The Importance of Load Vector in Physique Enhancement and Sport Training

An Excerpt from *Advanced Techniques in Glutei Maximi Strengthening*


By Bret Contreras, MA CSCS

Most experts in the fitness industry fail to recognize the role that the load vector plays in determining hip extensor recruitment during hip extension exercises. As a case in point, most articles written on glutei maximi training recommend axial loaded exercises such as squats, deadlifts, and lunges. But axial exercises are greatly outperformed in glutei maximi mean and peak activation by anteroposterior exercises. I don’t expect the experts to know this, as to my knowledge, I am the first author who is pointing this out scientifically. Although it’s been hinted about by strength coach Mike Boyle in the past and recently inferred (during the time I was writing this book) by vertical jump specialist Kelly Baggett, and although there have been many small-scale EMG studies performed in the scientific literature, to my knowledge a large-scale EMG study involving dozens of advanced and complex hip extension exercises has never been disclosed to the public — until now.\(^1\)\(^2\) I will discuss specific exercises and EMG data later in this book, but first let’s continue talking about load vectors.

I just performed a Google search for “best glute exercises” and the first article that came up was a web document written by Ray Burton, an ISSA Certified Trainer out of Canada, entitled “Glute Exercises – My Top Three Choices.” His top three choices are reverse lunges, sumo squats, and a special step up (a hybrid step-down/assisted pistol movement), which are all axial loaded exercises.\(^3\) I’m not trying to pick on Burton, as articles like these are littered throughout the Internet and forums. If you gave me a full day, I honestly believe that I could print out 300 articles, blogs, or forum posts that listed axial hip extension exercises as the absolute best glute exercises.

Furthermore, I just took a trip to Barnes and Noble and spent about three hours flipping through every popular book on strength training. I found books written by popular authors including Mark Verstegen, Pavel Tsatsouline, Nate Green, Lou Schuler, Ian King, Mike Mejia, and Men’s Health experts. Although every single book explained ways to provide extra loading to axial hip extension exercises, not one of them showed ways to provide extra loading to anteroposterior hip extension exercises. For some reason, our industry feels that we should load up squat, deadlift, and lunge (axial) movements but we should be content to stick to bodyweight bridge, quadruped, and hyperextension movements. Has anyone stopped to think how idiotic this is?

Thank God for Louie Simmons or we’d never even consider loading the anteroposterior vector (Simmons helped popularize weighted reverse hypers, back raises, pull throughs, and glute ham raises).

In his article entitled “Squats and Speed?,” Kelly Baggett stated the following:
“Squats allow one the biggest bang for the buck when strengthening and adding size to the glutes, quadriceps, and hams all in one shot in that order and that's why they are so effective initially.”

In *The Butt Book*, fitness author Tosca Reno states:

“You must learn to love squats. Performed correctly, squats will endow you with the best backside results when redesigning your glutes. Many of us have flat, even non-existent backsides that must be coaxed into curviness by performing the regular back squat.”

Later, she says:

“The best butt-mass builder is the back squat.”

In his article entitled, “Get a Great Ass,” popular trainer/author Chad Waterbury stated the following:

“The deadlift is most effective gluteus maximus builder known to man – or woman.”

In fact, a YouTube video shows a lean Monica Brant (figure and fitness competitor and cover model) doing deadlifts with 135 lbs and you can see her glutes contracting during the set. You can tell that her glutes are not contracting maximally (enough to exceed how hard she could contract them on her own, which is known as maximal voluntary contraction or MVC). If she were using the same amount of weight with hip thrusts (which I will teach you later), her glutes would contract much harder and she would most likely exceed MVC.

I should say that Waterbury redeemed himself in his last article entitled, “The Fast Track to a Hard Ass,” where he recommended sprints, swings, and bridges; three anteroposterior hip extension movements. However, he attributes the superiority of these exercises as glute developers to their explosive contractions and fails to mention the role of the load vector.

There have been several authors who have raised the issue of load direction. Legendary biomechanist Vladimir Zatsiorsky stated that one of the advantages to sprinting parachutes over other methods of resistance training is:

“The resistance (drag) force acts strictly in the direction of the athlete’s movement.”

Speed coach and entrepreneur Lauren Seagraves stated in his article entitled, “Neuro-Biomechanics of Maximum Velocity,” that the four primary objectives to increasing maximum velocity are:
Popular trainer/author Juan Carlos Santana discusses in his article entitled, “Training with Bands and Pulleys: Beyond Free Weights,” the following:

“When the body moves, every segment creates a momentum vector. In many cases, the movement is rotational, in which case angular momentum is created. Most movements are a combination of both horizontal momentum and angular momentum. Regardless of combination of movements throughout the body, running (and other functional movements) deals with horizontal forces, especially when decelerating. Since many functional activities have a horizontal component, it would be advantageous to load this component in order to enhance one's ability to neutralize and overcome it.”

