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A Correlational Study between the Physical Analyses of Distinct Lower Body Exercises and the Block Start in Athletics

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Abstract

The aim of this study was to establish a correlation between the lower body mechanics expressed during the first steps of the block start and those seen during several compound lower body strength exercises. The subject of analysis was relative joint angles at the hip and knee throughout first two steps of the block start and repetitions of each of the following exercises: front squat, high-bar back squat, low-bar back squat, and deadlift. One collegiate male sprinter participated in this experiment. He performed 10 starts in an uncontrolled outdoor environment and performed 5 repetitions of each exercise in a controlled weightroom environment. The data collected implied correlations between the low-bar back squat and deadlift and the power phases of the stride immediately following the sprint start, as well as between the deadlift and the positioning of the individual legs in the blocks. Based on the data, the utilization of the low-bar back squat and the deadlift to increase performance in the sprint block start can be suggested but not confirmed.

1. Introduction

The block start the phase of a sprinting event in track and field competitions where the athletes await the firing of the starting gun with their hands on the track surface and feet braced against starting blocks. Starting blocks are commonly utilized by athletes competing in sprinting events ranging from 60-meters to 400-meters in distance. Performance in the block start phase of the race becomes increasing important to overall performance as the length of the event decreases. Block start performance and efficiency are major training aspects for athletes whose specialties are the 60-meter and 100-meter dashes due to the much shorter distance and duration of the event.

There are many factors that play a role in optimal performance during the block start which include reaction time, muscular strength and power, and total body coordination – the majority of which can be bettered through practice and rigorous training. Even though the difference in reaction times could be miniscule, the end results that can determine first and last place can be equally minute. Hypothetically, if there were to be two completely identical sprinters, both in ability and from a physical standpoint, the sprinter that can reacts the quickest to the starting gun would ultimately win. This ability is one that, though difficult to master, can be trained and can have a direct carry over to performance in the block start.

Similarly the athlete's ability to generate force is equally as important. The block start signifies the beginning of the athlete's drive phase, the portion of the race during which the athlete is trying to accelerate to top speed as quickly as possible. Speed is defined simply as the magnitude of an object's velocity, the rate at which it covers distance.

$$v = \frac{d}{t}$$

Acceleration is the change in this rate over time. Therefore acceleration can be increase in two ways; either the change in velocity can be increased within the same amount of time, or the time in which it takes to increase velocity can be decreased.

$$a = \frac{\Delta v}{\Delta t}$$

Force is the product of the acceleration and the mass of the object. The amount of force can be increased by either decreasing the mass being accelerated, or accelerating the same mass at a greater rate.

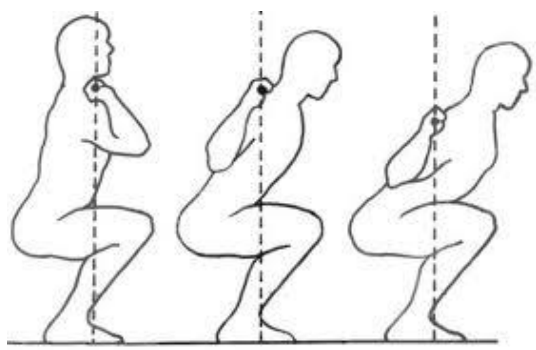
$$F = ma$$

In sprinting, the mass will be constant as this will be represented by the bodyweight of the sprinter. Therefore in order the increase amount of force the sprinter is capable of producing they need to be able to move their bodyweight at greater velocities.

By the nature of sprinting, the athlete must generate this force using their legs to push off the ground and propel them forward at increasing velocities. This means the athlete must have adequate muscular strength of the muscles in the legs to be capable of producing said force. This is the reason strength and conditioning is an integral part of a sprinter's training regimen. As an explosive athlete whose events is of such short duration, and in which success or failure can be determined by the most minute of increments, any increase in performance, however slight, could lead to a potential advantage.

Since sprinting is a total body effort, a well-developed strength and conditioning program for a sprinter includes both upper body and lower body exercises with the aim of increasing muscular strength and power. Lower body training takes precedence when it comes to direct translation to performance, however. There are many different techniques and methods of developing strength and power in the lower body and they are all used in equally different ways. However, one commonality between them all is that they incorporate full-body compound movements such as variations of the squat and deadlift.

The squat is one of the most basic compound exercises used in strength and conditioning. The movement involves having a load place upon the shoulders, the exact position of the load dependant on the variation being performed, squatting until both the knees and hips are in a fully flexed position, then standing back up. This exercise is known for its ability to increase strength in the extensors of the knee (quadriceps) and the extensors of the hip (gluteals and hamstrings). Three of the most common variations of the squat used in strength and conditioning are the front squat, the high-bar back squat, and the low-bar back squat.



The front squat variation involves placing the load across the front of the shoulder so that the bar rests upon the deltoid muscles just in front of the collar bones. This variation is very popular with Olympic weightlifters due to it being the receiving position of the clean portion of the Olympic lift known as the “clean and jerk”. The front squat is also known for its recruitment of core stabilizing muscles in the trunk. Due to the location of the bar and load in relation to the body’s center of mass, this variation of the squat requires the lifter to maintain a more upright torso throughout the motion. This causes a less acute angle to be form at the hip joint and greater movement to occur at the knee which in turn generates more muscular recruitment from the gluteal and quadriceps muscle groups and places less emphasis on the hamstrings.

The high-bar back squat literally refers to a bar position that is “high” across the “back” of the shoulders. More specifically, the bar rests across the upper portion of the trapezius muscle just above the spine of the scapula. This is the widespread and generally accepted method of squatting from beginner to advanced lifters, athletes and general fitness enthusiasts. In similar fashion to the front squat, the high-bar back squat requires the lifter to maintain an upright torso; however it is not so much as with the front squat. Since the bar is placed across the back, the angle created at the hip in the bottom position will inherently be more acute than achieved in the front squat. This leads to a slight increase in the involvement of the hamstrings in addition to the gluteals and the quadriceps.

In similar fashion, the low-bar back squat refers to the bar being placed “low” across the “back” of the shoulders. In this variation the bar is located just below the spine of the scapula so that it rests across the lower portion of the trapezius muscles and across the rear of the deltoid muscles in the shoulders. The lower bar position necessitates a greater forward lean of the torso in the bottom position of the squat, which leads to an even greater recruitment of the hamstrings. However, because the torso leans forward more the width of the feet needs to be slightly wider than normal to accommodate a greater range of motion for the hips.

The “conventional” deadlift, commonly referred to simply as the deadlift, is another exercise commonly found in strength and conditioning programs. It is defined as the act of lifting a loaded barbell from the ground to hip-level and returning it to the ground. In the bottom position of the lift, the hips are flexed to a relatively acute angle whereas the knees start at a far greater angle. With this positioning, the knee extensors (quadriceps) are less involved in the exercise than they are in the squat. This causes the hip extensions (gluteals and hamstrings) to be relied on the majority of the lift. It is because of this that the deadlift is very popular in strength and conditioning as a strengthener of the “posterior-chain”, a name for all of the muscle located on the back side of the body responsible for extension.

A popular trend in that has developed in the strength and conditioning world in regards to sports performance is the idea of “sports-specific” training. This involves utilizing exercises or movement in the weight room that directly mimic or reflect movements that are performance on the field of play. The degree to which sports specificity is adhered to in strength training can range from taking exact movements or partial movements from the playing field and adding weight to them, to finding compound movements to reflect the general body position and mechanics. An example for both would be a basketball player either assuming a defensive position wearing a weighted vest and performing drills, or the same basketball player performing a loaded back squat variation for repetitions.

