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Abstract

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Keywords: Body Composition, Female Sprinters, Strength Training, Plyometric Training, Physical Fitness

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Title

Influence of Six-Week Plyometric and Strength Training on the Performance of Female Sprinters of the Islamia University of Bahawalpur

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Contents

Abstract

This is a comparative analysis of the female sprinter of the plyometric and strength training groups. Thirty participants (21.17±1.94 years) were selected from the Islamia University of Bahawalpur and divided into two groups. The selected variables were height and weight, skinfolds, girths, lengths, breadths, 30-meter dash, flexibility, agility, 600-meter running, sit-ups, standing long jump, push-ups, and 100-meter sprinter races. Two video cameras for videography with Kinovea software for kinematic analysis. Repeated measures ANOVA revealed that six-week strength and plyometric training significantly affected calf skinfold, Ilic-crest skinfold, arm relax and flex girth, hand grip strength, flexibility, left ankle angle at starting position, knee angle at starting position, 30-meter dash, and agility, and 100-meter performance. It was concluded that strength and plyometric training significantly reduces body fat, improving physical fitness. On the other hand, six weeks of plyometric training more significantly improves sprinting performance than strength training.

Keywords: Body Composition, Female Sprinters, Strength Training, Plyometric Training, Physical Fitness

Introduction

Sprinting is a comprehensive technique that requires various training methods to enhance performance (Rimmer & Sleivert, 2000). Sprinters need an optimal body with strong muscles powerful legs to run fast, and good neuro-muscular coordination (Ronnestad et al., 2008; Young, 2013). Female athletes can increase their performance by following appropriate training programs (Chimera et al., 2004). Appropriate training to improve sprinting includes the following pattern sprint drills, overspeed training, resistance sprinting, weight training, and plyometrics. Plyometric

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exercises improve power output through vertical jumping which benefits short-term maximal performance (Aksović et al., 2020). A valuable training method in dynamic sports needs muscle power to enhance the endurance capacity of athletes (Neves et al., 1989). Plyometric exercises, with or without weight boost power, vertical jump, and sprint performance (Ronnestad et al., 2008).

In modern sprint racing, strength training is also essential for peak speed, which is notably proposed for young athletes during their practice sessions (Tomlinson et al., 2020). The main goal of strength training assist athletes in their technical skills to enhance the performance of female athletes in competitions (Whelan et al., 2016). Strength training can enhance the muscle hypertrophy of the lower limb which is associated with sprint performance (Fischetti et al., 2018). Therefore, maximizing sprint performance may improve one's ability to execute repeated muscular movement (Aura et al., 1986), which is necessary to increase sprint performance (Fowles et al., 2000), as in professional football (Baro et al., 2017). The most effective strategy to improve sprinting performance is to follow the training program and repeat continuously with major difficulty (Herbert, & Gabriel 2002).

Nevertheless, there is substantial variation in individuals' reactions to following training programs to enhance sprint performance (Weldon et al., 2003). Numerous athletic practices are required to effectively follow the training program to improve performance (Loturco et al., 2019), and intense training immediately improves an athlete's performance (Delecluse, 1997; Taipale et al., 2010). There are minimal studies of resistance training and plyometric training along with the kinematic parameters such as stride length and stride frequency during the initial and acceleration phase in 100-meter sprinting (Young, 2013). An 8-week plyometric and strength training program is proposed to improve the stride length and frequency of sprinters (Weldon et al., 2003). This study aimed to assess how eight weeks of plyometric and strength training programs effectively enhance the performance of female athletes and kinematic analysis will provide which training program effectively increases the stride length and frequency of athletes.

Research Methodology

The selected participants were (n = 30) female sprinters of (18.23 ± 1.23) years old from the Islamia University of Bahawalpur, Baghdad ul Jadeed campus. The participants were randomly divided into two groups: one for plyometric training and the other for strength training. All participants sign a consent letter to confirm their voluntary involvement in the study. Pre- and post-experimental data were collected at the sports complex of Islamia University in Bahawalpur, Pakistan. The plyometric training group engaged in an eight-week program of various jumps, hops, and bounds of exercises. The strength training group was engaged in an 8-week program featuring multiple exercises.

