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Effects of Hip Flexor Training on Sprint, Shuttle Run, and Vertical Jump Performance

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Abstract. Deane, R.S., J.W. Chow, M.D. Tillman, and K.A. Fournier. Effects of hip flexor training on sprint, shuttle run, and vertical jump performance. *J. Strength Cond. Res. 19(3): 615–621. 2005.*—Although hip flexion is integral in sports, hip flexion exercises are seldom emphasized in strength and conditioning for sports performance. This study aimed to determine whether a hip flexor resistance-training program could improve performance on a variety of tasks. Thirteen men and 11 women completed an 8-week hip flexion resistance-training program. Eleven men and 13 women served as controls. Isometric hip flexion strength, 40-yd dash time and the time for the first 10-yds, 4 × 5.8-m shuttle run time, and vertical jump height were evaluated at the beginning and end of the training and control period. Improvements were observed in the training group but not in the control group. Individuals in the training group improved hip flexion strength by 12.2% and decreased their 40-yd and shuttle run times by 3.8% and 9.0%, respectively. An increase in hip flexion strength can help to improve sprint and agility performance for physically active, untrained individuals.

Key Words. 40-yd dash, agility, countermovement jump, strength training

Introduction

Muscular strength is one of the components of physical fitness. Athletes of different sports use resistance training to improve their muscular strength. Among the exercises that are commonly performed by athletes, hip flexion is one of the most ignored exercises in strength and conditioning for sports performance. Hip flexion exercises are often neglected in strength training programs for popular sports such as football, basketball, and soccer (1, 7, 17, 19, 35). In addition, specific references to hip flexor exercises are often lacking in strength and resistance training texts (2, 4, 13, 18, 41). The lack of hip flexion exercises in strength and conditioning practices and related research may be partly the result of the relative difficulty in gaining access to equipment specifically designed to train the hip flexors.

Based on the action of the legs, a running cycle can be subdivided into 3 phases—a supporting phase that begins when the foot lands and ends when the athlete's center of gravity (CG) passes forward of it, a driving phase that begins as the supporting phase ends and ends as the foot leaves the ground, and a recovery phase during which the foot is off the ground and is being brought forward preparatory to the next landing (24). Although quadriceps, hamstrings, and calf muscles are mainly responsible for propelling the body forward during running and jumping exercises, hip flexor muscles may also contribute to these actions. Specifically, the hip flexor muscles assist in bringing the free leg forward and upward during the recovery phase of running (32). When performing a countermovement jump initiated from the standing position, it has been suggested that the elastic energy that contributes to a more explosive concentric contraction during the ascending (extension) phase would be lost if the countermovement (eccentric stretch or unloading) is slow (10, 39). It is possible that the hip flexor muscles can facilitate the unloading phase of a countermovement. Therefore, maximizing the strength of the hip flexor muscles is likely to be beneficial to athletes for whom running and jumping performance are integral parts of their sport.

Training methods for improving sprint performance have typically included general (which aim for hypertrophy and neuronal activation), velocity specific (speed and strength), and movement-specific (sprint-associated exercises) strength training (14). In an investigation into 2 types of training programs, it was observed that high-resistance training resulted in an improved initial acceleration phase, whereas high-velocity training resulted in an improved initial acceleration and maximum speed (15). In addition to traditional strength training, other interventions such as strength shoe (36) and Meridian shoe (26) have also been proposed for speed development. It is noteworthy that almost all methods or interventions focus on muscles associated with the driving phase of running (i.e., gluteus maximus, quadriceps, and plantar flexors), whereas the training of muscles responsible for the recovery phase has not been explored.

Similar to sprinting, vertical jump performance can be improved using a combination of resistance training and high-velocity training (5, 11, 20, 28). Regardless of the type of training, sprinters often perform hip flexor exercises in their training (16). However, hip flexion exercises are rarely emphasized in strength programs for athletes in other sports. The reason for not emphasizing the hip flexors is not known.