In his manual entitled, “3-Dimensional Strength Training,” trainer/author Tony Reynolds raises some very thought-provoking points:

1) If you could draw lines to represent the direction of the forces that athletes encounter, what direction would they be?
2) What you would discover is that pure vertical loading rarely exists in sport.
3) What it boils down to in the end, is that the joint angle does not provide the definitive decision on which muscles are going to be activated.
4) It’s the direction of the force that will make the final decision on how the muscles will be activated.
5) Form follows function.
6) Take a look at our own muscular anatomy and you’ll see that very few muscles in the body have fibers that are strictly vertical.
7) Most have fibers that run diagonally and horizontally to allow athletes to produce strength in rotation and against horizontally applied forces.
8) It is essential to include horizontal and rotational loading techniques when designing resistance training programs.

Trainer/author Mark Mancino wrote an excellent article about the squat entitled, “The Squat: Hip vs. Knee,” in which he mentioned the following:

“The direction of propulsive force will significantly impact the recruitment and activation patterns of the lower body musculature. A great example of this is seen in the contrast between the vertical jump and the horizontal long jump. The long jump motion will require the hips to move “forward and through” in a horizontal direction. This is supported by Ridderikhoff et al. who found that peak angular velocity in the hip joint was higher and the joint was more extended at take off in the long jump compared to the vertical jump. These findings demonstrate that
horizontal propulsive forces require significantly greater input from the hip extensors."14

In his recent article entitled “The Difference Between Running and Jumping: Why Some People Can Jump But Can’t Run,” Kelly Baggett states the following:

“In short, the primary reason some people can jump much better than they can run (other than specific experience in the event of choice and body structure), is primarily due to the muscle dominance differences in generating horizontal vs. vertical force. Sprinting inherently requires more horizontal force application which, in comparison to jumping, more heavily involves the muscles of the hips and hamstrings and involves less from the quads and calves. When compared to sprinting, jumping vertically requires more vertical force, which, in addition to plenty of hip activation, requires more contribution from the muscles of the quadriceps and plantar flexors and significantly less from the hamstrings. Your proficiency in extending your hips with power (e.g. driving down and back against the ground horizontally) is mainly responsible for your ultimate top end speed. In the research, horizontal jumping and bounding for distance off one leg has been shown to correlate very well with sprint times. (1) Horizontal jumping also more heavily involves the hip extensors. (2, 3) Real world observations support the notion that sprinters carry much more muscle in the hamstrings and dunkers are often hamstring deficient."15

In strength coach Mike Robertson’s article entitled, “Make Your Posterior Chain Your Strongest Link,” he informs us that:

“I typically like to start clients off with pull-throughs, because unlike Romanian deadlifts or good mornings, the resistance is moving forward and backward, instead of up and down."16

Sprint coach Carle Valle recommended the following exercises for sprinting in a 2006 blog:17

<table>
<thead>
<tr>
<th>General</th>
<th>Special</th>
<th>Specific</th>
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<tbody>
<tr>
<td>Low Step Ups</td>
<td>Hanging Horizontal Bridge</td>
<td>Straight Leg Bounds</td>
</tr>
<tr>
<td>High Step Up</td>
<td>Cable Hip Extension</td>
<td>B Drills</td>
</tr>
<tr>
<td>Lunge &amp; Reach – 3 Planes</td>
<td>Resisted Moon Walks</td>
<td>15 Degree Hill Sprints</td>
</tr>
<tr>
<td>Walking Lunge &amp; High Knee</td>
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Hanging horizontal bridges, cable hip extensions, and resisted moonwalks are all anteroposterior in nature.

And probably the best analysis of load vector comes from the great Mel Siff in his legendary book **Supertraining**. Here are a series of quotes from Siff:
“In some events, such as swimming, inertia plays a major role in the entire process, unlike in running, where the specificity of movement depends on horizontal thrust and the vertical oscillation of the athlete’s center of gravity.”

“To fulfill the criteria of correspondence with respect to the amplitude and direction of movement, it is advisable to select the exact starting position and posture of the athlete, as well as to calculate the direction of action of the forces associated with the working links of the system and the additional load. The line of action of the applied external resistance and of the loaded movement as a whole must also be taken into account.”

“For example, in middle-distance running, skiing and skating, a knapsack full of sand or a weight belt are sometimes used as resistance. However, the muscles which bear the load are those which resist the weight of the body. This can increase the ability to cope with vertical loading and develop general strength-endurance, but does not strengthen those muscles which propel the body horizontally.”

“Similarly, a skater may execute jumps on one leg on the floor or from a bench. These exercises strengthen the leg muscles supporting the body and the static-endurance of the back muscles, but do not fully imitate the working of the muscles for the push-off, where the force is directed backward.”

“Skaters should use another method or resisted movement by changing the direction in which the force of resistance is acting. [Figure showing three different towing methods; 1) towing a human, 2) towing a weighted sled, and 3) towing a sled with a human sitting on it while skating] These methods to a large extent match the training exercise to the dynamics of the sport specific actions.”

“The strength exercise should not only reproduce the full amplitude of the movement but also the specific direction of resistance to the pull of the muscles.”

