The Relationship Between Sprint Speed and Hip Flexion/Extension Strength in Collegiate Athletes

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The evaluation of strength and the development of methods to improve strength in the lower extremity are integral areas of interest in biomechanics and athletic training. Contemporary research has established that (1) the hip extensors and the hip flexors are the strongest muscle groups within the lower extremity, and (2) the extensors are the primary movers by acceleration of the body's center of gravity. Thus, the purpose of this study was to determine the relationship between sprint speed and hip flexor/extensor strength measured from a functional position. Forty-one intercollegiate athletes (mean age-19.4 yr, mean weight = 194.5 lbs) participated in this study. Sprint speed (SS) was determined from the mean of three 40-yard sprints on artificial turf. Muscular assessment was performed using a Cybex II isokinetic testing device. Test speeds of 60 deg/sec and 240 deg/sec were selected for assessment of peak torque (PT), peak torque/body weight (PT/BW), torque acceleration energy (TAE), average power, flexion/extension ratios, and endurance ratios. Unlike previous research, this strength assessment was performed from a functional standing position (right leg testing). A reliability study established consistency of strength measures on different occasions. Absolute intraclass correlation coefficients (ICC) of 0.91, 0.96, 0.93, and 0.82 were established for flexion at 60 deg/sec, extension at 60 deg/sec, flexion at 240 deg/sec, and extension at 240 deg/sec, respectively. Results of regression analysis showed significant ($p < 0.01$) correlations between SS and flexion PT/BW at 60 deg/sec ($r = -0.57$), extension PT/BW at 60 deg/sec ($r = -0.56$), flexion PT/BW at 240 deg/sec ($r = -0.42$), and extension PT/BW at 240 deg/sec ($r = -0.41$). This study suggests that when tested functionally, there appears to be a strong relationship between hip flexion and extension strength relative to body weight and SS. Additionally, it suggests that a cause/effect relationship could exist between enhanced hip flexion/extension strength and sprint speed.

Keywords: Sprint speed; functional concentric assessment; hip flexor/extensor ratio

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Introduction

The evaluation of strength and the development of methods to improve strength in the lower extremity are integral areas of study in the field of biomechanics, exercise physiology, motor development, and athletic training. Strength and speed are the two most common variables used to predict an athlete's talent or potential, yet research has been unsuccessful in establishing specific relationships between the two. Thus, nobody seems to understand the relationship between strength and speed of locomotion. Traditionally, strength training has been emphasized for the purpose of improving speed, but too often the focus has been the musculature about the knee, when previous research using cinematography and electromyography suggests the musculature about the hip may be more important.

Given that sprint running involves rapid acceleration of an appreciable mass, the ability to generate high levels of force is commonly considered as an important factor in contributing to successful perfor-

mance.[1,5] However, previous studies[3,5-7] have reported equivocal results regarding the relationship between strength and maximal sprint velocity. Biomechanists and exercise physiologists have attempted to establish the relationship between knee strength and sprint speed; however, these efforts have not provided substantial results to support a strong relationship.

These studies concluded that quadriceps/hamstring strength for knee extension and flexion do not appear to be related to sprint speed. On the other hand, the limited research attempting to establish a relationship between hip strength and sprint speed has shown more significant correlations.[5] For the most part, however, research attempting to determine any significant relationship between strength and sprint speed has been unsuccessful because it has neglected the importance of assessing strength from a functional position.

Thus, it has been established that there is reason to believe the musculature about the hip joint could be directly related to sprint speed. The aforementioned research suggests the need to further investigate the importance of hip strength in sprinting. It was hypothesized that there would be a significant relationship between hip flexor/extensor isokinetic strength (tested from a functional running position) and sprint speed. The purpose of this research was to determine the relationship between hip flexor/extensor strength and sprint speed in Division I intercollegiate athletes.

■ Methods

Subjects for the investigation included 41 Division I intercollegiate football and baseball players (mean age = 19.4 yr, mean weight = 194.5 lbs) with no history of hip injury. Subjects were randomly selected to participate as part of an off-season conditioning program. Initially, 10 subjects were randomly selected to test reliability of the strength-testing device. The strength of the right hip was measured twice on the same day with a minimum rest interval of 20 min. Approximately 1 week later, each subject was asked to participate in two tests, a speed test and a strength test. The tests were randomly performed on the same day, 30 min apart.

