RELATIVE MUSCLE CONTRIBUTIONS TO NET JOINT MOMENTS IN THE BARBELL BACK SQUAT

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INTRODUCTION

While the kinetics and kinematics of the back squat have been well documented [1], in addition to relative muscular efforts at the hip, knee, and ankle joints [2], only one study has examined the individual contributions of the monoarticular and biarticular hip extensors, and how either strategy may impact knee extensor efforts [3]; however, individual muscle contributions to hip and knee extension has not been thoroughly investigated. This information would help strength and conditioning professionals develop more effective programming, in addition to proper technique instruction, for developing maximal strength in athletes. The purpose of this model was to evaluate alterations in individual muscle contributions to hip and knee extension with respect to barbell loading and depth in the back squat exercise.

METHODS

Kinematic and kinetic data from ten resistance-trained women were obtained from Bryanton, et al. [2], wherein participants performed squats using 50 and 90% of their one repetition maximum (RM). Parameters for the model included joint angles and net moments as a function of squat depth (i.e., knee angle), in addition to subject height and mass.

Using data from Handsfield, et al. [4], Hawkins, et al. [5], Herzog, et al. [6], Nemeth [7], and Delp, et al. [8], a musculoskeletal model was constructed in MATLAB (MathWorks, Natick, MA) to estimate subject-specific muscle sizes and moment arms. An optimization algorithm then estimated muscle moment contributions (gluteus maximus, adductor magnus, biceps femoris, semitendinosus, semimembranosus, rectus femoris, v. lateralis, v. medialis, v. intermedius, medial gastrocnemius, lateral gastrocnemius, and soleus) to yield the necessary net joint moments, while minimizing the sum of squared activations [9].

The passive and active contributions of each muscle were modeled in accordance with their respective length-tension curve. Relative moment contributions of the hip and knee extensors were calculated by dividing each muscle's moment contribution by the net joint moment of the joint in question.

RESULTS AND DISCUSSION

The adductor magnus appears to play a pivotal role in hip extension during the squat, producing, on average, more than 50% of the net hip extension moment (Figure 1). Particularly, this role is most apparent in positions of greater squat depth and with lighter loads. This is likely due to its larger hip extension moment arm in positions of greater hip flexion [7].

In higher squat positions, the gluteus maximus has similar contributions as the adductor magnus in generating a hip extension moment (Figure 1). However, the decreasing moment arm with increasing depth does not allow the gluteus maximus to generate large hip extension moments in deep flexion, despite it being in stretch [8]. Interestingly, the relative moment contributions of the gluteus maximus do not appear to differ substantially between 50 and 90% 1RM; the gluteus

maximus contributes relatively less in greater degrees in hip flexion at both loads (Figure 1).
The hamstrings and adductor magnus appear to play a complementary role in hip extension; if the adductor magnus cannot produce a larger hip extension moment with increased load, the hamstrings increase their relative contribution in order to compensate (Figure 1).

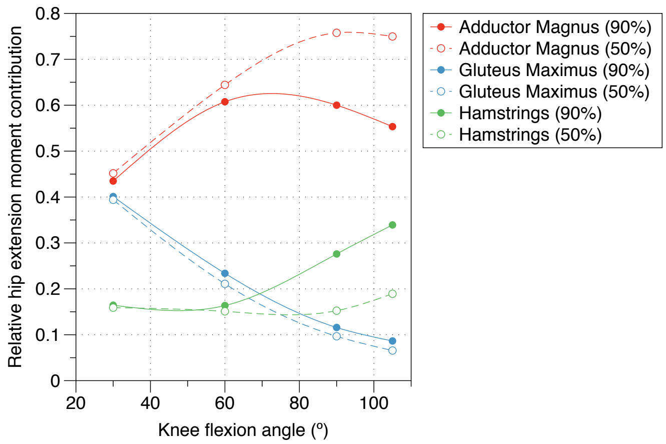

Figure 1. *Relative muscle contributions to hip extension during the squat with respect to depth and barbell load. Hamstrings represent the sum of the biceps femoris, semitendinosus, and semimembranosus.*

The increasing role of the hamstrings at the hip with greater barbell loading has implications for the quadriceps, in that a greater hip extension moment produced by the hamstrings necessarily means a greater knee flexion moment. This increased knee flexion moment must be countered by the quadriceps in order to produce a sufficient net knee extension moment [3] (Figure 2).

Although seemingly paradoxical, the rectus femoris does not appear to contribute to the knee extension moment in the squat (Figure 2). This is likely due to its biarticular nature, in that the hip extensors may not be able to produce a large enough moment to overcome both the external and internal hip flexion joint moments. Although the rectus femoris seems to be highly active during the back squat in electromyography studies [10], this may be a red herring, as the rectus femoris is highly susceptible to crosstalk from the vastii [11]. This is supported by Fonseca et al [12] who found that the vastii, but not the rectus femoris, hypertrophied following a back squat-only program [12].

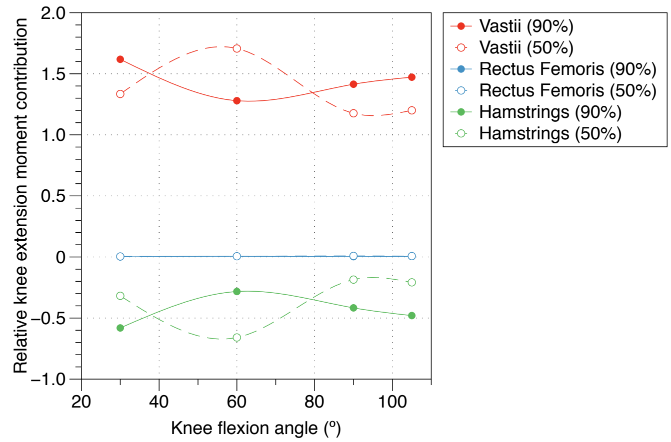

Figure 2. *Relative muscle contributions to knee extension during the squat with respect to depth and barbell load. Vastii represent the sum of the v. lateralis, v. medialis, and v. intermedis.*

CONCLUSION

This work builds upon previous work by Bryanton, et al. [3], by modeling the exact relative moment contribution of each major muscle involved rather than simply identifying a hip extension strategy. In turn, it appears that the respective role of each muscle during the back squat will vary as a function of squat depth and barbell load.

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