The Increasing Role of the Hip Extensor Musculature With Heavier Compound Lower-Body Movements and More Explosive Sport Actions

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ABSTRACT

HIP EXTENSION MOMENTS INCREASE TO A MUCH GREATER DEGREE THAN KNEE EXTENSION MOMENTS WITH INCREASING LOADS DURING THE SQUAT, LUNGE, AND DEADLIFT EXERCISES AND WITH INCREASING RUNNING SPEEDS, JUMP HEIGHTS, AND LATERAL AGILITY MANEUVERS. THEREFORE, HIP EXTENSION TRAINING SHOULD BE PRIORITIZED IN ATHLETIC CONDITIONING BY (A) USING HIP-DOMINANT EXERCISES IN THE ATHLETE'S PROGRAM, (B) EMPHASIZING HEAVIER LOADS DURING COMPOUND LOWER-BODY RESISTANCE EXERCISES AS THE ATHLETE MATURES, AND (C) INCORPORATING LOADS THAT MAXIMIZE THE HIP EXTENSION MOMENT DURING EXPLOSIVE LOWER-BODY TRAINING.

INTRODUCTION

It is generally assumed that sport actions and resistance-training exercises always require the same relative contribution of the hip and knee muscles, irrespective of loading or speed. However, the proportions of joint moments actually alter in an exercise or sport action depending on the load or speed of the movement. In this context, joint moments are the product of muscular force and moment arm length. Greater muscular force of the involved musculature therefore leads to greater joint moments, so long as moment arm lengths remain unaltered. Recent research indicates that a squat or deadlift with a heavier load is likely to require a different proportional involvement (i.e., ratio) of the hip and knee extensor muscles.

Some authors have used these ratios to categorize compound lower-body movements as knee-dominant (if the hip-to-knee extension moment is less than 1) or hip-dominant (if the hip-to-knee extension moment is greater than 1) (10). The ratio of hip-to-knee extensor moments increases with increasing load during squats (2), lunges (10), deadlifts (14), and to a lesser degree, hex-bar deadlifts (14). In these resistance-training exercises, this represents an increase in proportional hip involvement with increasing load. Additionally, the ratio of hip-to-knee extensor moments increases with increasing speed in running (11) and with increasing jump height in jumping (8). In jumping and running, this represents not only an increase in proportional hip involvement with increasing load but also a shift from knee-dominance at lower intensities to hip-dominance at higher intensities. These findings emphasize the critical role of the hip extensors in athletic activities and provide important information regarding the training of the hips for optimal performance.

HOW DO HIP EXTENSION MOMENTS CHANGE WITH INCREASING SQUAT LOAD?

Recent research indicates that hip extension moments increase with

KEY WORDS:
hip extensors; hip extension torque; hip extension moments; squat exercise; lunge exercise; deadlift exercise; sprint running; vertical jumping; hamstrings; gluteus maximus

Table 1
Hip-to-knee extensor moment ratios during the squat with different loads, Bryanton et al. (2)

	50% of 1RM	60% of 1RM	70% of 1RM	80% of 1RM	90% of 1RM
Ratio	1.12:1	1.23:1	1.32:1	1.38:1	1.49:1

increasing load to a greater extent than knee extension moments during the squat. Bryanton et al. (2) investigated the joint moments during the concentric phase of a squat performed by resistance-trained women at varying depths and different percentages of 1 repetition maximum (1RM) (i.e., loading) (Table 1). The researchers found that hip extension moments increased significantly with increased loading. However, knee extension moments remained fairly constant. This means that the ratio of hip-to-knee extension moments increases with increasing load, making the hips progressively more important to the lift. The researchers found that the ratio changed from 1.1:1.0 at 50% of 1RM to 1.5:1.0 at 90% of 1RM. The proportional contribution of hip extension moments at 90% of 1RM was 33.3% greater than at 50% of 1RM. This shows us that as the weights get heavier in squats, the hips display a proportionally greater increase in extensor moment than the knees (Figure 1).

HOW DOES HIP EXTENSION IMPULSE AND WORK CHANGE WITH INCREASING LUNGE LOAD?