The Procedure of the Measurement of Anthropometric

After reviewing various research articles on sprint races and other running events, these anthropometric, physical fitness, and kinematic factors were selected. The physical fitness measurements were age, height, weight, 30-meter sprint, agility, flexibility, standing broad jump, vertical jump, sit-ups, and endurance. Skinfold measurements, limb girths, lengths, breadths, body mass index, and strength. Before beginning anthropometric measurements, each participant marked their bodies according to the parameters established (Slimani & Nikolaidis, 2018). The dynamometer was calibrated and adjusted to match the hand range, with a one-minute interval between the first and second attempts. Each participant was given three trials, and the maximum score was deemed the final. The person was standing comfortably without any physical support. The biceps skinfold is performed on the front of the upper arm, elbow extended with the palm facing up (Styles et al., 2016). The measuring point is located on the front of the arm, almost midway between the shoulder and the elbow. Using a skinfold caliper, the skin was griped with the thumb and index finger approximately 1 centimeter above the specified location (Tenan et al., 2021). The subscapular skinfold is taken directly below the bottom point of the scapula, at a downward angle of around 45 degrees. The person conducting the investigation gently held the iliac crest skinfold above the right hip bone with his thumb and index finger (Tomlinson et al., 2020). A caliper was then used to take measurements. The caliper for the abdomen was set five centimeters to the right of the navel (Song et al., 2023). The caliper was held 45 degrees above the vertical axis of the ilium during supraspinal measurement. The frontal thigh skinfold was measured with the participant seated on a 46-centimeter box, their leg bent at a 90-degree angle (Schot and Knutzen,1992). An assistant used their index finger to grasp the upper central marked point of the mid-thigh. The calf skinfold measurement was taken while the subject remained seated, targeting the inside of the calf muscles (Rathi et al.,2023).

A non-elastic metal measuring tape was used to measure the circumferences of various body parts. As a basic interpretation model, the 0.1cm. The full circumference was measured by using the pass-hand method, shown when the left hand wrenched the edge of the tape, and the edges of the body parts while the right hand clutched the tape case. The tape measurement in centimeters was used to measure Arm girth relaxed, arm girth flexed, waist girth, hip girth, thigh girth, and calf girth. The leg length was established by using a measuring tape from the upper end of the thigh joint down to the floor. The measured features were computed in the following indices transverse breadth, hip breadth, humerus breadth, femur breadth, and shoulder breadth.

The Measurements of Physical Fitness

The subject stands behind the starting line, with two parallel lines 10 yards apart. At "go," they run to the opposite line, touch it, and return, this is repeated for 5 x 10 rounds, and time is recorded to the nearest tenth of a second (Loturco et al., 2019). The flexibility was measured by using sit-and - reach test by using the wooding box as feet flat placed at the box with legs extended, bent forward the upper body, held their fingers along the scale for three seconds, and extended their legs. After warming up, three trials were conducted (Singh, 2018). Speed was measured using a 30-meter sprint test with a stationary start. Participants were timed from start to finish using an audio signal, with measurement precision set at 0.01 seconds (Myer et al., 2005). The standing and broad jump test stood behind a marked line with feet slightly apart. They used a technique involving a two-foot take-off and landing, coordinating arm swings, and knee bending to propel forward. The goal was to achieve the highest jump and execute a two-footed landing without any backward rolling (Loturco et al., 2019).

Muscular endurance was measured as an individual lying on their back with knees bent, feet flat within a foot's distance from the buttocks. Elbows touched the floor, fingers interlocked behind the neck, with feet supported by a partner. From there, they transitioned to a seated position, aiming to touch their knees with their elbows (Prvulović et al., 2022). The ruler drops test was used for estimating reaction time while seated at a table, your forearm rested on it, hand hanging over the edge, palm down. Upon their release of the ruler, your task was to catch it swiftly, measuring your reaction time (Cheema et al., 2023). The one-leg stand was used to evaluate the balance, prolonged standing on one leg increased muscle fatigue, potentially enhancing muscular endurance (Peter et al., 2006).