Siff then explains how sport typically involves simultaneous coordinated tension of muscle groups, such as the simultaneous flexion and extension at the two hip joints in running, where the angular movement of one leg enhances the push-off movement of the other. He depicts the following exercises, which he credits to Verkhoshansky in 1977, to illustrate complex exercises for simultaneous strengthening of the hip flexors and extensors, and knee extensors.
Clearly you can see that not every strength-training expert is oblivious to the impact that load vectors have on muscle activation, but these ten references are few and far between.

Most articles written on the topics of strength training for sprinting improvements and jumping improvements recommend the exact same exercises. For the most part, the recommended exercises for both modalities are squats, deadlifts, Olympic lifts, and plyometrics, which are all axial loaded exercises. As an example, Mike Boyle wrote in Functional Training for Sports the following statement:

> “Increased strength in squatting movements is the first step in developing speed and increasing vertical jump.”

In his article entitled “Get Strong, Get Fast, Get Vertical!,” Christian Thibaudeau recommended a program that included ten different jump, squat, deadlift, and Olympic lift variations (all axial hip extension exercises) and failed to include any anteroposterior hip extension exercises. At the end of the article, Christian stated:

> “This program should yield impressive gains in vertical jump capacity, as well as in lateral agility and sprinting speed.”

Certainly, increasing strength in axial activities (squats, deadlifts, Olympic lifts, plyometrics) will transfer over to anteroposterior activities (sprints), just like increasing strength in anteroposterior activities (sprints, sled drags, back extensions, pull throughs) will transfer over to axial activities (vertical jumps) by way of increased core strength, increased stiffness, increased reactive ability, and increased hip and knee extensor strength.

However, the improvements are general, not specific. And since there is hip extension, forward hip translation, and glutei maximi activation in axial hip extension exercises, even in exercises like Olympic-style squats (quad dominant) and round back good mornings (low back dominant), of course you’ll see improved neural drive and increased myofibrillar cross sectional area (sarcomeric hypertrophy, sarcoplasmic hypertrophy – mitochondrial and capillary density, etc.).
For example, vertical plyometrics will improve horizontal sprinting speed by way of faster stretch-shortening cycles (SCC’s) due to increased Golgi Tendon Organ (GTO) excitability thresholds (decreased inhibition) from the inherent short ground contact times of vertical plyometric exercises.25

Vertical plyos also help by developing extreme coordination and stiffness in the foot/ankle complex and because (depending on the protocol) they might better target high threshold motor units and the phosphagen energy system than sprints. It takes around six seconds to maximize top speed in sprinting.26,27 When you have athletes do sets of 10-20 meter sprints, most don’t feel like they get a lot out of the activity because although they may be accelerating maximally, they don’t reach top speed. Give these same athletes vertical jumps in sets of 3-5 reps and they will feel like they get a lot out of the activity because they will have reached maximum height on one of those jumps.

The problem with axial training for anteroposterior activities and anteroposterior training for axial activities is that the two load vectors recruit different proportions of hip and thigh muscles.

On September 14, 2006 the editors of T-Nation posted the following quote:

“According to Charles Poliquin, the main muscles you need to train for a big vertical jump isn't the quads, but the glutes. Glutes contribute 40% of the power, followed by hamstrings at 25%. Quads contribute a measly 5%, outgunned by even the anterior deltoids, which contribute up to 15% (try jumping without your arms).”28

This quote was taken from an article written by popular trainer/author Charles Poliquin entitled “Posterior Chain Strength Preparation for the Vertical Jump.”29 I disagree very much with this quote. If Poliquin’s quote was referring to sprinting, then I would consider it slightly more accurate. Another site’s publication includes the following quote from Poliquin:

“Canadian strength coach Charles Poliquin has designed workout programs for more than 400 Olympians, and he says that approximately 40 percent of the power for sprinting and jumping comes from the glutes and 25 percent from the hamstrings.”30

So it seems that Poliquin believes that the same proportion of lower body muscles are responsible for vertical jumping and sprinting, which is not true based on my own personal EMG research, biomechanical analysis, and personal training experience.

Kelly Baggett was more accurate when he stated the following in his book, The Vertical Jump Development Bible:
“The muscles of the posterior chain (glutes, hamstrings, and lower back), and the muscles of the quadriceps are responsible for 80% of your leaping power with the quads and posterior chain contributing approximately an equal 40% to vertical jump performance. The small 20% remainder is split up among the calves and muscles of the upper body.”

The makers of Jumpsoles estimate that the calves contribute as much as 30% of the propulsion in running and jumping. I believe that this is exaggerated, especially in the case of running. Speed coach Charlie Francis states that there is a 7:1 ratio of hip/ankle power output in the sprint. I believe that Jumpsoles work primarily by increasing the stiffness in the foot/ankle/shin complex (gastrocnemii, solei, tibiales antici, tibiales postici, peronei longi, peronei breves, peronei tertii, plantares, poplitei, flexor digitorum longi, flexor hallucis longi, extensor digitorum longi, extensor hallucis longi, extensor digitorum breves, extensor hallucis breves, abductores hallucis, adductores hallucis, flexor digitorum breves, flexor hallucis breves, abductor digiti minimi, flexor digiti minimi, dorsal interossei, palmar interossei, quadratus plantae, lumbricals, dorsalis pedis, etc.).