In addition to exercise machines and free-weight exercises, resistance training using elastic tubing has been demonstrated to be effective in strength development and improving sports performance (38). Therefore, elastic tubing can be an inexpensive and effective alternative to more traditional exercise machines in some settings. Although the hip flexors contribute to running and jumping movements, it remains unclear if a training program targeting the hip flexors will have any effect on sprinting, agility, and jumping performance. To address this question, the purpose of this study was to determine whether a hip flexor resistance-training program using elastic tubing could improve the performance in a 40-yd (36.58-m) dash, shuttle run, and vertical jump. We hypothesized that an increase in hip flexor strength as a result of resistance training would decrease the 40-yd and shuttle run times and increase vertical jump height.

Methods

Experimental Approach to the Problem

This study used a repeat measures design. To determine the influence of hip flexor strength training on several performance variables (40-yd dash, shuttle run, vertical jump, and hip flexion strength), 24 individuals were trained for 8 weeks using elastic tubing as resistance. These individuals were evaluated before and after the completion of training. A second group of 24 individuals served as controls. The control subjects received no training and were evaluated at the beginning and end of an 8-week period.

Subjects

A total of 48 college-age volunteers who were physically active but were not trained sprinters or currently following a weight-training program were recruited as subjects. Our subjects signed informed, written consent documents that had been approved by the Institutional Review Board before their participation and were divided into a training group: 11 women (age 22.2 ± 3.9 years, height 164.6 ± 6.2 cm, weight 588.4 ± 81.6 N) and 13 men (21.1 ± 1.9 years, height 182.6 ± 6.8 cm, weight 820.0 ± 134.8 N); and a control group: 13 women (20.9 ± 2.8 years, height 164.5 ± 8.4 cm, weight 617.8 ± 126.2 N) and 11 men (21.4 ± 1.4 years, height 181.7 ± 6.8 cm, weight 774.8 ± 157.8 N). Because of limited resources, subjects in the training and control groups were not recruited at the same time (i.e., testing of control group subjects was conducted after the procedures for the training group were completed). Although the subjects in this study were not randomly assigned to the 2 groups, the possible errors associated with this limitation should not affect the major findings of this study.

Study Design

The training group underwent an 8-week, hip flexor strength-training program. Although subjects in the training group were permitted to maintain any usual physical activity they had been participating in, they were asked to refrain from engaging in any new physical or strength-training activities that could have contributed to an increase in hip flexor strength. Subjects in the control group were also instructed not to engage in any new physical or strength-training activities that might increase hip flexor strength during the 8-week control period. In addition to isometric hip flexion strength, sprinting, agility, and vertical jumping performance of subjects in both groups were evaluated immediately before and after the training or control period (pretest and posttest, respectively).

Pretest and Post-test Measurements

Dependent measures were collected through the performance of 4 activities: the 40-yd dash, shuttle run, vertical jump, and isometric hip flexion strength. The testing procedures in the pre- and post-tests were identical for subjects in both groups. All testing took place in an indoor gymnasium (40-yd dash and shuttle run) and a biomechanics laboratory (vertical jump and strength test). Each subject completed a pre- or post-test in one session. At the beginning of a testing session, the subject was asked to jog 2 laps around the gymnasium and stretch for about 5 minutes before testing. Because subjects were tested in a group of 3–4 people, the rest period between trials and tests was 12–15 minutes.

Forty-Yard Dash. The time to complete a 40-yd sprint from a stationary position was used to evaluate the acceleration and speed characteristics of our subjects. Wearing their own running shoes, each subject performed 2 maximal effort sprints of 40 yards. The 10-yd (9.14 m) and 40-yd (36.58 m) times were measured electronically using a Brower Timing System (Draper, UT). In each trial, the subject assumed a three-point stance, applying pressure with one hand to a sensor on the floor behind the start line. The timer was triggered when the subject began to run and the pressure was removed from the sensor. When the subject ran past the 10- or 40-yd mark, the infrared beam between the source and detector was blocked, resulting in a signal being transmitted to the timer. For each testing session, the trial with the best 40-yd time was selected for subsequent analysis.

Shuttle Run. Shuttle runs are commonly used to measure the agility of an individual. In the shuttle run test, the subject was asked to run back and forth between the foul line and baseline of a basketball court twice with maximum effort (4 lengths of 5.8 m). Each subject performed 2 runs, and the time to complete a run was recorded using a digital stopwatch operated by one of the investigators (RSD). For each subject, the trial with the shorter time for each testing session was used in the statistical analysis.