Speed testing began with warm-up and practice starts. Each subject then performed three 40-yard sprints on artificial turf at the university's indoor facility. The best time was accepted for the final data analysis. For each trial (approximately 10 min apart), the average of three times was collected by two independent time keepers in an attempt to eliminate the possibility of human error.

Strength testing was performed in an isokinetic testing laboratory, where the subjects were tested for hip flexor/extensor strength. Each subject performed a

Figure 1 Velcro (Velcro USA, Manchester, NH) strap (using figure of eight) secured around involved thigh, waist, and dynamometer arm.

5-min warm-up on a bicycle ergometer at a setting of 2.5 kg (70 rpm). Following the warm-up, the subject was positioned before the Cybex II Isokinetic Dynamometer with the dominant leg closest to the dynamometer arm. Only the dominant leg (kicking preference) was tested.

A stabilization frame was placed in front of the standing subject, which allowed him to undertake a functional running position with the trunk slightly flexed. Furthermore, a Velcro strap was secured (using a figure of eight) around the involved thigh, waist, and dynamometer arm to help prevent anterior/posterior displacement of the hip's axis of rotation (*Figure 1*). Using both hands, the subject gripped the frame for support. In addition, his weight was shared by the pelvis and uninvolved leg. The dynamometer arm was adjusted so the pad contacted the quadriceps just proximal to the knee. In an effort to standardize testing between subjects, the subject was instructed to keep the involved knee flexed to 90 deg throughout the test. The subject was able to freely move the arm in the frontal plane (anterior/posterior direction) without any obstructions through 115–125 deg range of motion, including both flexion and extension (*Figure 2*).

Once secured about the testing device, the subject performed four submaximal practice repetitions at the two testing speeds, 60 and 240 deg/sec. Subjects were reminded to work the entire range of motion by starting into flexion and ending with extension. Both flexion and extension measures were taken continuously. After a 5-min resting period (standing at testing device), subjects performed four maximal repetitions at 60 deg/sec, followed by another 5-min rest and a series of 25 maximal repetitions at 240 deg/sec.

After testing of all 20 subjects, the Cybex Data Reduction Computer was used for the analysis of six

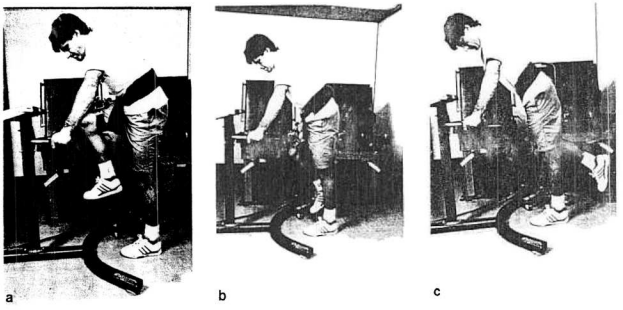

Figure 2 (a) Hip flexion at 90 deg. (b) Hip extension in continuation from full hip flexion. (c) Hip extension at 15 deg

muscle characteristics for hip flexion and extension. Testing included a measure of peak torque, torque acceleration energy, average power, endurance ratios, peak torque/body weight (PT/BW), and total work.

Data were analyzed using SPSS release 4.1. Initially, absolute intraclass correlation coefficients were determined using pre- and posttest data (10 subjects) to establish reliability. Spearman's rho correlational analysis was then used to determine relationships between flexion/extension values and sprint speed.

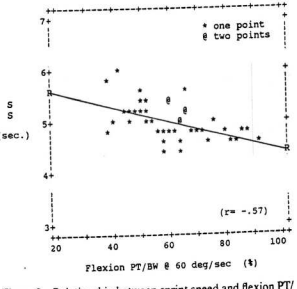

Figure 3 Relationship between sprint speed and flexion PT/BW at 60 deg/sec.

Results

Absolute intraclass correlation coefficients (ICC) of 0.82–0.96 were established for flexion at 60 deg/sec, extension at 60 deg/sec, flexion at 240 deg/sec, and extension at 240 deg/sec.