I would estimate that for most individuals the quads contribute around 40% of the locomotive power of a standing vertical jump, followed by about 15% from the calves/solei, 15% from the glutei maximii, 10% from the anterior delts, 10% from the hamstrings, 5% from the adductores magni, and 5% from smaller muscles such as the upper pecs and toe extensors.

In addition, lots of muscles have to be contracting very hard isometrically for stiffness and stabilization purposes. As Kelly Baggett has stated, “You can’t fire a canon out of a canoe.”

Kelly Baggett uses the following explanation to illustrate how little the calves contribute to a vertical jump:

“Stand on a stair step and let your ankles hang down. Without bending your knees try to hop up onto the next step. Did you make it? Probably not.”

I don’t agree with this line of reasoning. It is the sequential summation of propulsions created through shoulder flexion, hip extension, knee extension, ankle extension, and toe extension that produce the locomotive power in a standing vertical jump. The body is not very coordinated when trying to isolate a single component of the vertical jump. I don’t get very high when I try Kelly’s ankle extension trick, nor do I get very high if I stand on the tips of my toes and try to use just knee extension to jump, nor do I get very high if I stand on my heels and try to jump solely by rapidly extending my hips. In fact, contracting the hip extensors without the knee and ankle extensors would send you forward, not upward, as the hip extensors were designed for forward hip translation (vertical jump, squat, deadlift) or rearward thigh rotation (sprint, reverse hyper). Besides, it’s not the explosiveness of the ankle extensors that matters so much as their stiffness and ability to transfer kinetic energy.
I trained an extraordinary leaper named Kenny Dobbs who possessed a 48-inch vertical leap and can be seen on YouTube kissing the rim.\textsuperscript{36} Although his quad and calf strength were decent, he had the glutei maximi and hamstring strength of a fetal pig—yet he could jump higher than any man I’ve ever seen.

As Kelly Baggett and strength coach Eric Cressey would say, he was at the far end of the “springy” side of the static-spring continuum.\textsuperscript{37} If a glass represents maximum strength and the water in the glass represents maximum power (I’m bastardizing an excellent analogy from Chapter Seven entitled, “Is the Glass Half-Full or Half-Empty,” from Eric Cressey’s, \textit{The Ultimate Off-Season Training Manual}\textsuperscript{38}), then Kenny Dobbs’ glass was medium-sized but the water in the glass was filled to the rim. There is not doubt that he possessed extraordinary power, but the power was coming from the quadriceps and calves, not the glutei maximi and hamstrings.

Watch videos of great jumpers jumping and you’ll see that their knees jut out past their toes in order to move the center of gravity out in front of the toes, place the quadriceps into their optimal contraction zone, and maximize knee extension torque.

Some experts believe that the hamstrings and abdominals play critical roles in accelerating the body eccentrically into hip and knee flexion thereby inciting a more powerful myotatic reflex.\textsuperscript{39} In his article entitled, “Dirty Tricks for Higher Vertical Jumps,” strength coach Joe DeFranco states that:

\begin{quote}
“The speed of the descent is the most important factor in an athlete's vertical jump height.”\textsuperscript{40}
\end{quote}

I think that the importance of the hamstrings and abdominals during hip and knee flexion and rapid decent in vertical jumping have been exaggerated and are really not as important as the strength and power of the prime movers.

Many strength coaches describe sprinting as “leaping forward,” but this is inaccurate, as the center of gravity in running lowers itself as speed increases and the vertical displacement of the center of gravity at top speed in elite sprinters is only 5-10 cm (2-4 inches).\textsuperscript{41,42,43} You don’t see a lot of head-bobbing in elite sprinters as they’re racing down the track. As sprinter/coach Perry Duncan said, “You don’t run on the ground, you sprint over it.”\textsuperscript{44}

Many sprinters who train with sprints over 150 meters experience something they refer to as, “butt lock,” which is an extreme sensation of congestion in the upper hamstrings and glutes.\textsuperscript{45} Jumppers don’t get “butt lock” from repetitive vertical jumps no matter how many reps they perform. They would get “quad lock.”

By blending common sense, functional anatomy, physics, EMG, and practical experience, it all makes sense. Go to the track and do ten sets of 50 meter sprints resting 60 seconds in between sets. Your glutes will get a pump. Then do ten sets of five leaps.
Your quads will get a pump. Pay close attention to where you feel the propulsive power coming from.

A somewhat recent study showed that a 21% improvement in 1RM squat strength resulted in a 21% improvement in vertical jump, but only a 2.3% improvement in 40-m sprint. This is due to the fact that squats and leaps are both axial movements and both heavily involve the quadriceps, whereas sprinting is an anteroposterior movement that relies more heavily on the hip extensors.