Vertical Jump. Maximum vertical leap height was measured to evaluate any possible power gains resulting from training. While standing on a force plate (Type 4060–10, Bertec Corporation, Columbus, OH) with hands on hips, the subject performed 2 countermovement jumps with maximum effort. The vertical ground reaction forces during the jump phase (from the initiation of countermovement to takeoff) were used to determine the vertical velocity of the subject's CG (impulse-momentum relationship). The equations of uniformly accelerated motion were then used to determine the rise in CG during the flight phase (23). The rise in CG was used to represent the vertical jump height. For each testing session, the greater height for each subject was selected for subsequent analysis.

Isometric Hip Flexion Strength. With the intention of determining the efficacy of the hip flexor strength-training protocol, isometric hip flexion strength was measured. The subject was seated at the end of a treatment table with the distal portion of the thighs hanging freely over the edge of the table (Figure 1). The subject's arms were slightly extended (at the shoulder) to the rear with hands grasping the sides of the table. A 35-mm wide inelastic strap was placed approximately 10 cm proximal to the patella on the anterior surface of the thigh. The strap was connected to a load cell (Transducer Techniques, Temecula, CA, model SBO-300; nonlinearity 0.04% F.S. hysteresis 0.01% F.S., maximum capacity = 1,334 N), which was anchored to the floor. The length of the strap was adjusted so that both the hip and knee joint angles were 90° when the subject tried to bring his or her knee up (hip flexion) with maximum effort. The distance between the center of the strap and the greater trochanter of the femur (resistance arm) was measured before each contraction. Each isometric contraction lasted for about 4 seconds. Maximum hip flexion torque was computed as the product of the maximum force recorded by the load cell

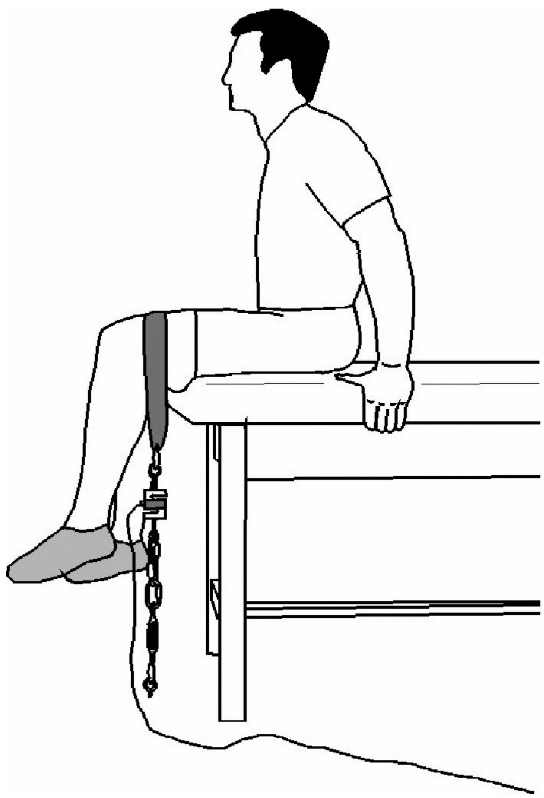

FIGURE 1. Experimental setup for the isometric hip flexion strength test.

and the resistance arm. For each subject, 2 isometric contractions were completed for each leg. The average of the highest torque value from each leg was used in subsequent analysis.

Strength Training

Subjects in the training group were trained 3 times a week for 8 weeks. To provide resistance against the hip flexion movement, elastic tubing of different resistances were used (Figure 2). Each subject performed 2 sets of 10 repetitions and a third set of maximal effort to failure for each leg. A maximum repetition (RM) of 10 is typically

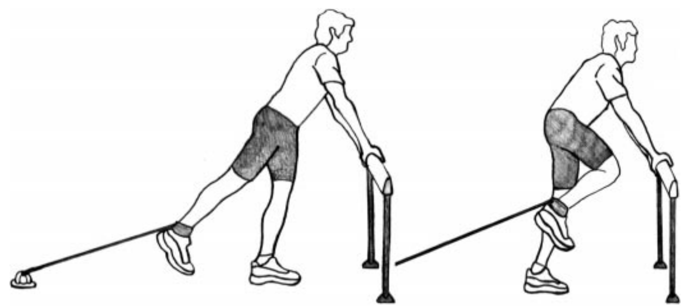

FIGURE 2. Hip flexion exercise using elastic tubing as the resistance.

associated with a load that is 75% of the 1RM (3) and is considered a moderate load for strength/power development (18). The repetitions were performed at a 2:4 tempo with a 30-second rest between consecutive sets. Once a subject could complete more than 20 repetitions in the third set, the resistance applied during the movement was increased. It has been suggested that RM loads of 20 and above show the greatest effect on muscular endurance measures but not on strength measures or maximal power outputs (18). All training sessions were conducted in a laboratory and under the supervision of the investigators.

