The optimal range of motion for hypertrophy: A review of the literature.

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N.B. Image sources are listed at the end.

The purpose of this unofficial review is to hopefully shed some light on various misunderstandings concerning range of motion (ROM) and its application. There are currently two reviews on the subject.[1,2] They both review the same studies but their conclusions are a bit different. Each seems to agree that it's not yet clear which is better. However, in the Schoenfeld et al.[1] review, full ROM has a small advantage for hypertrophy compared to partial ROM. But the Newmire et al.[2] review says that both are good and even that partial ROM may have an advantage in various conditions. Both reviews are way more nuanced than what I just said and even if it looks like they contradict each other, I think that they can both be right. Since it's useless for me to repeat everything that these papers are saying, I will therefore spend most of that review looking at the unanswered questions. First, I think it's important to define the different types of range of motion. The way I view it, is that full ROM is the range at which a joint, or many depending on the exercise, can move, and partial ROM is ambiguous because it's a part of the full ROM and it always needs to be defined.

Lower body musculature

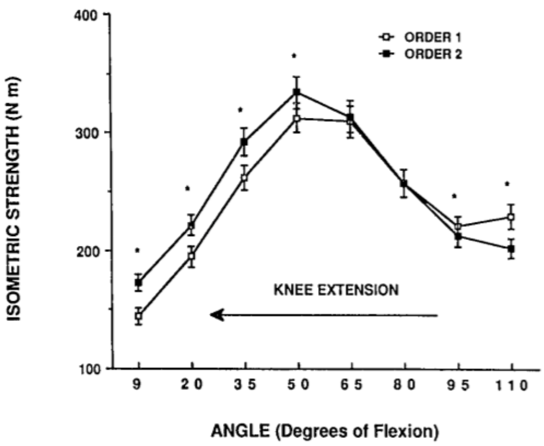


Figure 1—Torque (N·m) measurements for isometric contraction of the knee extensors at 9°, 20°, 35°, 50°, 65°, 80°, 95°, and 110° of knee flexion. Order 1 tests were performed beginning at 110° of knee flexion and progressed to 9° of knee flexion. Order 2 tests began at 9° of knee flexion and progressed to 110° of knee flexion. Data represent means ± SEM. * $P \leq 0.01$.

Studies focusing on which ROM is better for hypertrophy are using different exercises. That is probably why there is a lot of misunderstanding. You can't compare 0° - 60° knee flexion on a leg extension and with a squat. Some reasons are that at the "bottom" of a squat (~ 90° to 140° knee flexion) muscles like gluteus maximus and adductors helps lifting the weight, therefore they will have greater hypertrophy if you squat in a full ROM.[3] Another reason is that you have a lot of mechanical tension, which is the primary muscle hypertrophy stimulus, at 0° of knee flexion during a leg extension compared to basically none at 0° of knee flexion during a squat. Quadriceps, are stronger at 80° of knee flexion compared to 5°, for example.[4,5,6,7] So, if we keep the previous example, a 0° to 60° squat will miss the moment in the lift where the tension is at its greatest and a part of the moment where the quadriceps are able to produce a lot of force. In a 0° to 60° leg extension, tension will still be applied to a great extent. It doesn't mean that partial ROM leg extension is a great idea, it means that the impact of doing so will be different from a partial ROM squat, even if the degrees of knee flexion are equated.