Recent research indicates that hip extension impulse increases with increasing load to a greater extent than knee extension impulse during the lunge. Riemann et al. (10) investigated the differences in the work done and the net joint moment impulses during the concentric phase at the hip, knee, and ankle joints during lunges with loads equal to 12.5%, 25%, and 50% of bodyweight (Table 2). The researchers found that as the external load increased, the greatest increase in net joint impulse and work done occurred at the hip, followed by the ankle and then the knee. This suggests that as weight is added to the lunge exercise, it becomes increasingly reliant on the hips for progression. Again, the ratio of hip-to-knee extension impulses increases with increasing load. The researchers found that the ratio changed from 3.4:1.0 at 12.5% of additional bodyweight loading to 4.2:1.0 at 50% of additional bodyweight loading. The proportional contribution of hip extension impulse at 50% of additional bodyweight loading is 22.8% greater than at 12.5% of additional bodyweight loading. This shows us that as the weights get heavier in lunges, the hips display a proportionally greater increase in impulse than the knees (Figure 2).

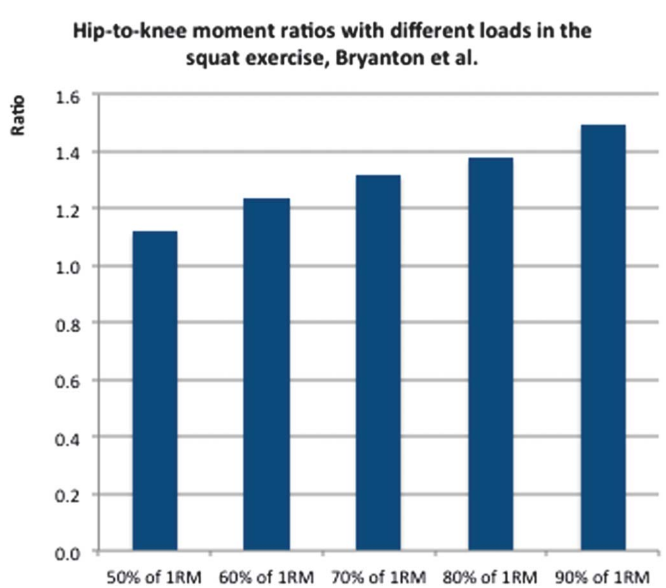

Figure 1. Hip-to-knee extensor moment ratios during the squat with different loads, Bryanton et al. (2).

HOW DO HIP EXTENSION MOMENTS CHANGE WITH INCREASING DEADLIFT LOAD?

Recent research indicates that the hip extension moment increases with increasing load by proportionally more than the knee extension moment during the conventional deadlift. Swinton et al. (14) investigated the peak net hip, knee, and ankle moments during straight bar conventional deadlifts and hex-bar deadlifts (Table 3). The researchers found that as the load lifted increased, there was a proportionally greater increase in hip extension moments compared with the knee or ankle moments. Hence, the hip-to-knee extension moment ratio increased with increased loading. The researchers found that the hip-to-knee extension moment ratio for the straight bar conventional deadlift increased from 2.8:1.0 at 10% of 1RM to 3.7:1.0 at 80% of 1RM. This represented an increase in hip-dominance of 33.3%. Similarly, they found that the hip-to-knee extension moment ratio for the hex-bar deadlift increased from 1.70:1.0 at 10% of 1RM to 1.78:1.0 at 80% of 1RM. This represents an increase of 5.1% in hip involvement. The increase in the hip-to-knee extension moment ratio is greater in the conventional deadlift compared with the hex-bar deadlift for the same relative increase in the load lifted. Both deadlift variations display an increase in hip involvement as the load is increased, just as is seen in the squat and in the lunge exercises, but the increase in hip involvement in the hex-bar deadlift was much smaller than

Table 2 Hip-to-knee extensor moment impulse ratios during the lunge with different loads, Riemann et al. (10)			
	12.5% of bodyweight	25% of bodyweight	50% of bodyweight
Ratio	3.39:1	3.77:1	4.16:1