The idea of sports-specific training is a subject that I find very interesting, however I do not necessarily agree with taking it to some of the extremes that it has been. I am of the thought that exercises performed in strength and conditioning programs for any athlete should have a direct correlation with their sport and performances in each should be comparable. In addition to my own professional endeavor of becoming a strength and conditioning coach where I would be able to apply this knowledge directly to the training of other athletes I am also a track and field athlete That is why I decided to embark on this research project. I believe that this research will lead to a deeper understanding of the relationship between strength training and sport-specific applications that will potentially increase my personal athletic performance.

2. Literature Review

Human beings are capable of performing a variety of powerful and explosive full-body movements that are both strength and speed oriented. In regards to speed and power, the block start, as represented in the 60m and 100m dash events in Athletics, is the most explosive movement that athletes engage in during their respective event [13]. Sprinters focus on exploding out of the blocks with as much power as they are capable of producing to accelerate through the next phase of their sprint and achieve maximal velocity as quickly as possible. In doing so, the most important steps during the block start are the first 2-4 contacts of each foot because these steps produce the most force and there is the greatest increase in velocity with each step [2, 4].

When initially pushing off the blocks, the angle of the sprinters torso relative to the plane of the ground increases sharply then ideally remains constant through the mid-drive phase. It is during this time that the athlete generates the most power through their legs as they cycle through stride phases of full flexion at the hip and knee (drive) to full extension of the hip and knee (push-off) [2, 10, 13]. When cycling through theses phases the sprinters ability to generate the most amount of force correlates with the maximal angular velocity of their hip and knee joints [13].

The muscles of the leg that are responsible for being able to produce these forces are primarily the quadriceps, which are responsible for hip flexion and knee extension, the hamstrings, which are hip extensors and knee flexors, and the gluteal muscles which contribute mainly to hip extension. Based on kinesiological characteristics of these muscle groups each contributes to specific phases of each stride during the drive phase; they are found to work synergistically through certain phases [4].

While it is true that during this phase the driving of the arms in time with the legs adds to the sprinters overall force production and center of mass acceleration and maximal velocity, the primary force production starts with the legs, making them a key factor when exploring strength training to increase start performance. Strength and conditioning programs that are designed to increase muscle strength and power capacities of the legs more often than not include exercises such as the front squat, back squat [14], and the deadlift. These exercises are chosen based certain characteristics that are not only specific to each athlete performing them, but also specific to each individual exercise.

The deadlift involves the athlete lifting a weight from the ground to about waist level in a coordinated extension at the knees and hips, and then returning it to the ground and repeating for each repetition. The mechanics of the movement begin with the hip and knee in a flexed position, each with relative angles greater than those in the bottom position of a squat [8]. This total body exercise relies heavily on recruitment of the gluteus, quadriceps, hamstrings, hip adductors and spinal erectors [1]. Generally, athletes are able to lift maximal weights that are equal to or greater than their maximal squat with greater vertical bar velocity[8] which lends to idea that athletes would be able to lift sub-maximal weights also with greater velocity, thus being able to generate more power than with a squat. Though the mechanic difference of each movement may influence this, the deadlift is a viable option when exploring training techniques to increase an athlete's ability to generate large amount of force quickly.

The squat movement has many variations, but the majority involves placing a load on the shoulders and, through coordinated flexion of the knees and hips, lowering the body until the thighs are parallel to the plane of the floor and standing back up [3]. The two main variation of the squat are the front squat and the back squat. The front squat require the load to be place on the anterior surface of the shoulder while the back squat refers to having the weight placed across the posterior surface of the shoulders and/or upper back [3, 6, 14]. The back squat can then be further subdivided based on the bar position on the back; the high-bar position refers to a bar placement across the upper trapezius, and the low-bar position involves the bar being positioned slightly lower on the back, just inferior to the spine of the scapula so that it rests across the middle trapezius and rear deltoids. The low-bar position also requires a slightly wider stance as to allow the torso to bend forward more without compromising the integrity of the lumbar spine.

Each of these variations is classified as a squat however with the change in bar position there is a subsequent alteration in the center of mass which will cause changes in angular positioning of the hips and knees. The front squat variation involves the athlete to maintain a more erect, or neutral, torso position in comparison to the back squat [14]. With the difference in relative joint positioning, the muscle recruitment during the performance of each squatting variant changes slightly. The front squat relies more on activation of the quadriceps and glutes, whereas the back squat recruit more of the hamstrings as well as the quadriceps **6**. The gluteus maximus becomes more activated as the width of the stance increase, so therefore the low-bar back squat requires greater gluteus maximus involvement due to its inherently wider stance width [5, 11].

In regards to training, with any of these exercises, the loading parameters are based on a percentage of the maximum weight the individual can lift in each exercise with proper technique. Most programs elicit strength gains by training under heavier loads, calculated at higher percentages of the athletes one-rep max. When training for power programs call for lighter loads, relatively lower percentages, and the focus is on completing each repetition at a high velocity [12]. Based on force/velocity and power/velocity relationships the faster the athlete can move a weight, the more force and power they can generate. Just as well, the heavier the weight the athlete is able to move at higher velocities, the force and power outputs are even greater [12].

There have been many studies that have been aimed at quantifying all of the block starts as well as the squat in all its variations, and there has been much speculation as to what technique is optimal to each movement itself. There have also been a great number of strength and conditioning programs designed with the intent of increasing an athlete's performance by increasing their lower body strength and power. The goal of this study is unique in that it aims to find a direct correlation, if any, between the lower body mechanics displayed during the block start and the mechanics of lower body exercises such as certain squatting variations and the deadlift. If any correlation can be established it will leads to more "sport-specific" exercise programming in regards to building strength and power using movements that more closely mimic the movement pattern both mechanically and kinesiologically.

3. Methods and Procedures

Subject. All observations will be made of a single male subject, 21 years old with a body weight of 180 lbs and a height of 5 ft 11 in. The subject is a trained decathlon athlete and is also well trained in the exercise movements associated with this study. Subject has personal best performances in the 60m and 100m dashes of 7.54-seconds and 11.74-seconds, respectively, and one-rep maxes of each lift as follows: Front Squat 315 lbs, High-bar Back Squat 335 lbs, Low-Bar Back Squat 365 lbs, and Deadlift 440 lbs.

Procedures. The subject will engage in 10 block starts, as in the fashion of a 60m or 100m dash. A camera will be set up as to capture, from a lateral view, the first 2 steps after block clearance. 5 videos will be taken from the subjects' right side (RS) and 5 videos will be taken from the subject's left side (LS). The subject will be marked with several visible cues on such anatomical landmarks as the glenohumeral joints (GH), the lateral iliac crests (LIC), the greater trochanter of the femur (GTF), the lateral epicondyle of the femur (LEF), the medial epicondyle of the femur (MEF), the lateral maleolus (LM) and the medial maleolus (MM). These landmarks will be used to establish the relative joint angles of the hip and the knee.

Relative joint angles will be measured at 4 stages within the stride of each limb; full flexion at the end of the knee drive (FF), toe-contact (TC), full extension just before toe-off (FE), and begin-swing through before the knee drive (BS). After all trials have been analyzed the data collected will be averaged, with regards to standard deviation included.