Squats

There are two studies looking at the hypertrophic response of partial vs full ROM squats. However, they used different ROM to do so. The Bloomquist et al.[8] study used 0-60° of knee flexion during the eccentric phase for partial ROM vs 0-120° for full ROM squats, but the Kubo et al.[3] study used 0-90° vs 0-140° of knee flexion for partial ROM and full ROM respectively. They both used untrained individuals, the benefit is that the effects are bigger and thus, easier to measure. However, it can give weird results because the effects are bigger. Both studies resulted in a greater hypertrophy of the quadriceps muscle with full ROM squats, so 120° and 140° of knee flexion. Although there is a difference, it's quite minor. It's logical, you take untrained subjects and you make them squat close to failure, they will grow. The difference was more significant between 60° vs 120° than 90° vs 140°. If we put both studies in the same basket, 60° squats didn't produce a lot of hypertrophy, but 90°, 120° and 140° were basically equal when we only looked at the quadriceps. The difference was in terms of the hypertrophic response of the adductors and the gluteus maximus. In the Kubo et al.[3] study, the 140° squat produced a significantly bigger cross-sectional area (CSA) increase in the adductors and gluteus maximus compared with the 90° squat. The Bloomquist et al.[8] study found a significant increase in the adductors CSA with the 60° squat. Why is that? They explain it by the fact that the partial ROM group used more load, therefore the muscles that activate at the beginning of the movement grew. It's all relative, they only measured CSA of the adductors at "the most proximal sections", which is a small part of the adductors that doesn't really change the physical appearance of your legs. It's also a part of your adductors that works best closer to a full hip extension compared with the bigger part of your adductors, which has a lot of tension at the bottom of a squat where hip flexion is more present. That is why we see a significant difference in CSA increase of the adductors in the 140° squat compared with the 90° squat, they measured the adductor magnus, adductor longus, and adductor brevis which gives a result that is maybe more accurate of the actual effect ROM has on adductors. For the gluteus maximus, there is only the Kubo et al.[3] study that looked at it and their conclusion was that a full ROM squat is better for glute hypertrophy. I am confident saying this even if one study was done on the subject because there is also a complementary way to look at this. If partial ROM squat is not good for glutes hypertrophy and full ROM is good based on that only study, and that a full ROM squat is better for gluteus maximus hypertrophy than the hip thrust (which is considered to be a good gluteus maximus exercise) based on another study,[9] I can say with a straight face that we don't need another study to confirm this. It also helps to understand exercise mechanics, the results become really easy to understand. During a full ROM squat, you take the gluteus maximus through a more complete ROM and you benefit from the bottom of the movement, which is where there is the greatest amount of tension[10] and mechanical tension is the main driver of hypertrophy.[11,12,25]

Leg extension and complete leg training

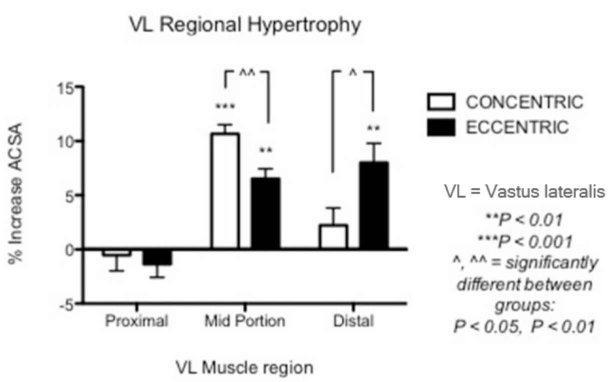
The other two studies that looked at how ROM influence hypertrophy for the lower body musculature either used leg extension[13] or a full leg training[14]. The Valamatos et al.[13] study, which measured CSA increase with a partial or full ROM leg extension of 0° - 60° or 0° - 100° of knee flexion respectively. They only measured the vastus lateralis muscle. The results correspond with the previous studies, the full ROM group gained more muscle but it's barely significant. However, even if time under tension was equated in that study, full ROM seemed to have a benefit. Something that needs to be taken into consideration is the fact that, except the control group who didn't train, each participant trained with a partial ROM with one leg and full ROM with the other. The leg doing full ROM was randomly selected and the other leg was automatically in the partial ROM group. The thing is, we now know that training one side of the body might have an impact on the other side.[15] The fact that one leg was either doing a 60° to 0° or 100° to 0° knee extension probably had an impact on the other leg. The result is still that full ROM seemed to be better for hypertrophy but maybe the difference would have been bigger between partial and full ROM if they didn't use the same subjects to do both approaches.

Table 2. Resistance training program outline.*†

Exercise	Reps	Sets	Recovery (s)	Intensity (1RM %)
Day 1				
BB back squat	10	3	90	80
Knee extension	10	3	60	80
Bulgarian split squat	10	3	90	80
DL Sampson chair	4 × 10-s holds	3	60	-
Day 2				
BB back squat	10	3	90	80
Knee extension	10	3	60	80
Leg press	10	3	90	80
DB lunges	10	3	60	80
Day 3				
BW squats	30	3	90	-
DL Sampson chair	4 × 20-s holds	3	60	-
BW lunges	30	3	90	-
SR Sampson chair	5 × 5-s holds	3	60	-

