons (the one taking the results and the other participant) on two separate occasions and for a short amount of time. I was only able to try each scenario once.

The goal of this study was to measure the amount of weight the hip musculature was able to pull isometrically in a romanian deadlift and stiff leg deadlift. Since it was isometric with the bar at the knee level, the only difference was that, for the stiff leg deadlift, the bar was further from the body. Knee angles were similar (~35°) every time. To measure the weight being pulled, I attached a digital fish scale (Klau, illustrated as the orange line) to the floor and to the bar that already had 155lb on it. The results were filmed and then the average, since the weight was constantly changing, of the weight being pulled was calculated and added to the weight of the bar.

Both participants did the same 4 tests. A romanian deadlift (RDL), a stiff leg deadlift (SLD), a romanian deadlift with straps attached to the feet to counter the friction (RDL-F) and a stiff leg deadlift with straps attached to the feet to counter the friction (SLD-F). The straps are illustrated as the grey lines.



The visual representation is not perfect. During the SLD and SLD-F the subjects had a tendency to lean forward due to a change in center of mass, theoretically increasing friction compared to RDL but equal to RDL-F.

## Results

Subject 1

| Exercise | Weight lifted (kg) | Torque (N m) |
|---|---|---|
| RDL | 150.82 | 49.77 |
| SLD | 124.74 | 49.90 |
| RDL-F | 147.42 | 48.65 |
| SLD-F | 121.34 | 48.54 |

*The distance parallel to the floor from the barbell to the hip is 0.33 meter for RDL and RDL-F and 0.4 meter for SLD and SLD-F

Subject 2

| Exercise | Weight lifted (kg) | Torque (N m) |
|---|---|---|
| RDL | 154.22 | 50.89 |
| SLD | 149.69 | 56.88 |
| RDL-F | 151.50 | 50.00 |
| SLD-F | 132.45 | 50.33 |

*The distance parallel to the floor from the barbell to the hip is 0.33 meter for RDL and RDL-F and 0.38 meter for SLD and SLD-F

## Discussion

This study tried to demonstrate a better way of calculating tension between the two current methods. Based on the results, friction does not seem to affect the amount of weight a person can isometrically pull. However, there is a correlation between the amount of tension with RDL and SLD or with RDL-F and SLD-F when you use the first method, which is the distance perpendicular to the tension to the moving joint. There is no difference in the amount of weight being pulled no matter if there is friction or significantly less. If friction had an impact, there would be a blatant difference because, even if weight is further from you it wouldn’t have an impact. Therefore, someone could pull as much in a SLD than with a RDL if you diminish friction.

Someone could make the argument that the reason subjects lifted less in SLD and SLD-F is because of the instability of having the weight far from you and not because of friction or because the amount of tension differs due to the distance between the weight and joint.[4,5] Is the weight more difficult to lift at the top of a (deltoids) lateral raise because of instability or because of the amount of tension? Or is it strictly because muscles are weaker when they are shortened?[6, 7,8] You could design the same experience but instead use cables with its pulley at the same height of your hands. The distance perpendicular between the tension (cable) and the moving joint (shoulder) would be at its furthest when the deltoids are lengthened. However, it is more difficult at the bottom of the movement and gets easier at the top. If you use that example, it means that you could not only use the fact that a muscle is shortened or not or instability to say if you can lift more or less weight. It seems that there is more to it, even if overall stability and sarcomere length are really important to determine your muscles capacity to generate force.

With the upper body musculature, it is well established among highly knowledgeable trainers, not scientists, that the best way of determining the amount of tension on a muscle is with the first method. It would make sense that the method that works for most skeletal muscles would work for all of them.

Are there any exceptions?

Some could say that the hip thrust is one of them. Why are the glutes the primary targeted muscle[9] if there is no distance between the weight and the moving joint? Why is it significantly more difficult at the top of the movement than at the bottom? I don't think there are exceptions. The hip thrust works the glutes because they stretch and contract while the weight offers a resistance. No, a bench press does not work the latissimus dorsi to a significant degree[10] because even if there is movement, the weight does not offer a resistance to these muscles. I think that the hip thrust is more difficult at the top of the movement because the sarcomeres are shortened, so their capacity to generate force is lesser. Also, at the bottom of the movement, other muscles are in a good position to produce force. In other words, muscles like quadriceps and hamstring are able to help lift the weight[11], more so at the bottom of the movement.[12]

## Is friction useless?

I think friction needs to be taken into account but I don't think it influences the amount of tension on a specific muscle or muscle group.

Based on my finding, no matter the amount of friction, the amount of tension was in correlation with the distance perpendicular to the tension to the moving joints. Based on my understanding of other studies, friction could be used as a way to bias a muscle more than the other or to increase activation of a specific muscle.

Studies on mind muscle connection (MMC) are interesting for this. Even if MMC is supposedly an internal focus[13], the way to measure what MMC does is often to use actual internal focus (eg. "think about your pectoralis major" or "contract your pectoralis major" during bench press). Nonetheless, sometimes researchers will use external focus, different from "lift the weight from point A to B", to examine MMC. A good example is a particular study[14] where they asked participants to "attempt to bring your elbows to each other when you push" to work pectoralis major during bench press or "attempt to turn away your elbows from each other when you push" to work their triceps. Even if it is a way to make sure the subjects focused on the desired muscle, this technique will probably influence friction between the hands and the bar. The pectoralis major, for example, has to work during bench press because it contracts so horizontal humeral adduction happens. If you "bring your elbows to each other when you push", it will increase friction between your hands and the bar. The pectoralis major will also contract independently of the necessary contraction to move the bar from A to B, it will increase its activation.

The reason why the SLD seems to work more the hamstring than the glutes compared with a RDL, even if knee flexion and range of motion are equated, is probably due to friction. There is an isometric contraction of the hamstring during the lift to counteract friction. So, even if the amount of tension, the length of the sarcomeres, and other metrics are equal, the hamstring will probably have higher activation (EMG) during a SLD than during a RDL. The hamstrings will be doing isometric contraction at the bottom of the movement to keep you stable and they will help extend your hips with your glutes to lift the weight.

## Limitations

There were a ton of limitations since it was not done in a lab. There is probably ~1% difference in the actual weight being lifted. I double checked the accuracy of the scale by weighing different weight plates. Every result was within 1% of the actual weight written on the plates. The distance between the bar and the hip joint was measured 2-3 times but I can't guarantee that the distance is exact since the distance was not measured while the lift was being done. There was maybe a ± ¼ inch difference between the distance used in the equation and the actual distance. Every test was only done once because of Covid-19 restrictions.

## Conclusion

Even if the study was done outside of academia with a limited budget, I tried to be as precise as possible and when it was impossible I wrote it above. My goal is to inspire real professionals to do the work. Even if mechanotransduction seems to be the primary pathway of hypertrophy signaling within resistance training, the amount of tension is not yet used in studies. We need a big paradigm shift in hypertrophy research. If mechanical tension could be measured with accuracy, we would finally be able to say if an exercise is "better" than another with a similar resistance profile and depending on the individual and their differences. We would also be able to have amazing science on resistance profiles and their application to training. EMG data is useful but it is currently used de facto, even if we know activation does not automatically mean hypertrophy.[15]

Based on my findings, the better way to calculate the amount of tension on a specific muscle is: "The weight" x " The distance (from the moving joint to the tension in a straight line that is perpendicular to the tension)" which is also known as torque. Friction could be useful if we want to increase activation of a specific muscle.

## Citations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