Spearman's rho correlational analysis showed significant ($p < 0.01$) correlations between sprint speed and flexion PT/BW at 60 deg/sec, extension PT/BW at 60 deg/sec, flexion PT/BW at 240 deg/sec, and extension PT/BW at 240 deg/sec. The relationships are represented graphically (*Figures 3–6*). All 41 subjects' peak torque values and PT/BW ratios were averaged (*Table 1*).

Table 1 Absolute torque and relative torque means for isokinetic strength.

	Absolute	Relative*
Extensor 60 deg/sec		
Flexor 60 deg/sec		
Extensor 240 deg/sec		
Flexor 240 deg/sec		

* Normalized to body weight.

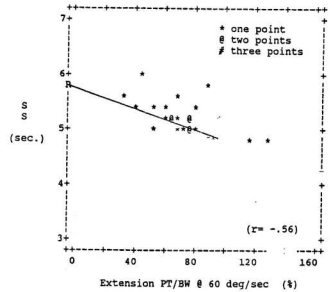

Figure 4 Relationship between sprint speed and extension PT/BW at 60 deg/sec.

Discussion

This study provides preliminary data relative to the relationship between hip strength and sprint speed. The data showed strong relationships between sprint speed and hip flexion/extension relative to body weight in Division I collegiate baseball and football players. Most importantly, as hip strength increased, sprint speed improved. In many cases, the lighter subjects actually had stronger hip flexors and extensors than the heavier subjects, who turned in slower sprint times. The hip extensors (gluteus maximus, semitendinosus) on average were 1.25 times as strong as the hip flexors (psoas major, iliacus), which is in agreement with previous research.[4,8,9]

These data suggest several reasons for studying the improvement of sprint speed. First and foremost, the results support the earlier cinematographic and electromyographic studies that claimed that the hip musculature is most important for acceleration.[8,10,15] The correlations established between sprint speed and hip strength for PT/BW at slow and fast speeds found in the current study are more significant than correlations found in previous studies looking at sprint speed and knee strength.[5,6] Thus, as hypothesized based on previous research, it appears that the musculature at the hip needs to be researched further.

Secondly, isokinetic strength of the hip musculature has traditionally been assessed from the prone and supine positions; however, research has suggested the need to establish a more functional method of assessment. These data also support this belief, as evident when comparing the results with Farrar's[5] correlations of sprint speed to hip strength measured from the traditional position. Farrar[5] found low sprint speed to hip strength correlations for hip flexion at 60 deg/sec, hip flexion at 300 deg/sec, hip extension at 60 deg/sec, and hip extension at 300 deg/sec. In agreement with Farrar, earlier related studies[3,7] also were unsuccessful in establishing significant relationships between strength of the lower extremity and sprint performance. In both of these studies, alternative modes of strength assessment were used. Costill[3] found only a correlation of 0.20 between 40 yard dash performance and squat

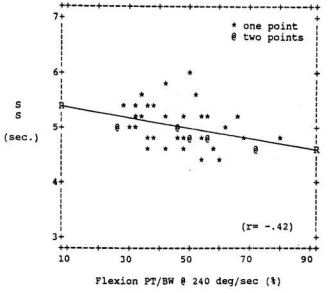

Figure 5 Relationship between sprint speed and flexion PT/BW at 240 deg/sec.

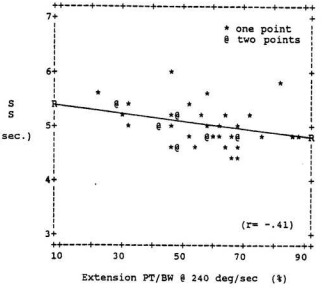

Figure 6 Relationship between sprint speed and extension PT/BW at 240 deg/sec.

strength, whereas Liba[7] found a correlation of 0.41 between leg extension strength and 50 yard dash performance. Level of significance for both studies was $p < 0.05$. These findings led Farrar[5] to conclude that "collectively, such results indicate that little of the interindividual variability in sprint performance can be accounted for by leg strength." However, the current study established much higher correlations in measuring basically the same variables.

It is our opinion that assessment from the prone and/or supine position does not allow for optimal torque generation. The rationale behind any research attempting to establish such correlations should seriously consider the anatomy, physiology, and biomechanics involved with sprint running. This in turn calls for more functional testing. In other words, an athlete does not sprint from the supine position; therefore, he or she should not be tested from a supine position if the research is assumed to be applicable to sport-specific skills.