Statistical Analyses

For each experimental condition, group means (men and women, pre- and posttests) and standard deviations were computed for the 10-yd time, 40-yd time, shuttle run time, maximal isometric hip flexor strength, and vertical jump height. The 5 dependent measures were compared using a 2 × (gender) × 2 (training and control groups) × 2 (pretest and posttest) multivariate analysis of variance (MANOVA) with repeated measures on the last factor. An a priori alpha level of 0.05 was used, and follow-up univariate tests were performed in the event of a significant interaction.

RESULTS

Gender differences were detected for each of the dependent variables. As shown in Table 1, men were signifi-

TABLE 1. Mean (*SD*) for different dependent measures with respect to gender, treatment, and test condition. Sample sizes in square brackets.

	Men				Women			
	Training [11]		Control [13]		Training [13]		Control [11]	
Measure	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
10-yd time (s)†‡	2.076 (0.180)	1.838 (0.156)	1.931 (0.106)	2.003 (0.109)	2.394 (0.167)	2.149 (0.120)	2.348 (0.170)	2.374 (0.190)
40-yd time (s)†‡	5.625 (0.362)	5.378 (0.388)	5.674 (0.485)	5.699 (0.392)	6.688 (0.505)	6.474 (0.364)	6.973 (0.677)	6.945 (0.597)
Shuttle run time (s)†‡	6.578 (0.362)	5.928 (0.392)	6.610 (0.392)	6.721 (0.419)	7.840 (0.600)	7.199 (0.455)	7.728 (0.561)	7.767 (0.593)
Hip flexion torque (N·m)*‡	135.2 (43.0)	150.6 (40.8)	125.9 (35.9)	117.5 (39.5)	60.2 (13.6)	68.8 (13.4)	65.8 (15.3)	62.4 (13.4)
Vertical jump height (m)*	0.341 (0.086)	0.346 (0.092)	0.322 (0.175)	0.302 (0.062)	0.227 (0.046)	0.217 (0.040)	0.204 (0.034)	0.198 (0.047)

* Significant difference between men and women at $p < 0.001$.
† Significant difference between training and control groups at $p \leq 0.001$.
‡ Significant interaction between treatment and test condition at $p \leq 0.002$.

TABLE 2. A 2 × 2 × 2 MANOVA comparing the vectors of performance scores between genders, training, and control groups over pre- and posttests.

Source	Wilk's λ	*F* Value	Hypothesis df	Error df	*p*	η_p^2	Observed Power
Gender (Ge)	0.176	37.440	5	40	<0.001	0.824	1.000
Group (Gr)	0.833	1.608	5	40	0.180	0.167	0.502
Test (T)	0.395	12.240	5	40	<0.001	0.605	1.000
Ge × Gr	0.851	1.399	5	40	0.246	0.149	0.441
T × Ge	0.978	0.183	5	40	0.968	0.022	0.088
T × Gr	0.271	21.538	5	40	<0.001	0.729	1.000
T × Ge × Gr	0.945	0.469	5	40	0.797	0.055	0.160

TABLE 3. Univariate analysis of variance (ANOVA) statistics for different dependent measures (between subjects).