A vertical jump is a dual-limb, closed-chain, axial loaded, sagittal plane, hip and knee extension movement. A 100 meter sprint is a single-limb, closed chain, anteroposterior loaded, sagittal plane, hip extension/hyperextension with semi-straight leg movement. Of course, these descriptions oversimplify and ignore the movements’ eccentric components and stabilization efforts in the frontal and transverse planes, but they allow us to focus on the primary propulsion components in each activity.

<table>
<thead>
<tr>
<th>Movement</th>
<th>Limb number</th>
<th>Load Vector</th>
<th>Hip Action</th>
<th>Knee Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Jump</td>
<td>Dual Limb</td>
<td>Axial</td>
<td>Extension</td>
<td>Extension</td>
</tr>
<tr>
<td>Sprint</td>
<td>Single Limb</td>
<td>Anteroposteri</td>
<td>Hyperextension</td>
<td>Semi-Straight</td>
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The following is a breakdown of Usain Bolt’s world record 100 meter dash:

- Reaction Time: 0.165
- 10m: 1.85 (Reaction Time Included)
- 20m: 2.87 (1.02)
- 30m: 3.78 (0.91)
- 40m: 4.65 (0.87)
- 50m: 5.50 (0.85)
- 60m: 6.32 (0.82)
- 70m: 7.14 (0.82)
- 80m: 7.96 (0.82)
- 90m: 8.79 (0.83)
- 100m: 9.69 (0.90)

Top speed is usually reached at around 50-60 meters in elite male sprinters and is only maintained for 2-3 seconds. As you can see in the chart above, Bolt reached top speed at 60 meters and maintained top speed for 20 meters until he reached the 80 meter mark. Bolt’s average speed was almost 23.1 mph and his top speed was 27.3 mph. He ran the race in 41 strides (the silver medalist needed 44 strides and the bronze medalist 49), had an average stride length of 2.44 meters/step (8 feet), and an average stride rate of 4.23 steps/second.

Dozens of factors contribute to a sprinter’s ability to win a race including:

- body composition and mass
- nervous system excitability and high threshold motor unit stimulation
- technique and minimization of energy leaks
- contraction and relaxation sequences
- elastic and damping efficiency
- muscle viscosity
- type II muscle fiber proportion
- tendon insertion points
- anabolic and catabolic hormone and growth factor levels
- anthropometry and leverages
- anaerobic substrate and enzyme levels
- maximum hip extensor/flexor and shoulder extensor/flexor strength and power
- calf/quadricep/core stiffness
- reaction time (quickness)

Here is a series of quotes from Mel Siff’s *Supertraining*, most likely the greatest book ever written in strength training.

“A number of qualities determine sprinting ability, including explosive strength, quick acceleration ability at the start, the development and maintenance of maximum movement speed, and resistance to fatigue.”

“The ability to relax muscle is very important for rapid movements, especially in cyclical actions which involve resynthesis of ATP during the phases between muscle contractions. It has been found that muscle relaxation time decreases markedly as the athlete’s skill improves. In some sprinters, improvement in performance is largely a consequence of strength increase while the ability to relax muscle remains much the same, whereas some talented sprinters improve more because of an increase in their capacity for efficient muscle relaxation.”

“The adequate retrieval of elastic energy stored in the muscle complex, together with the stretch-shortening potentiation of force output, are valuable prerequisites for high velocity cyclic and acyclic movement. Verkoshansky reports that economical sprinting activity can result in the recovery of about 60% of the total mechanical energy expended in the movement cycle.”

“It has been established that athletes who possess a large proportion of fast fibers in their muscles, under equal conditions, display greater movement speed and ability to generate force. It has been shown that the propulsive muscles of sprinters contain more (up to 75%) fast-contractile fibers and that long-distance runners have more (up to 90%) slow-contractile fibers.”

“Excitability of the nervous system is a factor which governs individual speed level. It has been shown that people with high excitability of the nervous system are distinguished by great speed of movement. Thus, speed, as a characteristic of motor potential, has an upper limit that is largely predetermined by genetics, and its enhancement in training tends to be restricted to this limit. Therefore, the preparation of high-class sprinters is associated not so much with the absolute
development of speed as it is with the selection of genetically gifted people and
the efficient organization of training to enable them to utilize their natural ability
maximally. The halt in improvement of results in sprinting is not due to the
existence of a “speed barrier,” but to reaching the limits of one’s speed potential.”

“Speed of movement or displacement is a function of quickness, reactive ability,
strength, endurance and skill to effectively coordinate one’s movements in
response to the external conditions under which the motor task is to be
executed.”

Ultimately, a 100 meter sprinter’s time depends on how quickly he or she gets out of the
blocks, how quickly he or she accelerates to full speed, how long he or she maintains full
speed, and how little he or she decelerates until the finish line.