The subject will also engage in 4 distinct lower body strengthening exercises identified as such: Front Squat (FS), High-bar Back Squat (HBS), Low-bar Back Squat (LBS), and Deadlift (DL). Each exercise will be performed for 5 repetitions using sub-maximal load (70% 1RM). Subject will be marked at the same anatomical landmarks (GH, LIC, GTF, LEF, MEF, LM, and MM) to establish relative joint angles. Angles will be measured at 4 stages of each exercise: full extension at the top position (FE), mid-flexion of the eccentric phase (MD1), full flexion at the bottom position (FF), and mid-extension of the concentric phase (MD2).

The toe-contact (TC) phase of the block start will be comparable to mid-extension (MD2) phase of the concentric portion of the strength exercises. The begin-swing through (BS) phase of the block start will be comparable to the mid-flexion (MD1) phase of the eccentric portion of the strength exercises.

Angles will be assessed for each repetition of each exercise, and then all data collected will be averaged respectively. Data collected from the blocks start trials and each lower body strengthening exercise will then be compared and correlated.

Apparatus. The subject will be using GILL Fusion I Starting Blocks during the block start trials on a standard track surface runway. A standard 7 ft Olympic barbell (45 lbs) will be used in conjunction with 17.7-inch diameter bumper plates used in 10, 25, 35, and 45 lbs increments. A FUJIFILM Finepix J12 digital camera set up on an adjustable tripod will be used to collect each video trial and video analysis will be done using Dartfish™ Video Analysis Software.

4. Results

It was found that during the Front Squat (FS) exercise the hip joint moved through average relative joint angles ranging from 179.5-degrees at full extension to 51.7-degrees at full flexion. At the mid-points of both flexion and extensions (MD1 and MD2) the hip achieved very similar positioning at 119.2-degrees and 117.7 degrees on average, respectively. The knee joint was found to travel from an average relative joint angle of 178.2-degrees at full extension to 54.5-degrees at full flexion, with MD1 and MD2 positions at 114.1-degrees and 110.1-degrees, respectively [*Table 1.1*]. This exercise was performed under a load of 220-lbs, 70% of the subject's 1-rep maximum (1RM).

During the High-bar Back Squat (HBBS) the hip was found to move through an average joint range of motion ranging from 170.6-degrees at full extension to 52.5-degrees in full flexion. The knee averaged 172.2-degrees at full extension to 57.8-degrees in full flexion. Points of mid-flexion and mid-extension (MD1 and MD2) were found to be, on average, 105.1-degrees and 109.1-degrees respectively at the hip and 109.8-degrees and 110.4 degrees respectively at the knee [*Table 1.2*]. This exercise was performed under a load of 235-lbs, 70% of the subject's 1RM.

The Low-bar Back Squat (LBBS) presented average hip angles of 171.3-degrees at full extension and 39.7-degrees in full flexion, and average knee angles of 117.8-degrees at full extension and 54.0-degrees in full flexion. The mid-point of flexion and extension at the hip were 100.3-degrees and 93.4-degrees, respectively; at the knees they were 114.3-degrees and 104.6-degrees, respectively [*Table 1.3*]. This exercise was performed under a 255-lbs load, 70% of the subject's 1RM.

The average hip angles found during the Deadlift (DL) were 177.8-degrees in full extensions and 61.3-degrees in full flexion. The angle at the knee averaged 176.1-degrees in full extension and 108.9-degrees in full flexion. The average mid-flexion points were 113.8-degrees and 155-degrees for the hip and knee respectively. The average mid-extension points were 107.4-degrees at the hip and 153.5-

degrees at the knee [*Table 1.4*]. This exercise was performed with a load of 305-lbs, 70% of the subject's 1RM.

Front Squat		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Avg.
FE	Hip	180	179.3	179.6	179.8	179	179.5
	Knee	178.4	178.1	179.1	178.4	177.1	178.2
MD1	Hip	118.1	120.7	119.8	116.8	120.7	119.2
	Knee	115	114	114.3	112.4	114.7	114.1
FF	Hip	52.9	50.2	52.7	52.2	50.4	51.7
	Knee	53.5	57.7	55.4	51.8	54	54.5
MD2	Hip	117.7	117.1	120.1	117	116.4	117.7
	Knee	108.4	110.4	110.4	111	110.1	110.1

Table 1.1 - Relative joint angles during repetitions of the Front Squat

High-bar Back Squat		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Avg.
FE	Hip	168.7	173.6	170.9	169.4	170.7	170.6
	Knee	173.4	173.6	171.9	170.2	171.8	172.2
MD1	Hip	105	103.3	106.4	106.4	104.4	105.1
	Knee	109.8	108.8	109.2	110.6	110.7	109.8
FF	Hip	52.1	55	47.6	56.4	51.2	52.5
	Knee	53.6	55.8	59.9	61.8	57.8	57.8
MD2	Hip	108.5	109.1	109.6	110.1	108.1	109.1
	Knee	109.4	111.7	111.9	110.3	108.7	110.4

Table 1.2 - Relative joint angles during repetitions of the High-bar Back Squat

Low-bar Back Squat		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Avg.
FE	Hip	175.7	172.5	169.9	170.5	168	171.3
	Knee	179	176.4	178.6	179.8	175	177.8
MD1	Hip	102.7	100.6	98	99.6	100.6	100.3
	Knee	116.9	114.6	113.4	113.3	113.1	114.3
FF	Hip	40.3	39.8	38.6	39	40.7	39.7
	Knee	52.8	55.8	53.1	53.4	54.7	54
MD2	Hip	95	94.4	92.9	95.2	89.3	93.4
	Knee	101.3	104.3	107.1	106.4	104.1	104.6

Table 1.3 - Relative joint angles during repetitions of the Low-bar Back Squat.

Deadlift		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Avg
FE	Hip	178.2	179.7	179.4	175.4	176.1	177.8
	Knee	174.1	177.1	175.6	176.8	176.9	176.1
MD1	Hip	112.7	115.7	112.7	112.9	114.9	113.8
	Knee	156	156.8	156.2	153.8	152.1	155
FF	Hip	58.3	64.7	62.1	59.8	61.1	61.2
	Knee	104.7	102.6	113.2	109.6	114.2	108.9
MD2	Hip	114	107	102.1	108.5	105.3	107.4
	Knee	147.2	155	152.2	157.7	155.4	153.5

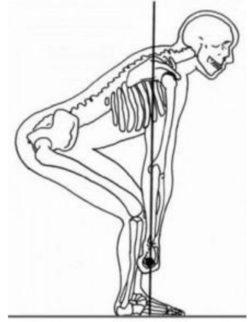
Table 1.4 - Relative joint angles during repetitions of the Deadlift

The angles of the legs measured while the subject was still in the starting blocks were measure on each leg independently. The average angles for the left leg, the leg farthest back, were 71.6-degrees at the hip and 100.5-degrees at the knee. The average angles for the right leg, the front leg, were 49.5-degrees at the hip and 86.7-degrees at the knee. During each full-extension phase of the 3 steps of the start, the hip averaged 178.9-degrees at full extension, 70.0-degrees at full flexion at the end of the knee drive, and 96.5-degrees at the point of toe contact with the ground. The knee averaged 170.3-degrees at full extension, 94.7-degrees in full flexion at the end of the knee drive, and 101.7-degrees at the point of toe contact [*Table 1.5*].