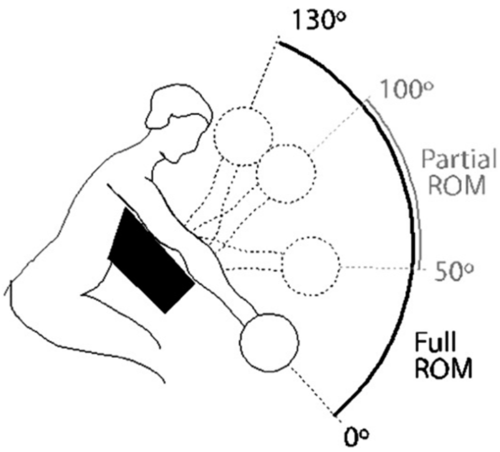
*BB = barbell; DB = dumbbell; DL = double-legged; SR = single-legged; BW = body weight; RM = repetition maximum.
†Exercises were carried out at 80% 1RM where appropriate or using body mass.

What about the full leg training study?[14] They compared 0° to 50° and 0° to 90° of knee flexion for partial ROM and full ROM respectively. So, their full ROM was the partial ROM of the Kubo et al. research.[3] Their training program (as shown on the side of this paragraph) was a mix of different exercises that put emphasis on different parts of the movement. Squats, leg presses, split squats and lunges have a lot of tension when the quadriceps are in a lengthen position. Leg extension has a constant tension throughout the movement compared with free weight exercises. Depending on which model of Pulse Fitness leg extension was used for the research, maybe there was a slight deload close to knee extension but it's insignificant compared with the deload at the end of a squat, for example. They also used isometric contraction (Sampson chair / Wall sit) during the resistance training program. This particular research was the closest to a real life situation due to the fact that it was a complete leg workout and also that the degrees of knee flexion used were similar to what most people use in the gym. The results were quite clear, 90° of knee flexion for the eccentric phase produced more hypertrophy than 0° to 50°. The most distal and proximal part of the vastus lateralis had a significant increase in CSA in the full vs partial ROM. However, at 50% of femur length they didn't see a difference between the two groups. It is in line with studies on concentric versus eccentric training. Concentric training tends to increase CSA at the medial part of a muscle compared with the distal and the proximal portion.[21,22] Even if there is technically a difference between only performing the concentric portion and simply doing the part of the movement where the muscle is most contracted are different, I would suggest that the underlying mechanism regarding the hypertrophic stimuli specific to that exercise are similar in these scenarios. Both would increase metabolic stress to a higher degree, independent of mechanical stress, than a regular full ROM exercise, due to muscles being in a almost constant contracting or shortened state.[19,23,24]



Based on the four papers that looked at the hypertrophic response of different ROM on lower body musculature, it looks like 50° and 60° are suboptimal for hypertrophy and that 90°, 100°, 120° and 140° are basically equal, and better than partial ROM, in term of quadriceps hypertrophy. If your goal is overall lower body development, doing a bigger ROM, like 120° or 140° of knee flexion is probably a good idea because you can also increase CSA of the adductors and gluteus maximus.

Upper body musculature



The Pinto et al. study looked at CSA increase of the elbow flexor (biceps brachii, brachialis and brachioradialis).[16] They compared 0° of elbow flexion to 130° for the full ROM group and 50° to 100° of elbow flexion for the partial ROM group during a preacher curl. It is different from every lower body musculature paper because they used the middle of the movement to analyze the effect of different ROM on hypertrophy. They put a metallic bar at 50° and another one at 100° of elbow flexion so that the ROM was tightly regulated within the partial ROM group. However, it can be problematic if they are not taught properly to not bounce the weight on the metallic bars. More so because they were untrained individuals and it can be tempting to use the metallic bars to facilitate the change in direction. The results of this study suggested that full ROM was better for hypertrophy of the elbow flexors but that difference was extremely small. I think that it can be explained by the fact that; (a) they were untrained individuals so they tend to respond a lot no matter what; (b) the partial ROM group did more volume and we know that more volume is often correlated with better hypertrophy;[17,18] (c) the partial ROM group used more load; (d) the partial ROM was in the part of the movement where tension was at its highest.[26] Nonetheless, the full ROM group had a bigger CSA increase compared with partial ROM.