If you’ve trained a bunch of athletes, you’ll know that there isn’t a linear correlation
between sprinting and leaping. Some athletes are great sprinters, some are great leapers,
some are both, and some are neither. Anthropometry and muscular strength ratios play
huge roles in determining sprinting and leaping ability.

Dolicomorphs (short limbed people) tend to have great leverages for traditional weight
room exercises like squats and bench press, while brachiomorphs tend to have great
leverages for the track, field, or court (sprinting and leaping) as well as for non-traditional
weight room exercises like hip thrusts, back extensions, and reverse hypers
(anteroposterior exercises). Dolicomorph Ben Johnson could half-squat 600 lbs for 2 x 6
and bench 407 for 2 reps while weighing 178 lbs. I doubt brachiomorph Usain Bolt, the
fastest man ever, can bench or full squat much weight. He isn’t built for it. However, I
bet Usain Bolt would be very strong at the hip thrust. In a few months of training the
exercise, he could easily be using 400+ lbs for reps.

Research hasn’t shown a direct correlation between sprinting speed and maximum
strength, most likely because axial exercises were used in the studies. If anteroposterior
exercises such as hip thrusts, weighted back extensions, or weighted reverse hypers were
used in the studies, perhaps we’d see a correlation.

To simplify the matter of sprinting speed, we see that Bolt is simply generating more
force per stride than his competition. Stride length is a measure of how hard an individual
is propelling themselves forward. Usain is pushing his body forward harder than his
competitors. But what muscles are producing this power?

In The Charlie Francis Training System, Charlie Francis stated:

“Hip action is the most critical factor in sprinting since the greatest forces are
generated around the hip joint. If the action of the hips is limited, sprinting
efficiency is limited too.”
I would estimate that for most individuals around 30% of the locomotive propulsion in top speed sprinting comes from the glutei maximus, followed by 15% hamstring contribution, 15% adductor contribution, 15% contralateral latissimus dorsi contribution, 10% quadriceps contribution, 10% calf/soleus contribution, and 5% contribution from other muscles such as the rhomboids and mid traps.

Of course, just like in a vertical jump, lots of muscles have to be contracting very hard isometrically for stiffness, stabilization, and energy transfer purposes. The front delts, hip flexors, and tibiales antici are important during the swing phase in sprinting.

Knee flexion and knee extension strength is overrated in sprinting, as those movements occur when the leg is unloaded in the air and while the hip is flexing or extending. When the foot touches down on the ground and the characteristic “paw back” action (and primary propulsive force generation) occurs, it’s all hip extension with slightly bent legs. This is why we should train for sprinting with a mixture of anteroposterior straight leg and anteroposterior bent leg exercises.

Charlie Francis speaks often about “the sprint position” characterized by an erect posture in a 100 meter race. He describes how only a few athletes in the world possess the hip strength to maintain this positioning throughout the entire race. He also likes to say, “If it looks right, it flies right,” mainly referring to the hamstring and gluteal development of a sprinter. Lastly, he conveys how sprinters know they didn’t get a good sprint in if they feel it in their quads, since they know they should feel it in their glutes/hamstrings. This is why Francis used the reverse leg press (butt blaster or kickback motion) as his primary posterior chain exercise and also incorporated hip raises (both anteroposterior hip extension exercises).58 Francis is years ahead of his peers, however, improvements from these exercises are possible, which will be shown later in this book.

Charlie Francis’ Main Lower Body Exercises Were the Squat, Power Clean, and Reverse Leg Press

In his article, “Using a Weighted Sled for Acceleration Improvements,” Mike Boyle makes the following series of extremely logical points:

1. Sport is about acceleration, not speed.
2. In training for track, coaches frequently make reference to the pulling action in running and work on drills to develop a pawing action against the ground.
In sport the action is primarily pushing with the center of gravity slightly ahead of the feet, kind of a reverse Michael Johnson.

3. Weighted sled drills target the specific muscles used in sprinting and help to bridge the gap between form running drills and weight room exercises like squats and Olympic lifts.

4. Many athletes can squat large amounts of weight. Far fewer athletes seem to be able to run fast. Any student of speed will tell you that many of the strength exercises commonly recommended for speed development work hip extension but, not hip hyperextension.

5. In running speed all of the force production is from hip hyperextension. The ability to apply force to the ground and create forward movement can only occur when the foot is placed under the center of mass and pushed back.