Measure	Source	Sum of Square	df	Mean Square	*F*	*p*	η_p^2	Observed Power
10-yard time	Gender (Ge)	2.902	1	2.902	76.537	<0.001	0.635	1.000
	Group (Gr)	0.076	1	0.076	1.999	0.164	0.043	0.282
	Ge × Gr	0.0289	1	0.0289	0.762	0.388	0.017	0.137
	Error	1.668	44	0.0379				
40-yard time	Ge	32.957	1	32.957	73.504	<0.001	0.626	1.000
	Gr	1.887	1	1.887	4.209	0.046	0.087	0.519
	Ge × Gr	0.224	1	0.224	0.500	0.483	0.011	0.106
	Error	19.728	44	0.448				
Shuttle run time	Ge	32.869	1	32.869	78.872	<0.001	0.642	1.000
	Gr	2.445	1	2.445	5.866	0.020	0.118	0.659
	Ge × Gr	0.204	1	0.204	0.489	0.488	0.011	0.105
	Error	18.336	44	0.417				
Hip flexion strength	Ge	110,248	1	110,248	67.905	<0.001	0.607	1.000
	Gr	2,775.06	1	2,775.06	1.709	0.198	0.037	0.249
	Ge × Gr	2,584.4	1	2,584.4	1.592	0.214	0.035	0.235
	Error	71,437.3	44	1,623.6				
Vertical jump height	Ge	0.318	1	0.318	46.887	<0.001	0.516	1.000
	Gr	0.017	1	0.017	2.492	0.122	0.054	0.339
	Ge × Gr	0.0007	1	0.0007	0.100	0.754	0.002	0.061
	Error	0.299	44	0.00679				

cantly faster (10-yd and 40-yd dash), more agile (shuttle run), stronger (hip flexor strength), and more powerful (vertical leap). When comparing the average performance scores exhibited by the 2 groups in the pretests, the training group performed better in all but the 10-yd time (Table 1). The training group had better scores than the control group in all dependent measures in the posttests. The MANOVA revealed a significant difference between genders and the pre- and posttests and a significant interaction between the 2 groups and 2 tests (Table 2). Follow-up univariate tests revealed significant main effects for Gender in all 5 dependent measures (Table 3). In addition, main effects for Group were detected for the 40-yd dash and shuttle run times (Table 3), and main effects for Test were found relative to the 10-yd, 40-yd, and shuttle run times (Table 4). The univariate tests also revealed significant Test × Group interactions in all measures except the vertical jump height (Table 4). The interactions indicate apparent improvements in 10-yd, 40-yd, and shuttle run times and in hip flexion strength from pretest to posttest for the training group (Figure 3). However, such improvements were not observed in the control group.

DISCUSSION

As expected, the men in this study outperformed their women counterparts in all measures investigated. The differences are likely the result of differences in muscular strength in general. According to pretest hip flexion torques, the women in our study were 48% as strong as the men. This value is lower than the 66% reported by Miller et al. (33) for knee extension strength. Interestingly, those investigators did not find any gender differences when the strength data were normalized to muscle cross-sectional area. In other words, their data suggested that there is no significant difference in muscle quality between men and women.

In general, the isometric hip flexion torques exhibited by the subjects of this study are comparable to those reported in the literature (27). An average increase of 12.2% in hip flexion strength due to resistance training is comparable to the strength gain from a training period of 8–10 weeks reported in the literature (12, 21, 22).

All subjects in the training group increased their training loads 3–4 times in the first 4–5 weeks, which was followed by a leveling off in the last few weeks of the training period. This suggests that most of the hip flexor strength gained by subjects in the training group occurred in the first 4–5 weeks of the training period. Because subjects in this study are considered nontrained individuals, the strength gained in the first few weeks of training is probably the result of neural adaptation (or learning effect), a modification of neural input to muscles that results in an enhanced muscular contraction (37).

TABLE 4. Univariate analysis of variance (ANOVA) statistics for different dependent measures (within subjects).