A Goto et al. study[19] looked at the triceps brachii hypertrophy of a partial ROM lying barbell (BB) triceps extension compared with a full ROM. The partial ROM group did 90° to 45° elbow extension while the other group went from a completely flexed (120°) elbow to a full (0°) elbow extension. At first glance, it looked quite similar to the previous (preacher curl) study in terms of exercise and ROM selection. However, the results were different, the partial ROM group gained more muscle and the CSA increase difference was actually quite big. That particular study, because of the fact that the result differs from the other studies, really helps to shape the understanding of how to apply ROM to a resistance training program. First, I want to note a couple key differences between the preacher curl study and this one: (a) partial ROM group in the triceps hypertrophy study didn't use more load than the full ROM group. However, the speed (angular velocity) at which they lifted the weight was slower in the partial ROM group, meaning that they constantly controlled the weight with an active muscular contraction; (b) a lying BB extension puts the triceps in a more lengthen position compared with the preacher curl, which puts the biceps in a more shorten position, it's all due to the impact of a shoulder flexion on both of these muscle. The former tends to be better for hypertrophy;[20] (c) the study was done on trained individuals; (d) no matter the ROM of a preacher curl the biceps are always in line with the tension. On the other hand, based on the individual differences in anatomy and mobility, it is not the case for a lying BB triceps extension. You need to have an above average mobility if you are able to do that exercise in a full ROM and always keep your humerus in line with gravity (which increases tension on the muscle)[27], while having a pronated grip (figure 5). To cope with that and to validate our understanding of exercise mechanic; a study where they would've used a shoulder width — neutral (or hammer) grip would be a great idea. Instead of a barbell, they would've needed a multi grip bar (figure 6). I think that, with those changes, a bigger ROM would actually be better for triceps hypertrophy.

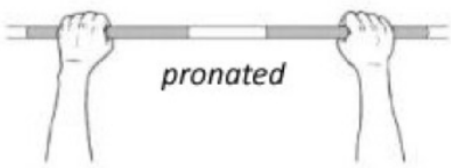


Figure 5

Figure 6

Discussion

Based on the finding of the six studies that looked at the difference in cross-sectional area (CSA) increase between a full range of motion (ROM) versus a partial ROM, we really can't say that "full ROM is better for hypertrophy" and even less that "partial ROM is better for hypertrophy". Full ROM is interesting if you want to increase muscle mass of different muscles without being specific (eg. squats for the lower body instead of squats for quadriceps). The problem with that approach is that it can become a problem if you only need quadriceps hypertrophy, to keep the same example. This is where active ROM comes into play. Based on the six research that we have and our understanding of exercise mechanics, I think that it is, and will always be, impossible to say if full ROM is better than partial ROM without adding active ROM into the equation and precisely defining every type of ROM. The way I view it is that full ROM is the range at which a (or many depending of the exercise) joint can move, partial ROM is a part of the full ROM and it always needs to be defined and active ROM is the range at which the specific muscle you want to train is the primary mover of the tension. So, full ROM is mostly about the joint, partial ROM is ambiguous and active ROM is about a specific muscle. When we add active ROM everything becomes more clear, mostly because we lose the vagueness of partial ROM. We could also define active ROM as full ROM, but only if; (a) we are not talking about the full ROM of a joint but of a specific muscle; (b) the exercise selection is made so that the athlete can take that specific muscle into a full ROM (see (a)) while keeping that specific muscle the primary mover; (c) we agree that it can differ from person to person. In that scenario: active ROM = full ROM. However, I think that keeping the terms partial, active and full ROM is a good idea due to its simplicity of understanding for the general public who wants to lift weight for health, physique or performance benefits. With active ROM, we can explain why a 60° squat is suboptimal for quadriceps hypertrophy but that 90° of knee flexion or more are all equally good for hypertrophy of the quadriceps. We can also explain why a full ROM preacher curl is better for hypertrophy than a partial ROM, but that it's the opposite for a lying BB triceps extension. Everything becomes more clear when we add that variable and that we understand ROM should be about the muscle and not the joint.

Conclusion

Finally, I think it's fair to say that, concerning the hypertrophy of a muscle, using the muscle architecture as a reference frame for measuring range of motion is superior to the joint's degrees of freedom. New research on how to build a computer vision system that links sarcomeres length to joint angle would help a virtual trainer make recommendations on the optimal ROM for the goal.

Image Credit

First image is from Graves, J E et al. [4]
Second image is from McMahon, G E et al. [14]
Third image is from Franchi, M V et al. [21]
Fourth image is from Pinto R S et al. [16]

Citations

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