6. Although squats etc. will train the muscles involved, the training is not specific to the act of sprinting. This may be one reason we see a higher correlation to vertical jump improvement than to speed improvement through strength training.\(^{59}\)

The points made by Mr. Boyle are very insightful. The differences in running form during the acceleration phase and top speed phase are quite different from one another due to the trunk angle. During acceleration, there is a significant forward lean of the torso, whereas during top speed, the torso is upright. In acceleration, the body’s center of mass is slightly ahead of the feet, whereas in top speed, the body’s center of mass is slightly behind the feet. As Bill Parisi would likely attest, acceleration is actually a perfect blend of axial and anteroposterior load vectors, as the typically forward lean is half way between each vector at a 45 degree angle.\(^{60,61}\)

According to my research, vertical jumping and sprinting activate the following percentages of glute muscle:

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Mean Glute Activation Percentage</th>
<th>Peak Glute Activation Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Jump</td>
<td>62</td>
<td>496</td>
</tr>
<tr>
<td>10-Meter Sprint</td>
<td>145</td>
<td>513</td>
</tr>
</tbody>
</table>

A 10-meter sprint involves more quadriceps activity and less glute/hamstring activity than a 60-meter sprint. Since the body is leaning forward at around a 45° angle in a 10-meter sprint, the knee joint moves through a greater range of motion and the hip joint moves through a lesser range of motion. If the body was more upright in a top speed sprint, the mean and peak glute activation would be even higher. I couldn’t test the top speed sprint because I didn’t want to risk damaging the Myotrace 400. This chart clearly shows us that a sprint is more hip extensor dominant than a vertical jump.

The only problem I see with pushing a sled or pulling a sled with excessive lean is that it prevents the hips from hyperextending, which is the maximum contraction zone for the glutei maximi.
If you want to jump high, perform axial loaded hip extension exercises, Olympic lifts, axial loaded plyometrics, axial loaded ballistics, and calf raises and target the knee and ankle extensors (quads and calves).

If you want to attain high top-speed in sprinting, perform anteroposterior loaded hip extension exercises, anteroposterior loaded plyometrics, and anteroposterior loaded ballistics, and target the hip extensors (glutei maximi, hamstrings, and adductores magni).

If you want to accelerate quickly, perform exercises from both load vectors, as well as sled pushes and pulls, stadium sprints, walking lunges, and 45 degree hypers, which contain an even mixture of axial and anteroposterior components, and target the hip, knee, and ankle extensors (glutei maximi, hamstrings, adductores magni, quads, calves).

If you want to jump high, attain high top-speeds, and accelerate fast, and basically be as athletic as possible, target both load vectors through all types of knee actions.

Although there is significant overlap of physiologic improvements between the training of the two load vectors, such as increased core strength, increased stiffness, and increased reactive ability, the specific onset of hip extensor recruitment is different in addition to the proportion of hip extensor activity. In sports-specific training, we are in search for optimal methodology, not sufficient methodology.

Mr. Boyle also pointed out that force production in running is produced by hip hyperextension. In proper axial lifting there is no hyperextension, as hyperextension is very dangerous with axial loading. Hip hyperextension is not as dangerous during anteroposterior loading, especially during unilateral movements. If it were, we’d all be injured from sprinting.
And finally, Mr. Boyle pointed out that there is a gap between form running drills and weight room exercises like squats and Olympic lifts. However, there doesn’t need to be. We just need to apply the same amount of creativity toward anteroposterior training as we have toward axial training.

For vertical leap training, we have a continuum with vertical jumps, axial loaded plyometrics, and axial ballistics on the left; jump squats, Olympic lifts, and axial loaded speed lifts in the middle; and limit squats, deadlifts, good mornings, lunges, and other maximal axial loaded hip extension exercises on the right. There is no gap between the weight room and the sports arena for jump training.

We can eliminate the gap between the weight room and sports arena in sprint training by applying the same principals as we do for vertical leap training. In our sprint-continuum we have sprints, anteroposterior loaded plyometrics, and anteroposterior ballistics on the left; towing (parachute, human, sled) and anteroposterior speed lifts in the middle; and heavy hip thrusts, pendulum quadruped hip extensions, back extensions, and reverse hypers on the right. Heavy anteroposterior exercises are better suited for 5 reps or more so I wouldn’t advise maxing out.

<table>
<thead>
<tr>
<th>Vertical Leap Training</th>
<th>Light</th>
<th>Medium</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Vertical Jumps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Axial Loaded Plyometrics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Axial Loaded Ballistics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Jump Squats</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Olympic Lifts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Axial Loaded Speed Lifts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Limit Squats</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Limit Deadlifts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Heavy Good Mornings</td>
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<td></td>
<td></td>
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<tr>
<td>• Heavy Lunges</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>• Other Heavy Axial Loaded-Hip Extension Exercises</td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sprint Training</th>
<th>Light</th>
<th>Medium</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sprints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Anteroposterior Loaded Plyometrics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Anteroposterior Loaded Ballistics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Parachute Towing</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>• Human Towing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Sled Towing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Anteroposterior Loaded Speed Lifts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Heavy Hip Thrusts</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>• Heavy Pendulum Quadruped-Hip Extensions</td>
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<td></td>
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<tr>
<td>• Heavy Reverse Hypers</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>• Heavy Back Extensions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Other Heavy Anteroposterior-Loaded Hip Extension Exercises</td>
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</tbody>
</table>

Vertical Leap and Sprint Training Continuums; Exercises Will Be Shown Later in the Book

Here’s another item to think about it; we’ve invented a thousand different ways to squat and deadlift. We’ve invented unique barbells and apparatuses, used different stance widths, grip widths, toe flares, depths, stride lengths, and developed unique machines. As an industry, we’ve dedicated a lot of time toward improving and adding variety to axial loading. And although we’ve developed a number of excellent machines for anteroposterior loading, most aren’t utilized, and many can’t even be used properly by men or athletes because their selectorized weight stacks are geared toward women and beginners. We definitely haven’t developed the same number of unique
variations of anteroposterior exercises as we have axial exercises. It’s time the strength training field dedicates equal time and attention to axial and anteroposterior exercises.