Measure	Source	Sum of Square	df	Mean Square	F	p	η_p^2	Observed Power
10-yard time	Test Condition (T)	0.203	1	0.203	23.683	<0.001	0.350	0.991
	T × Gender (Ge)	0.0071	1	0.0071	0.831	0.367	0.019	0.145
	T × Gr (Group)	0.530	1	0.530	61.837	<0.001	0.584	1.000
	T × Ge × Gr	0.00473	1	0.00473	0.552	0.462	0.012	0.112
	Error	0.377	44	0.00857				
40-yard time	T	0.320	1	0.320	11.806	0.001	0.212	0.919
	T × Ge	0.0006	1	0.0006	0.024	0.878	0.001	0.053
	T × Gr	0.314	1	0.314	11.579	0.001	0.208	0.914
	T × Ge × Gr	0.0109	1	0.0109	0.402	0.530	0.009	0.095
	Error	1.1194	44	0.02713				
Shuttle run time	T	1.938	1	1.938	41.624	<0.001	0.486	1.000
	T × Ge	0.0058	1	0.0058	0.125	0.725	0.003	0.064
	T × Gr	3.093	1	3.093	66.421	<0.001	0.602	1.000
	T × Ge × Gr	0.00972	1	0.00972	0.209	0.650	0.005	0.073
	Error	2.049	44	0.04657				
Hip flexion strength	T	224.821	1	224.821	1.247	0.270	0.028	0.194
	T × Ge	4.037	1	4.037	0.022	0.882	0.001	0.052
	T × Gr	1,914.035	1	1,914.035	10.619	0.002	0.194	0.890
	T × Ge × Gr	213.651	1	213.651	1.185	0.282	0.026	0.187
	Error	7,931.202	44	180.255				
Vertical jump height	T	0.00124	1	0.00124	1.125	0.295	0.025	0.180
	T × Ge	0.000004	1	0.000004	0.004	0.953	<0.001	0.050
	T × Gr	0.000563	1	0.000563	0.509	0.479	0.011	0.107
	T × Ge × Gr	0.001153	1	0.001153	1.043	0.313	0.023	0.170
	Error	0.04867	44	0.001106				

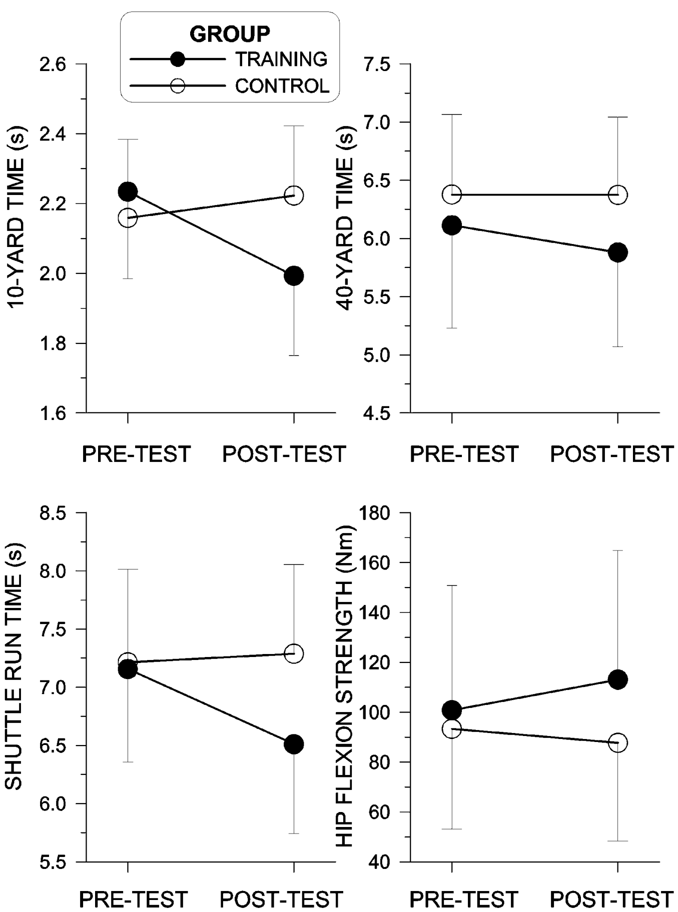

FIGURE 3. Significant interactions between Groups and Tests were found in the 10-yd, 40-yd, and shuttle run times and in hip flexion strength.

Increases in strength after the first few weeks of strength training are primarily the result of structural changes such as increases in the cross-sectional area of the muscle (hypertrophy). It has been demonstrated previously in untrained women that an increase in muscular performance occurred during the first 12 weeks of training when using a low-volume, single-set program (30). However, muscular performance only continued to improve after the first 12 weeks when a periodized, high-volume, multiple-set training program was used.