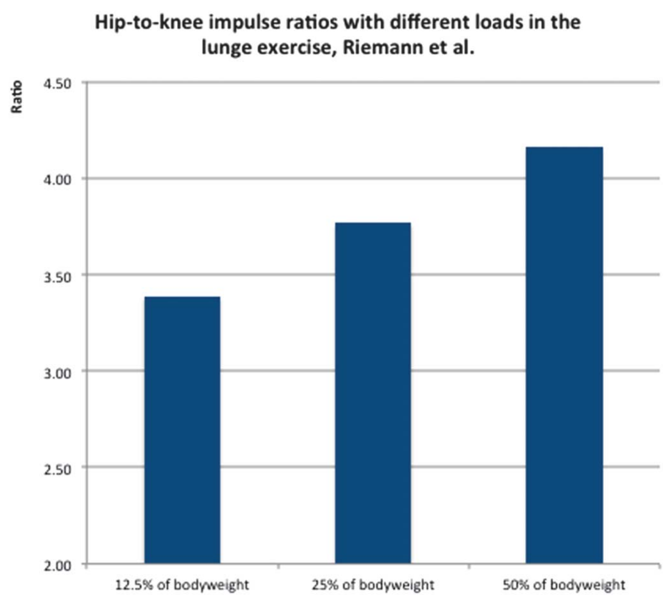

Figure 2. Hip-to-knee extensor impulse ratios during the lunge with different loads, Riemann et al. (10).

in the conventional deadlift. This shows us that as the weights get heavier in conventional deadlifts, the hips display a proportionally greater increase in moments compared with the knees (Figure 3).

HOW DO HIP EXTENSION MOMENTS CHANGE WITH INCREASING RUNNING SPEED?

Recent research indicates that hip extension moments increase with increasing speed to a greater extent than knee extension moments during running at different speeds. Schache et al. (11) investigated the joint moments during running at various speeds (Table 4). They recorded moments at different points in the gait cycle, and the greatest hip extension moments were recorded during terminal swing. It was found that the ratio of hip-to-knee extensor moments increased with increasing running speed, suggesting that the hips become progressively more involved at greater velocities. At 3.5 m/s, it was found that the ratio of peak hip-to-knee extensor moments was 0.29:1.0, whereas at 8.95 m/s (considered "sprint running"), the ratio of peak hip-to-knee extensor moments was 1.18:1.0. This shows that the hips became 304% more involved as running speeds progress from 3.5 m/s to 8.95 m/s and that the activity of running shifts from knee-dominance to hip-dominance (i.e., greater hip than knee extensor moments) as a result. This shows that as running speed increases, the hips display a proportionally greater increase in moments compared with the knees (Figure 4).

HOW DO HIP EXTENSION MOMENTS CHANGE WITH INCREASING JUMPING HEIGHT?

Recent research indicates that hip extension moments increase with increasing jump height to a greater extent than knee extension moments. Lees et al. (8) studied jumps of 3 different intensities, which they labeled "low," "high," and "maximum" (Table 5). The low jump averaged 35 cm, the medium jump 44 cm, and the maximum jump height 53 cm. Lees et al. (8) recorded the joint moments and the work done at each joint during the various jumps and found that the work done at the hip increased markedly with increasing jump height but the work done at the ankle and knee did not increase relatively to the same extent. Joint moments followed a similar trend. Consequently, it was found that the ratio of hip-to-knee work done in the concentric phase increased from 0.64:1.0 in the low jump (i.e., the jump was actually knee-dominant) to 1.67:1.0 in the maximal jump. This represented an increase in hip involvement of 163% and a shift from knee-dominance to hip-dominance as a result. This shows us that as jumping height increases, the hips display a proportionally greater increase in work done (and extension

Table 3 Hip-to-knee extensor moment ratios during the deadlift and hex-bar deadlift with different loads, Swinton et al. (14)								
	10% of 1RM	20% of 1RM	30% of 1RM	40% of 1RM	50% of 1RM	60% of 1RM	70% of 1RM	80% of 1RM
Deadlift	2.76:1	2.88:1	3.12:1	3.15:1	3.42:1	3.57:1	3.68:1	3.68:1
Hex-bar deadlift	1.70:1	1.65:1	1.72:1	1.76:1	1.75:1	1.77:1	1.78:1	1.78:1