Combined Block Start

Trial	L1/R1		L2/R2		L3/R3		L4/R4		L5/R5		AVG	
Angle	Hip	Knee	Hip	Knee	Hip	Knee	Hip	Knee	Hip	Knee	Hip	Knee
L - In Block	72.9	100.4	71.8	107	68.8	98.2	73.3	99.5	71.3	97.2	71.6	100.5
R - In Block	49.2	81.6	49.5	86.7	47.9	85.7	51	92.2	49.9	87.1	49.5	86.7
L - FF	71.1	96.7	69.1	95.2	66.4	85.7	63.9	88.2	67.8	91.3	67.7	91.4
R - FE	176.1	174.9	178.4	171.6	178.8	162.8	179.9	174.8	176.4	171.7	177.9	171.2
L - Toe Contact	93.6	100.6	95.1	107.7	93.9	102.7	89.2	98.3	102.9	108	94.9	103.5
R - Begin Swing	171	138.6	171.3	145.5	169	132.2	159.7	131.6	163.1	137.5	166.8	137.1
L - FE	179.3	178.4	179.8	174.6	179.8	175	179.3	174.9	178.2	175.2	179.3	175.6
R - FF	73.1	91.2	80.9	97.1	72.8	94.3	75.9	99.9	70.8	96	74.7	95.7
L - Begin Swing	177.6	132.2	145.7	95.1	169.2	118.9	167.3	120.4	163.9	119.7	164.7	117.3
R - Toe Contact	102.1	97.6	102.9	101.2	99.4	100.7	90.5	99.2	95.1	100.7	98	99.9
L - FF	67.1	97.5	62.2	105.3	68.3	97.3	70.4	92.3	70.2	92.6	67.6	97
R - FE	179.5	165.7	180	160.7	179.7	161.3	179	165.3	179.8	167.7	179.6	164.1

Table 1.5 – Relative joint angles during phases of the block start.



5. Discussion

The results of this study clearly show the difference in basic kinematics between the 4 different lower body strength exercises as well as a few correlations that can be inferred between these mechanics and those experienced during the block start. The relative joint angles measured during trials of the front squat, high-bar back squat, low-bar back squat, and deadlift affirmed the previously stated variations in biomechanical position of each exercise; the front squat requires a more upright torso than the high-bar and low-bar back squat while experiencing a deep flexion at the knee, the high-bar back squat requires increased flexion at both hip and knee however the low-bar variation causes a deep flexion of the hip, and the deadlift retains more obtuse angles at the knee while the hips move through a greater range of motion.

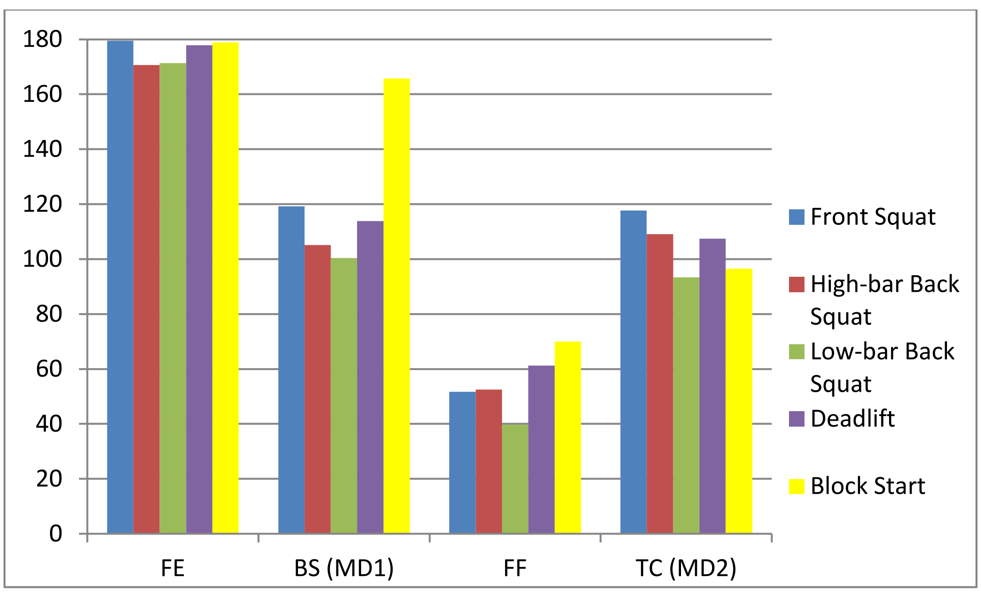


Figure 1 - Average Relative Joint Angles at the Hip

Based on these positions the muscular activation tendencies are as follows: the front squat and high-bar back squat stimulate greater activation in the quadriceps and gluteals, the low-bar back squat increases hamstring recruitment in addition to the quadriceps and gluteals, and the deadlift has decreased quadriceps activation but has greater hamstring and gluteal involvement. During the block start and sprint running the main muscle groups responsible for forward propulsion of the body are the gluteals and the hamstrings, however the quadriceps do play a supporting role synergistically with knee extension coordinated with hip extension during the pull-through, from toe contact to toe-off, phase of the stride.

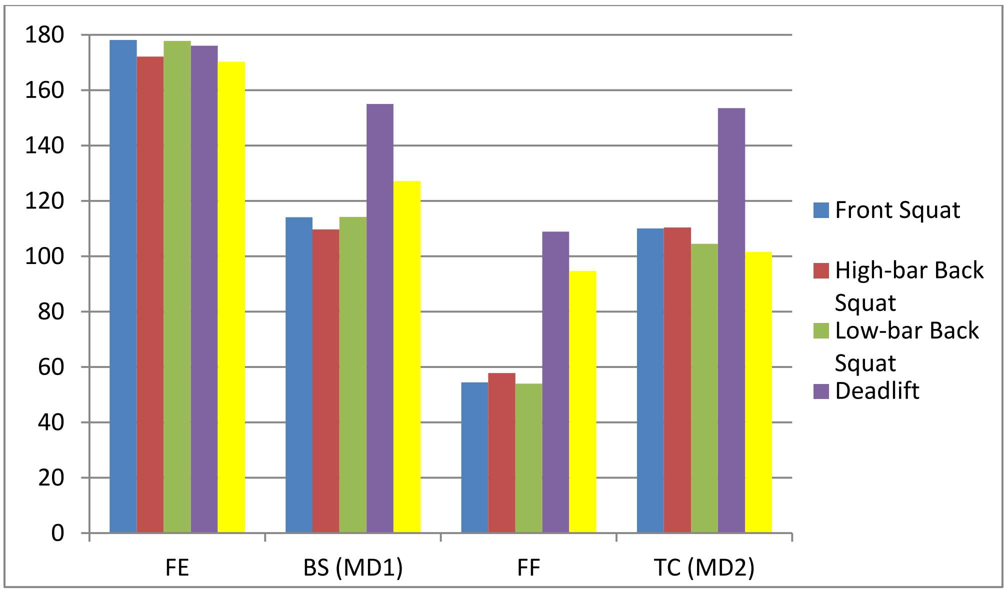


Figure 2 - Average Relative Joint Angles at the Knee

The point during the stride at which the power developed within these muscle groups is exerted is from initial toe-contact through full extension. This can be viewed as equivalent to the full-flexion (FF) through mid-extension (MD2), and full-extension (FE) phases of each repetition of the strength exercises because it is between these points that the same muscle groups are recruited to exert the force necessary to lift the load. More specifically, the initial point of toe-contact (TC) post-knee-drive can be associated with the point of mid-extension (MD2) during repetitions of each strength exercise. This is based on the kinematic observation that full flexion is attained at both hip and knee at the end of the knee drive and that the point of toe-contact (TC) is after the hip and knee are being extended.