According to reports describing speed changes during a 100-m race, it takes 25–35 m to reach the maximum speed from a stationary start (9, 40). Therefore, the 40-yd time is a measure of one's ability to accelerate. The first 10 m from the start is often referred to as the initial acceleration phase (15). The results of this study clearly demonstrate the positive effect of hip flexor strength on the acceleration phase of a sprint and support the work of Mann and colleagues (29), who postulated that the majority of forward motion during jogging, running, and sprinting results from rapid hip flexion. Subjects in the training group experienced a significant reduction in times for the initial 10 and the total 40 yd. A closer examination of the data revealed that the decrease in the total 40-yd times was mainly the result of the decreases in the 10-yd times. These results are different from the effects of sprint, endurance, and combination training on sprint performance reported by Callister et al. (8). Regardless of the mode of training, Callister et al. found a significant decrease in 50-m dash time after 8 weeks of training. However, the decrease in the 0–20-m split time was not significant statistically.

On average, subjects in the training group decreased their 40-yd time by 0.233 seconds, whereas they also reduced their 10-yd times by 0.241 s. Because running speed is the product of stride length and stride frequency, the increase in running speed during the initial acceleration phase measured in the current study can be a result of a longer stride length, a greater stride frequency, or a combination of both. Future studies should investigate the changes in stride characteristics due to hip flexor training.

The average 40-yd dash time for the men entering the study was 5.6 seconds, and they were slower than the subjects in several other studies in which 40-yd performance was reported. The range of average 40-yd times for different subject groups of college men in the Porcari et al. study (36) was 5.00–5.04 seconds. The corresponding ranges for the Division 1-A football players studied by Black and Roundy (6) and Division 1-AA football players examined by Hoffman et al. (25) were 4.46–5.23 seconds and 4.83–5.23 seconds, respectively. The difference in sprint performance between our subjects and subjects reported in previous studies becomes smaller when considering the differences between hand times (manually recorded using stopwatches) used in previous studies and automatic times recorded in the present study. In track competition, an adjustment of up to 0.24 seconds is employed when converting a hand time to an automatic time (34).

The subjects in our study, although physically active, are considered untrained individuals. It is not certain whether the training protocol used in this study would cause similar improvement in sprint performance in highly trained, elite athletes. Furthermore, it should be noted that hip flexor training is not the only factor potentially related to sprint performance. Our subjects were previously untrained and improved after only 8 weeks of hip flexor training. Continued sprint enhancement may require additional sprint-specific training (e.g., start mechanics, running form, etc.).

The hypothesis that the shuttle run time decreases with hip flexor training was supported. On average, a 0.646-second (or 9%) decrease in shuttle run time was observed in subjects in the training group. If a shuttle run can be considered an agility task involving several acceleration phases, and hip flexor training can improve the acceleration phase of sprinting, improvements in shuttle run times appear to be logical. Again, a study examining the changes in stride characteristics during a shuttle run as a result of hip flexor training is recommended.

The hypothesis that hip flexor resistance training would significantly improve countermovement jump performance was not supported. Because jumping movement was not captured for analysis, it is unclear if hip flexor training had any effect on the duration of the unloading phase of the jump. According to McBride et al. (31), training with light-load (30% 1RM) squat jumps resulted in improved movement velocity during a jump squat and increased jump height. However, training with heavy-load (80% 1RM) squat jumps did not. In the present study, the training load is estimated to be 65–75% 1RM (3). If the improvement in vertical jump performance is influenced by the speed of movement during training, a lighter load should be used in the hip flexor training.

In conclusion, the present study represents an initial attempt to explore the roles of hip flexor strength in the performance of selected movement tasks commonly required in many sports and recreational activities. The 8-week hip flexor training protocol used in this study was effective in improving the acceleration time of a sprint and shuttle run time, but not the vertical jump performance, in young recreational athletes (relatively untrained individuals). Future studies should determine whether such a training protocol would cause similar improvement in highly trained, elite athletes. Because the decrease in 10-yd time accounts for the decrease in 40-yd time as a result of training, future studies comparing the stride characteristics in the first 10 yd before and after the hip flexor strength training are recommended.

PRACTICAL APPLICATIONS

Our data indicate that young recreational athletes can achieve performance improvements as a result of hip flexor strength training. Thus, hip flexor strength training is recommended for relatively untrained individuals who participate in sports, recreational activities, or under physically demanding circumstances. Whether the training protocol used in this study would cause similar performance improvement in highly trained, elite athletes remains unclear.

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