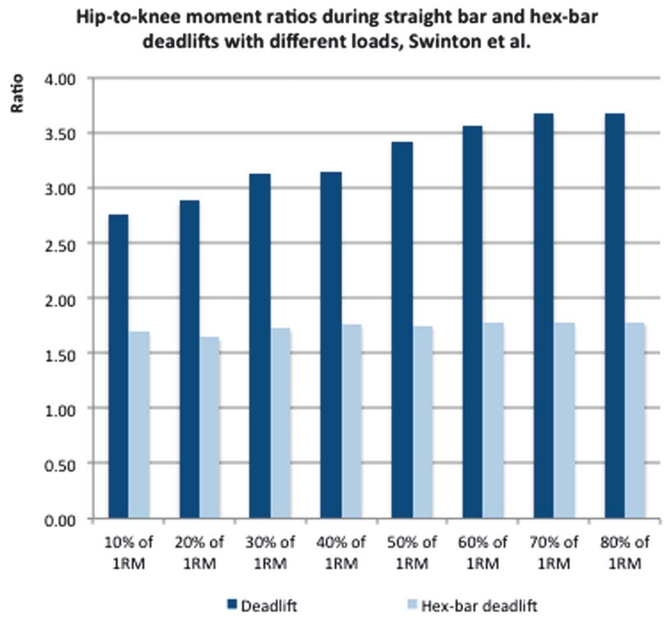

Figure 3. Hip-to-knee extensor moment ratios during the deadlift and hex-bar deadlift with different loads, Swinton et al. (14).

Table 4
Hip-to-knee extensor moment ratios during sprinting at different speeds, Schache et al. (11)

	3.5 m/s	5.02 m/s	6.97 m/s	8.95 m/s
Ratio	0.29:1	0.40:1	0.68:1	1.18:1

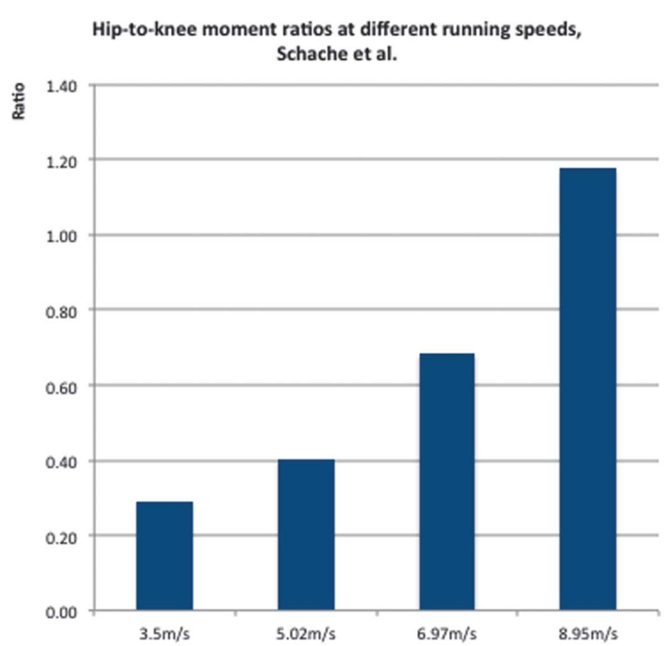

Figure 4. Hip-to-knee extensor moment ratios during running at different speeds, Schache et al. (11).

moments) compared with the knees (Figure 5).

WHAT IS THE ROLE OF THE HIP EXTENSORS IN LATERAL MOVEMENTS?

Although all the above movements occur primarily in the sagittal plane, 2 recent studies have investigated the role of the hip extensors in side-stepping. Inaba et al. (6) found that hip extension moments increased significantly with increasing side step distances but hip abduction moments did not. Similarly, Shimokochi et al. (12) reported that hip abductor function did not seem to be the critical factor for lateral movements but rather that faster hip extension motions were the key to more explosive movements in the frontal plane.

WHY DOES THE ROLE OF THE HIP INCREASE WITH INCREASING INTENSITY?