The most significant correlation that can be observed during these specific phases of both the strength exercises and the strides after the block start is that the Low-bar Back Squat emulates the closest relative positioning of the hip and knee during concentric motion at the mid-extension point. The average hip and knee angles at the point of toe-contact (TC) are 96.5-degrees and 101.7-degrees respectively [*Table 1.5*]. At the point of mid-extension (MD2) during the Low-bar Back Squat the average angles at the hip and knee were measured at 93.4-degrees and 104.6-degrees respectively [*Table 1.3*]. This relationship is significant in that the Low-bar Back Squat is the exercise that stimulates all three of the major muscle groups, with emphasis on those of the posterior chain (hamstrings and gluteals) which are the same muscles recruited during forward propulsion of the body during sprint running.

A secondary correlation can be made about the point of full-flexion during the strength exercises and the phase of full-flexion at the end of the knee drive during the strides of the block start. The relative angles measure at the hip and knee during repetitions of the Deadlift (DL) are closer in relation to those measured at full-flexion during the block start trials than any of the other strength exercises [*Figures 1 & 2*]. The average angles at the hip and knee in full flexion during the block start trials were 70.0-degrees and 94.7-degrees respectively. The angles measure during the Deadlift averaged 61.2-degrees at the hip and 108.9-degrees at the knee [*Table 1.4*]. The transition from the full-flexion point of the knee drive to the toe-contact phase of the stride involves extension at the hip while maintaining a flexed knee position. This major muscle groups required to accomplish this movement are the gluteals and the hamstrings, both of which are the main muscle groups activated during the Deadlift.

A third correlation can be made between the relative joint angles measure during repetitions of the observed lower body strength exercises and those measured while the subject was in the start position in the blocks. The subject of this study was positioned with the left leg in the rearmost block and the right leg in the front most position, therefore the left (rear) leg is in a more extended position and the right (front) leg is more flexed when the starting “set” position is attained. When the average relative joint angles of the rear leg are compared against those measured during repetitions of the strength exercises the position of the hip and knee have a strong correlation to those of the hip and knee in the full-flexion (FF) phase of the Deadlift [*Figure 3*]. However, when compared to the relative angles measured at the mid-extension (MD2) point, the correlation with the Deadlift is significantly diminished but a similarity with the positioning during the Low-bar Back Squat becomes more evident [*Figure 4*].

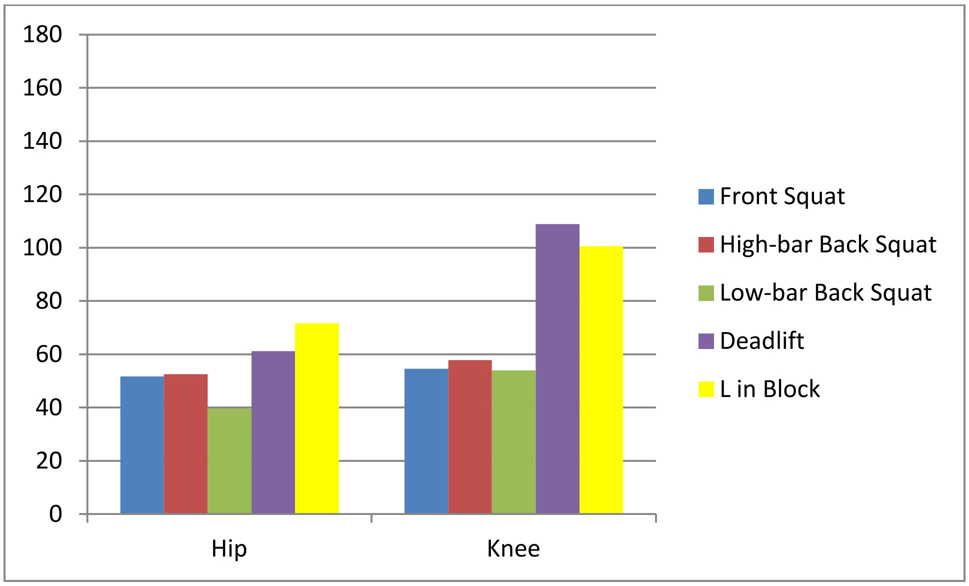


Figure 3 - Left Leg Position in Block vs. FF Position during Strength Exercises

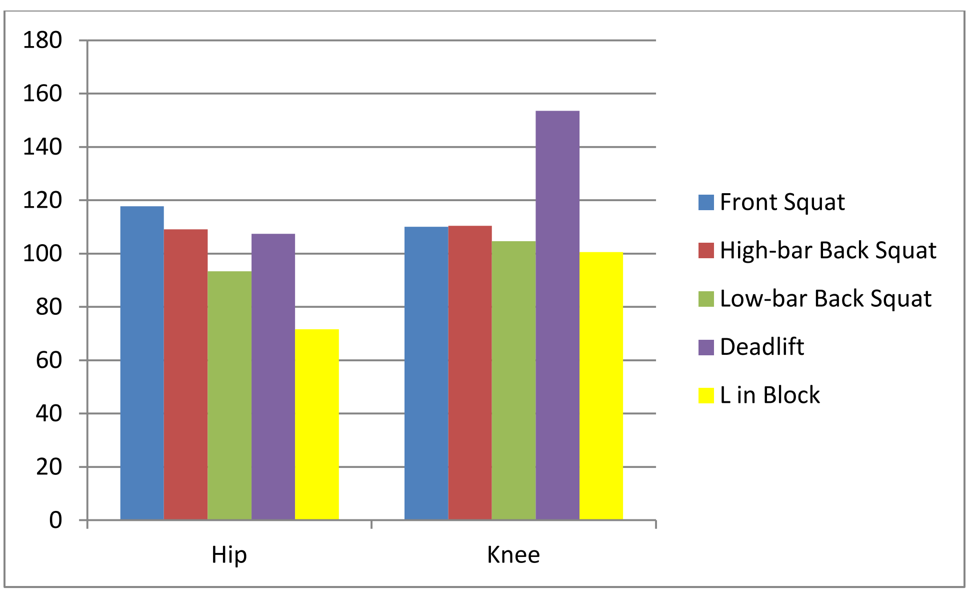


Figure 4 - Left Leg Position in Block vs. MD2 Position during Strength Exercises

In a similar fashion, the positioning of the right (front) leg in the blocks can be compared to the full-flexion (FF) and mid-extension (MD2) positions during repetitions of the lower body strength exercises. The average angle measure at the hip of the right leg is very similar to those of the Front Squat (FS) and High-bar Back Squat (HBBS) when in the full-flexion (FF) position. The knee, however, has a closer correlation to that of the average angles during the Deadlift (DL) [*Figure 5*].