Several contemporary studies of the lower extremity suggest that the prime movers of the hip are responsible for generating the most force during sprinting. Studies have reported that the hip extensors, followed by the hip flexors, are the strongest muscle groups within the lower extremities.[4,8] Furthermore, it was reported that the hip extensors are the primary movers for acceleration of the body's center of gravity.[4,5] Still, others have reported that the main muscle group responsible for increasing the speed of gait is that of the hip flexors.[10] Several biomechanists have reinforced the importance of hip involvement over knee involvement during sprinting. These studies, usually involving electromyography and cinematography, have determined that these muscles are most important during the ground phase of the running cycle, driving the body in a forward direction. Thus, during sprinting, this assumes special importance because acceleration takes place during the ground phase.

From a biomechanical perspective, one would expect the hip flexors and extensors to be most important in sprint running. Cinematographic recordings,[15] suggested that the extensors of the knee joint were somewhat important for acceleration of the body's center of gravity, but to a much lesser degree than the muscles of the hip. Furthermore, Simonsen[15] concluded that the biarticular muscles (hip extensors, hamstrings, gluteus maximus) are performing a large amount of eccentric work during the second half of the swing and two thirds of the flight phase. According to Simonsen's research, this action will decelerate the forward swing of the thigh and shank, so that these movements are turned into extension of the hip joint during the last one third of the flight two phase (full hip flexion to touch down) and during the ground phase.

Most researchers agree that this ground phase is most important for acceleration. However, contradictory research exists concerning the prime movers for acceleration. Simonsen[15] concluded that the hip extensors act as the primary movers because the hamstrings and the gluteus maximus perform all their eccentric work during the flight phase. He also claims that cinematography studies have suggested this theory to be correct. Mann,[8] on the other hand, concluded that the hip flexors are the main muscle group appearing to increase speed of gait. His rationale is based on electromyographic studies and the knowledge that the hip flexors are closely linked to the knee extensors in order to propel the body forward in the line of progression. Furthermore, the hip extensors have a remarkable ability, in comparison with the much more limited monoarticular muscles about the knee (vastus medialis and vastus lateralis), to perform both eccentric and concentric work during the ground phase.[15]

Optimal torque generation will occur with the proper length–tension relationship about the musculature at the hip. This optimal length–tension relationship occurs from an upright position when considering the gluteus maximus, semitendinosus, semimembranosus, psoas major, and iliacus. In a related study, Worrell *et al.*[16] attempted to more closely simulate a functional position while assessing hamstring strength for knee flexion. They concluded that the prone position may be best because greater force is produced by both the flexor and extensor groups from this position. This should also be considered in assessing strength at the hip. The upright testing position more closely approximates the musculature at both the hip and knee during many sport activities such as running.[16] The standing assessment method used in the current study is by far more functional than the traditional prone (hip extension) and supine (hip flexion). Furthermore, isokinetic testing from this position occurs with the assistance of gravity, which is also very specific to sprinting.

In the only other study considering a testing method similar to this, Cahalan[2] concluded that it was a valuable tool in assessing functional muscle strength in creating a database of normal strength values at multiple isokinetic speeds and isometric angles for a wide variety of ages.

Finally, the research suggests that enhanced hip flexion/extension strength may result in faster sprint speeds. This is an important area that needs investigation. An isokinetic training protocol will probably be most appropriate for this research in order to meet the principle of "specificity of training."[11–14] Recently there has been increased popularity in hip-strengthening devices using weights, such as variable-resistance devices. However, there are very few isokinetic de-

vices that allow for a functional yet practical method of strength training and assessment at this joint. The development and manufacturing of appropriate adaptors to the testing apparatus would benefit such future research.

Conclusions

Before this study, functional assessment of hip strength has been limited. This study determined that (1) reliable methods of functionally assessing hip strength are available; (2) there is a significant relationship between hip strength and sprint speed when strength is assessed from an upright position; (3) the hip musculature, as previous research suggests, is probably more important than knee musculature in evaluating sprint speed; and (4) this topic needs to be further investigated through the use of training studies.

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