Athletes rarely injure themselves from jumping, as we have prepared their tissues to absorb the shock with the many different axial exercises we prescribe. But athletes often injure themselves while sprinting. Their tissues have not been prepared by heavy anteroposterior hip extension training exercises which contain concentric, isometric, reversal, and eccentric component. These components may prepare body tissues for concentric-based explosive activity (which is characteristic of athletics) in a complementing fashion with the sport or activity itself and “bullet-proof” the athlete against injuries. Simply incorporating heavy anteroposterior hip extension exercises will go a long way in preventing hamstring or groin pulls.

It’s important to note that as glute strength increases, movement characteristics might change. As Charlie Francis stated in The Charlie Francis Training System:

“As you develop physical qualities to new levels, the neural motor patterns dictating correct sprinting technique must be updated to properly use these new levels of ability to run faster. Running at continuously higher and higher speeds while holding the sprint position is a critical aspect of learning to sprint.”

In strength training the principle of individuality is very important. Since the human body varies so much from one individual to the next in terms of shape, size, and location of various bones, muscles, and tendon attachment points, there is no one best exercise for everyone. That being said, I will still go out on a limb and say that every human’s glutei maximus muscles are better recruited from anteroposterior loading than from axial loading.

The glutes, although worked in axial loading, are more heavily recruited in anteroposterior loading. Anteroposterior exercises outperform axial exercises in both mean and peak glutei maximus activation percentages. I know this might be hard to accept for many people, because for so long they have believed that squats, deadlifts, and lunges are the best ways to work the glutes, but science doesn’t lie, nor does practical experience. Perform twenty bodyweight squats compounded with twenty walking lunges. Rest a few minutes, and then perform twenty single leg glute bridges compounded with twenty quadruped hip extensions. In the squat/lunge series, your quads will be pumped, whereas in the single leg glute bridge/quadruped hip extension series, your glutes will be pumped.

Simply put, the glutei maximii were meant for forward translation of the hip or rearward rotation of the thigh. This is why they are more involved when you sit back in a squat or deadlift, when you perform a walking lunge compared to a static lunge, and when you sprint compared to walking. Furthermore, the glutei maximii are best targeted directly anteroposteriorly; there is increased glutei maximii activation from a feet-elevated glute bridge to a shoulder-elevated glute bridge, and from a 45 degree back extension to a back extension.
Contrary to popular opinion, even employing the sit back and long stride techniques in axial exercises won’t get you near the glutei maximi activation of a proper anteroposterior exercise of similar intensity. The trick to anteroposterior hip extension exercises is learning how to transform ordinary “glute activation” exercises into challenging, full-range, optimally-loaded exercises.

### The 6 Categories of Hip Extension Exercises

<table>
<thead>
<tr>
<th>Category</th>
<th>Start Position</th>
<th>End Position With Directional Load Vectors</th>
<th>Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Axial Extension</td>
<td>(Resistance comes from top to bottom, knee extended)</td>
<td>11</td>
<td>1. Squat/Static Lunge RFESS/Step Up/Single Leg Box Squat</td>
</tr>
<tr>
<td>2. Axial Semi Straight Leg</td>
<td>(Resistance comes from top to bottom, knee is slightly bent)</td>
<td>11</td>
<td>1. Deadlift/Good Morning/Single Leg RDL</td>
</tr>
</tbody>
</table>
| 3. Anteroposterior Bent Leg | (Resistance comes from front-to-back, knee stays bent) | 11 | 1. Bent Leg Reverse Hyper/Quadraped Hip Extension  
2. Bent Leg Back Extension  
3. Bent Leg Bridge/Shoulder Elevated Hip Lift |
| 4. Anteroposterior Straight Leg | (Resistance comes from front-to-back, knee stays straight) | 11 | 1. Reverse Hyper  
2. Back Extension  
3. Straight Leg Bridge |
| 5. Anteroposterior Extension | (Resistance comes from front-to-back, knee extended) | 11 | 1. Donkey Kick/Bird Dog  
2. Pull Through/Kettlebell Swing |
| 6. Anteroposterior Flexion | (Resistance comes from front-to-back, knee bends) | 11 | 1. Sliding Leg Curl/Sliding Leg Curl/  
Rolling Leg Curl  
2. Glute Ham Raise |
| Hybrids                | (Half anterior/half posterior blend at 45 degree angle) | 11 | 1. Walking Lunge/Sliding Lunge/Reverse Lunge  
2. 45 Degree Hyper |

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