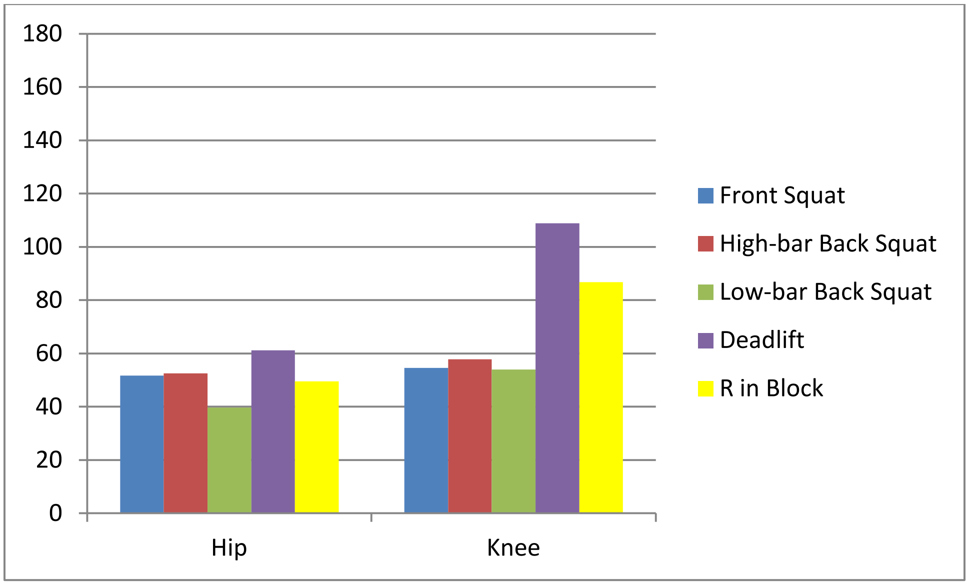


Figure 5 - Right Leg Position in Block vs. FF Position during Strength Exercises

When compared to the mid-extension (MD2) position of the strength exercises there is no significant correlation in the relative joint angles [*Figure 6*].

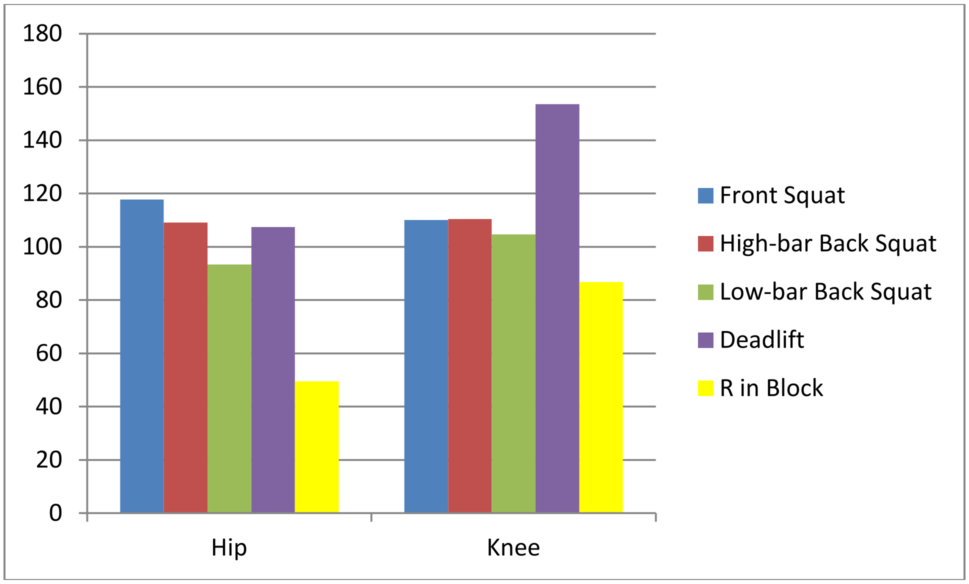


Figure 6 - Right Leg Position in Block vs. MD2 Position during Strength Exercises

This is not unexpected as the right (front) leg is in a much more flexed position than the left (rear) leg so it would therefore have a stronger correlation with the full-flexion (FF) position. The left leg correlates better with the Deadlift (DL) in the full-flexion (FF) position as the Deadlift inherently has greater angles in that position than the squatting variations and the correlation shifts at mid-extension (MD2) as the angles of the Deadlift exceeds those of the left (rear) leg but the Low-bar Back Squat (LBBS) achieves a more similar position.

Based on the data collected and over the course of analysis during this study, it has become clear that several correlations can be observed between the kinematics of certain lower body strength exercises, mainly the Deadlift (DL) and the Low-bar Back Squat (LBBS), and those of the sprint block start. Each exercise observed in this study has it individual benefits when used in training however they all share the common benefit of building strength and power in the legs, primarily in the quadriceps, hamstrings, and gluteals. For sprinters looking to increase their performance in the block start, there are some more unique advantages to performing one exercise over another.

Most strength and conditioning programs divide an athlete's schedule into several different phases of training, each of which has a specific training goal in mind; in simplest terms they can be viewed as Off-Season, Pre-Season, In-Season, and Post-Season. Off-Season training ultimately has the goals of increasing the base strength of the athlete in a general sense, whereas during Pre-Season training the athlete begins to engage in exercises that are aimed at increasing specific strength related to their sport. In-Season training is often relegated only those exercises that will give the “most bang for their buck” and the goal is simply to maintain the level of strength achieved during Off- and Pre-Season training over the course of season. Post-Season training is more recovery oriented and holds not significant in relation to this study or its implications.

For sprinters, the significance of performing one variation of the squat or deadlift over another during Off-Season training is very slight as they all are good choices for overall leg strength development, and the majority of strength programs will have these exercises programmed in one capacity or another. As training transitions to the Pre-Season phase and the goals shift to more specific strength, exercise selection becomes more particular.

Based on this study’s finding, a sprinter looking to increase their performance in the block start would most likely benefit greater from incorporating the Low-bar Back Squat variation and the Deadlift into their training based on their kinematic correlations with each other. However, the other variations of the squat (Front Squats and High-bar Back Squats) can still be performed in an accessory capacity.

Once the athlete enters the In-Season training, total weight training volume will be diminished but they will be performing the most productive exercises to maintain their levels of strength. During this phase relying on the Low-bar Back Squat and Deadlift as the main lower body exercises to be performed is indicated by the results of this study. The reason is that both exercises are full-body, compound movements that stimulate a strength response in the same muscle groups used in sprinting and that by performing these exercises the athlete will be engaging in total lower body strength training as well as benefiting from the sport-specific correlations they have with the mechanics of the block start.

The results of this study cannot be absolutely generalized as only one male sprinter participated. This study does provide certain valuable information that can be used integrated or used in conjunction with subsequent similar studies. In order to collect more specific data, more advanced and sophisticated equipment that was not available during the conduction of this study should be used to gain a more precise perspective of the correlations observed. This type of data would be valuable in sport science and athletics to those in the professional discipline of strength and conditioning or coaching and is worth further researching.

6. Appendices

Tables

Front Squat		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Avg.
FE	Hip	180	179.3	179.6	179.8	179	179.5
	Knee	178.4	178.1	179.1	178.4	177.1	178.2
MD1	Hip	118.1	120.7	119.8	116.8	120.7	119.2
	Knee	115	114	114.3	112.4	114.7	114.1
FF	Hip	52.9	50.2	52.7	52.2	50.4	51.7
	Knee	53.5	57.7	55.4	51.8	54	54.5
MD2	Hip	117.7	117.1	120.1	117	116.4	117.7
	Knee	108.4	110.4	110.4	111	110.1	110.1

Table 2.1 - Relative joint angles during repetitions of the Front Squat

High-bar Back Squat		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Avg.
FE	Hip	168.7	173.6	170.9	169.4	170.7	170.6
	Knee	173.4	173.6	171.9	170.2	171.8	172.2
MD1	Hip	105	103.3	106.4	106.4	104.4	105.1
	Knee	109.8	108.8	109.2	110.6	110.7	109.8
FF	Hip	52.1	55	47.6	56.4	51.2	52.5
	Knee	53.6	55.8	59.9	61.8	57.8	57.8
MD2	Hip	108.5	109.1	109.6	110.1	108.1	109.1
	Knee	109.4	111.7	111.9	110.3	108.7	110.4

Table 1.2 - Relative joint angles during repetitions of the High-bar Back Squat

Low-bar Back Squat		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Avg.
FE	Hip	175.7	172.5	169.9	170.5	168	171.3
	Knee	179	176.4	178.6	179.8	175	177.8
MD1	Hip	102.7	100.6	98	99.6	100.6	100.3
	Knee	116.9	114.6	113.4	113.3	113.1	114.3
FF	Hip	40.3	39.8	38.6	39	40.7	39.7
	Knee	52.8	55.8	53.1	53.4	54.7	54
MD2	Hip	95	94.4	92.9	95.2	89.3	93.4
	Knee	101.3	104.3	107.1	106.4	104.1	104.6

Table 1.3 - Relative joint angles during repetitions of the Low-bar Back Squat.