The findings of these studies indicate that the ratio of hip-to-knee extensor moments or related variables increases with heavier loads during squats, lunges, deadlifts, and hex-bar deadlifts (Table 6). Additionally, the studies indicate that the ratio of hip-to-knee extensor moments or related variables increases with greater speeds in running and with greater heights in jumping. This may happen as a result of different movement strategies being used with different loads and speeds, as indeed Frost et al. (4) recently observed. Frost et al. (4) found that when performing lifting or squatting tasks with a faster movement speed, subjects used a less upright posture and shifted to a more hip-dominant pattern involving an increase in trunk inclination toward the horizontal. Such alterations in kinematics would be expected to lead to corresponding changes in kinetics. Indeed, Hay et al. (5) observed a simultaneous change in trunk inclination along with a proportionally greater increase in hip extension moment during squat exercises with increasing load. However, exactly what drives this change in the

Table 5 Hip-to-knee extensor work done ratios during vertical jumping to different heights, Lees et al. (8)			
	Low	High	Maximum
	0.35 ± 0.03 m	0.44 ± 0.03 m	0.53 ± 0.04 m
Ratio	0.64:1	1.04:1	1.67:1

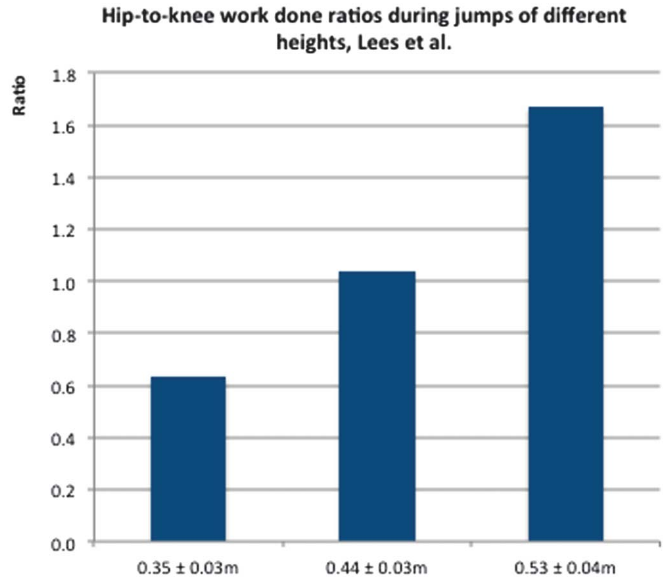

Figure 5. Hip-to-knee extensor work done ratios during vertical jumping to different heights, Lees et al. (8).

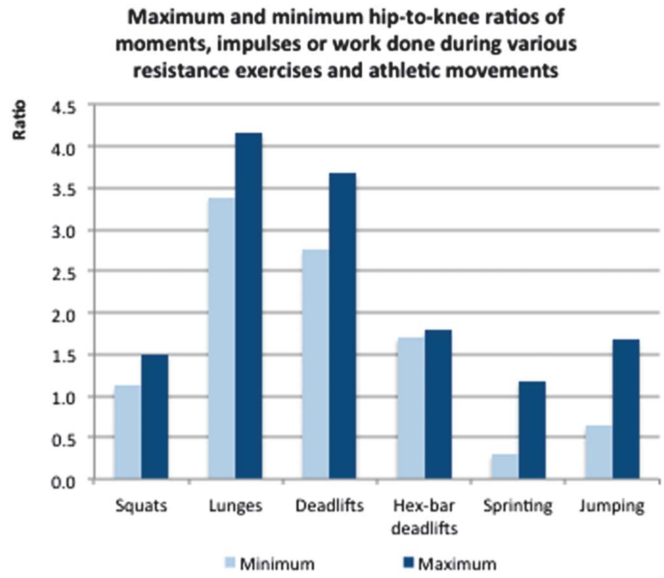

Figure 6. Summary of hip-to-knee extensor moment, impulse or work done ratios, Bryanton et al. (2), Riemann et al. (10), Swinton et al. (14), Schache et al. (11), and Lees et al. (8).

kinematics and kinetics of the movement patterns as intensity increases is unclear. It is possible that as the demand of the movement increases, individuals find they are able to move faster or lift heavier by leaning forward more, which may then lead to a shift in the proportion of hip and knee extension moments in favor of the hip. Because athletes typically display significantly greater hip extension moments than knee extension moments during maximal isometric testing (e.g., Buśko and Gajewski (3)), it may be the case that this shift occurs because the hip muscles are stronger than the knee muscles and therefore provide greater scope for increased moments. However, because maximal isokinetic moments do not demonstrate such clear differences between the magnitude of hip and knee extension moments at all angular velocities (e.g., Smith et al. (13) and Blazevich and Jenkins (1)), the exact reasons for the changes remain unknown.