Deadlift		Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Avg
FE	Hip	178.2	179.7	179.4	175.4	176.1	177.8
	Knee	174.1	177.1	175.6	176.8	176.9	176.1
MD1	Hip	112.7	115.7	112.7	112.9	114.9	113.8
	Knee	156	156.8	156.2	153.8	152.1	155
FF	Hip	58.3	64.7	62.1	59.8	61.1	61.2
	Knee	104.7	102.6	113.2	109.6	114.2	108.9
MD2	Hip	114	107	102.1	108.5	105.3	107.4
	Knee	147.2	155	152.2	157.7	155.4	153.5

Table 1.4 - Relative joint angles during repetitions of the Deadlift

Combined Block Start

Trial	L1/R1		L2/R2		L3/R3		L4/R4		L5/R5		AVG	
Angle	Hip	Knee	Hip	Knee	Hip	Knee	Hip	Knee	Hip	Knee	Hip	Knee
L - In Block	72.9	100.4	71.8	107	68.8	98.2	73.3	99.5	71.3	97.2	71.6	100.5
R - In Block	49.2	81.6	49.5	86.7	47.9	85.7	51	92.2	49.9	87.1	49.5	86.7
L - FF	71.1	96.7	69.1	95.2	66.4	85.7	63.9	88.2	67.8	91.3	67.7	91.4
R - FE	176.1	174.9	178.4	171.6	178.8	162.8	179.9	174.8	176.4	171.7	177.9	171.2
L - Toe Contact	93.6	100.6	95.1	107.7	93.9	102.7	89.2	98.3	102.9	108	94.9	103.5
R - Begin Swing	171	138.6	171.3	145.5	169	132.2	159.7	131.6	163.1	137.5	166.8	137.1
L - FE	179.3	178.4	179.8	174.6	179.8	175	179.3	174.9	178.2	175.2	179.3	175.6
R - FF	73.1	91.2	80.9	97.1	72.8	94.3	75.9	99.9	70.8	96	74.7	95.7
L - Begin Swing	177.6	132.2	145.7	95.1	169.2	118.9	167.3	120.4	163.9	119.7	164.7	117.3
R - Toe Contact	102.1	97.6	102.9	101.2	99.4	100.7	90.5	99.2	95.1	100.7	98	99.9
L - FF	67.1	97.5	62.2	105.3	68.3	97.3	70.4	92.3	70.2	92.6	67.6	97
R - FE	179.5	165.7	180	160.7	179.7	161.3	179	165.3	179.8	167.7	179.6	164.1

Table 1.5 – Relative joint angles during phases of the block start.