PRACTICAL IMPLICATIONS

The 5 examples shown in this article demonstrate that as loads get heavier (squat, lunge, conventional deadlift, and hex-bar deadlift), running gets faster, and jumps get higher, hip extension moments or related variables contribute proportionally more to the movement and knee extension moments or related variables contribute proportionally less (Figure 6). Similarly, faster lateral movements require greater increases in hip extension moments than hip abduction moments. This means that for athletes training to produce maximal power and speed, whether in the sagittal or frontal plane, developing the muscular strength of the primary hip extensors (i.e., the gluteus maximus and hamstrings) must be a primary concern.

For athletes training with exercises that closely resemble their competitive activities (e.g., sprinters sprinting or powerlifters squatting), it is likely

Table 6
Summary of hip-to-knee extensor moment, impulse, and work done ratios, Bryanton et al. (2), Riemann et al. (10), Swinton et al. (14), Schache et al. (11), and Lees et al. (8)

Study author	Exercise	Minimum	Maximum
Bryanton et al. (2)	Squats	1.12:1	1.49:1
Riemann et al. (10)	Lunges	3.39:1	4.16:1
Swinton et al. (14)	Deadlifts	2.76:1	3.68:1
	Hex-bar deadlifts	1.70:1	1.78:1
Schache et al. (11)	Sprinting	0.29:1	1.18:1
Lees et al. (8)	Jumping	0.64:1	1.67:1

that submaximal performances will involve significantly lower hip-to-knee extension moments. Therefore, strength coaches will want to address this deficit. The deficit could be addressed in several ways. First, additional work could be performed for the hip extensors. This could take the form of assistance work in the gym, comprising hip-dominant compound movements such as Romanian deadlifts, good mornings, back extensions, reverse hypers, barbell hip thrusts and/or kettlebell swings, and waist-attached sled dragging, which has been shown to be superior to shoulder-attached sled dragging in terms of hip extensor moments (7). Second, maximal work could be emphasized and submaximal work de-emphasized, to the degree that this is possible within the periodized program that the coach considers necessary for the long-term development of the athlete. Finally, although most researchers have emphasized the optimal load for power training as being the load that leads to the greatest overall power output, it may be more fruitful to train with the load that maximizes power output at the hips. Moir et al. (9) recently reported that power output was maximized at the hip during jump squats at 42% of 1RM, whereas system power output was maximized with no load (i.e., 0% of 1RM). Future research should be conducted to determine the optimal loads for hip extension power with other explosive lifts, and to determine whether training at these loads is more beneficial for performance than training at optimal loads for system power.

CONCLUSIONS

As we have seen in the previous examples, the ratio of hip-to-knee extensor moments or related variables increases with heavier loads during squats, lunges, deadlifts, and hex-bar deadlifts. Additionally, the ratio of hip-to-knee extensor moments or related variables increases with greater speeds in running and with greater heights in jumping. In these movements, this represents a shift from knee-dominance at lower intensities to hip-dominance at higher intensities. It is not surprising that the hips produce greater moments as intensities increase during these movements. However, the fact that the hip moments rise to a greater extent than knee moments shows that the mechanics (i.e., form or technique) are altered during these movements in a manner that relies more on the hips and less on the knees for propulsion. As force increases, therefore, the role of the hip extensors becomes much more important and their contribution to the movement increases. This has important ramifications for training and performance.

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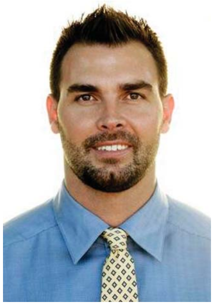
Chris Beardsley *is the Director of Strength and Conditioning Research Limited.*



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