Figures

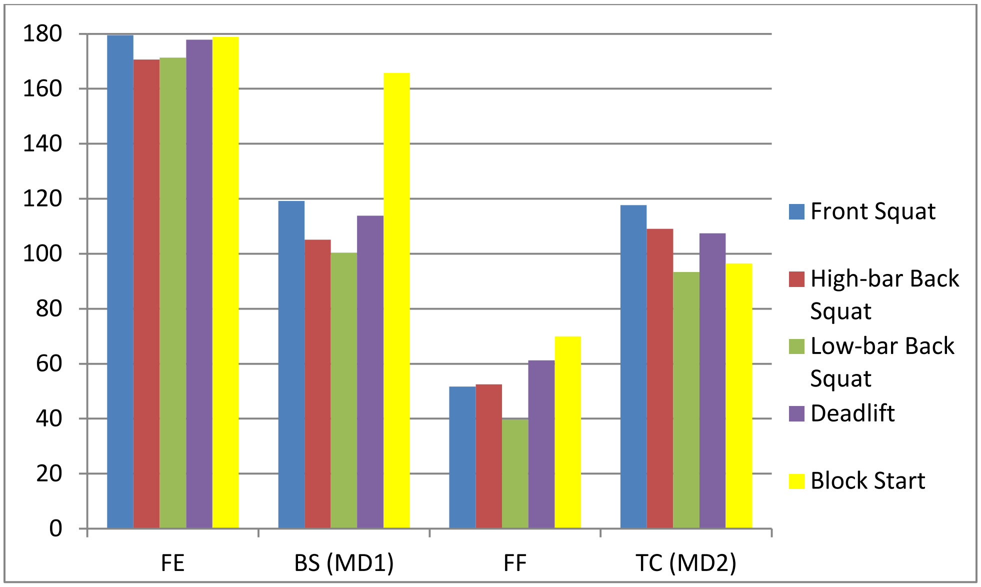


Figure 2 - Average Relative Joint Angles at the Hip

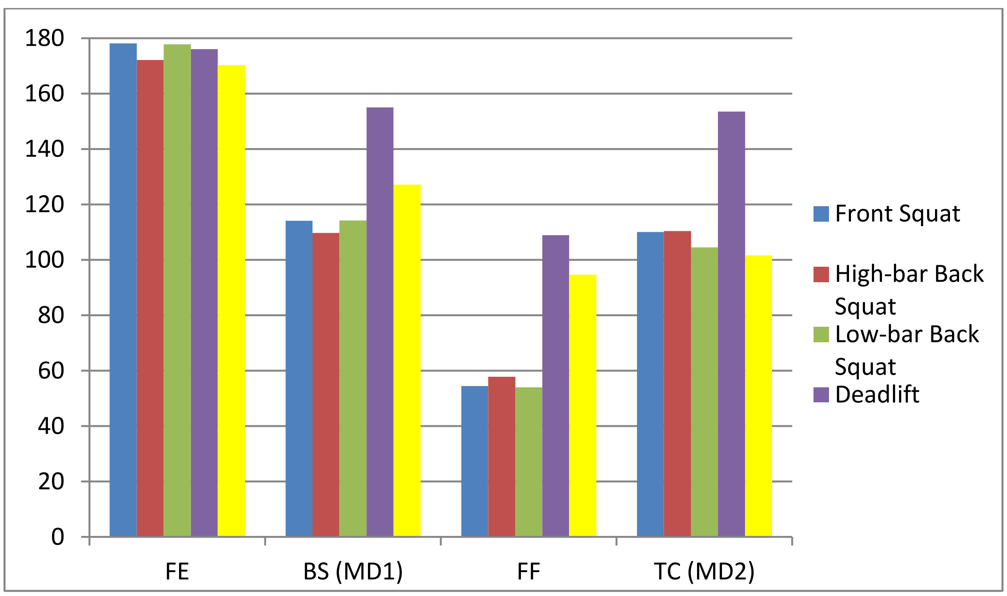


Figure 2 - Average Relative Joint Angles at the Knee

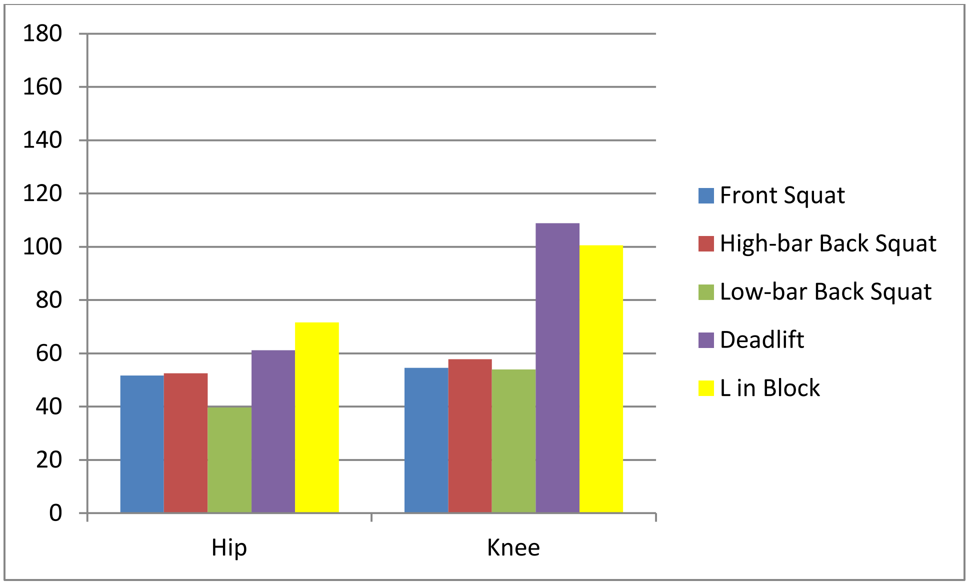


Figure 3 - Left Leg Position in Block vs. FF Position during Strength Exercises

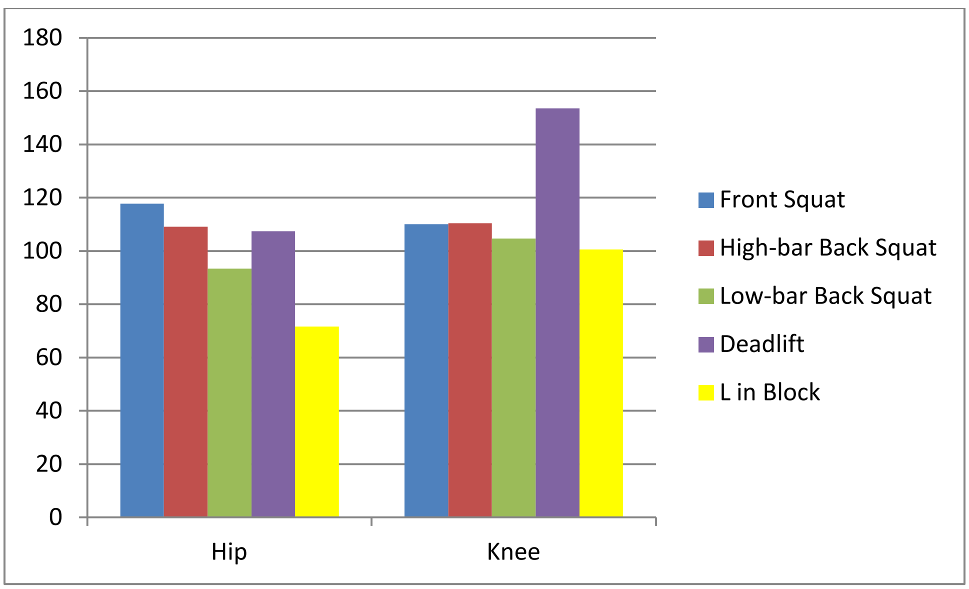


Figure 4 - Left Leg Position in Block vs. MD2 Position during Strength Exercises

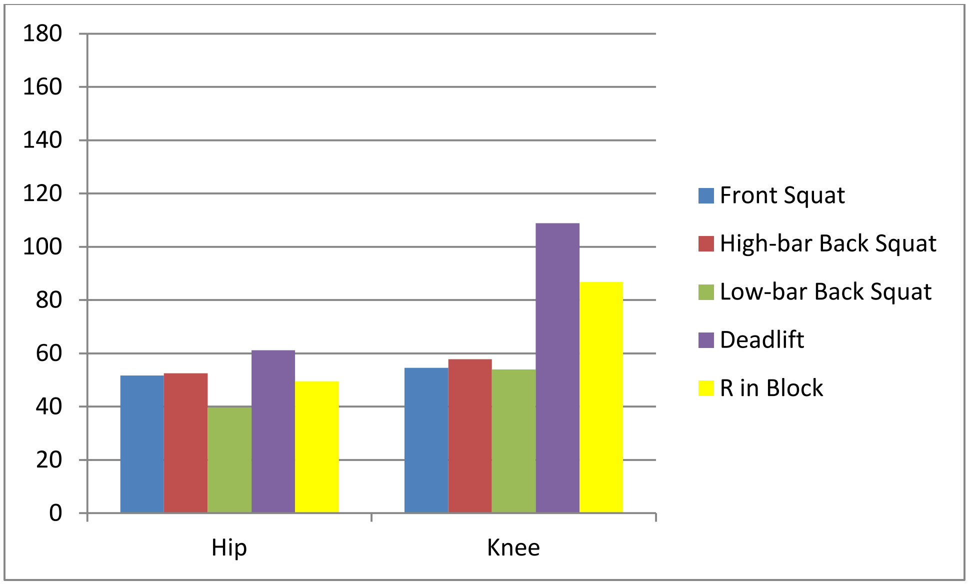


Figure 5 - Right Leg Position in Block vs. FF Position during Strength Exercises

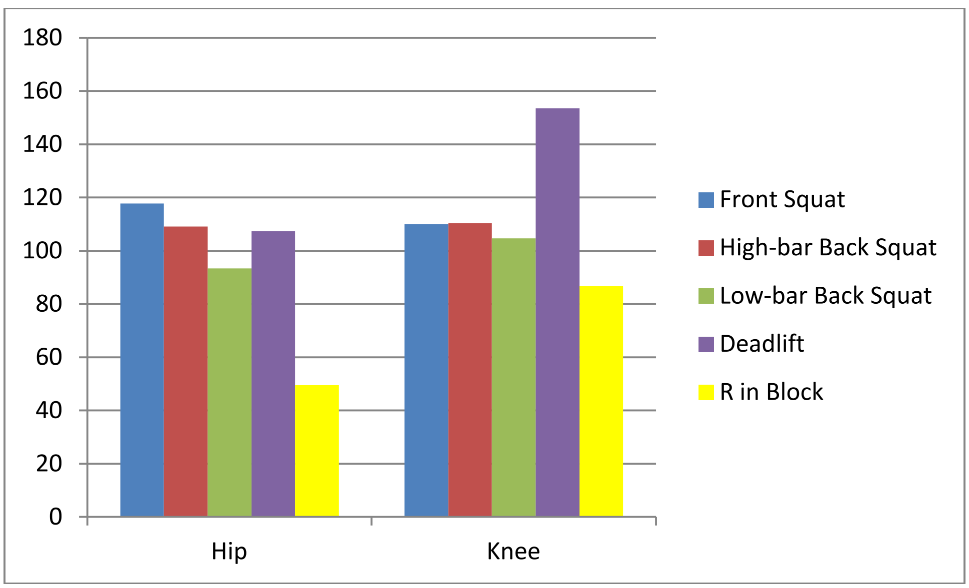


Figure 6 - Right Leg Position in Block vs. MD2 Position during Strength Exercises

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