The Measurements of Sprint Performance

In a 100-meter sprint race, the runner's speed varies throughout the roughly 10-second duration of the all-out run. Therefore, the changes in velocity during a 100-meter sprint can be categorized into three phases: the acceleration phase, the maximum speed (constant speed) phase, and the deceleration (speed maintenance) phase. The acceleration phase lasts approximately 30 to 50 meters from the start of the 100-meter sprint. Previous studies that focused on sprinting up to 40 meters may have used a short distance for athletes to reach their maximum velocity. An athlete's starting position and technique can greatly impact the outcome of a sprint. Sprinting is more intense than running and involves more muscle groups. It requires a correct method for sprinters to effectively utilize their energy and propel themselves forward on the track. At the beginning of the 100m sprint, the sprinter's back leg, which starts extended, makes the first rapid step forward. The front leg quickly follows, propelling the sprinter forward. The hips extend, lifting and pushing the sprinter ahead.

Table 1

Plyometric and Strength Training program

Week	Set	Exercise
	Warm up, and cool down for 15 minuts every day	
1 to 2	7x3 sets	Squats
	1x3 sets	Sprint 10 m two-legged jumps 10 m
	1x3 sets	Sprint 10 m with one-leg jumps

Week	Set	Exercise
	1x3 sets	Progressive sprint 30 m
	1x3 sets	Deep jumps with two feet
	1x3 sets	Jumps with one and another zig-zag
	3x3 sets	Two-legged plyometric box jumps
	1x8 sets	Jumps with both feet
	5x3 sets	30 m dash
3 to 4	3x4 sets	Deep jumps on the Swedish box
	1x3 sets	Progressive sprint 30 m
5 to 6	5x10 sets	0.4 m hurdle jumps
	4x10 sets	0.4 m drop jumps
	1x3 sets	Progressive sprint 40 m
	4x2 sets	Deep jump on the Swedish box 40 m
	3x8 sets	Depth jumps

(Delecluse, 1997)

The Data Collection and Descriptions of the Kinematics Variables

The 100m dash was filmed at the grounds of Islamia University in Bahawalpur. In this research, two high-speed cameras were employed for fixed-focus filming of 10 meters in the acceleration phase, with a camera elevation of 1.25 meters, covering a total field of view of 15 meters. The primary optical axis was aligned with the center of the field and perpendicular to the sprinters' movement plane, and the filming distance was set at 15 meters, with a recording frequency of 30 Hz. The initial four stages focused on investigating a specific kinematic parameter. The first part of stance position, mid-stance position, and running phase. The duration of acceleration was established by examining the initial position of the knee and its extension almost to full length. To achieve optimal acceleration, sprinters adopt the appropriate angle of knee bend in the set position at the start of the sprint. The standard for calculating stride length involved measuring the horizontal distance from the toe to the heel along the X-axis (Liu et al., 2016). Ankle angles on both the left and right sides of the body were determined by intersecting vectors from the toe and ankle at the knee joint. Knee angles were assessed at the junction where the vector extending from the ankle joints to the knees intersected with the vector from the knees to the hips. The angle between the forearm and the upper arm is determined by measuring from the elbow to the wrist. Furthermore, full extension of the joint was designated as 180 degrees, whereas complete flexion of the joint was designated as 0 degrees. The joint angle was determined by computing the angular disparity between adjacent body segments situated internally (Kumar et al., 2019). The subject was recorded from two angles: a side view at 30 frames per second (Nagahara et al., 2020). A video camera was additionally utilized to capture the participant's movement sequence. Three out of the six trials of each participant were selected for kinematic analysis. The side perspective track was digitized manually. The pre-contact phase was noted to initiate 15 frames before contact. The contact phase included absorption, while the follow-through extended for seven frames after release. Linear displacements and average velocities were assessed for each phase. Contact time was calculated based on the rear perspective footage. Experiment logs were created from the films and analyzed. Significance at the 0.05 level was determined through analysis of variance to identify differences.

Reliability of the Anthropometric Variable

The intra-rater test was selected due to its strong validity and reliability coefficients (Murphy et al., 2021). Through an intra-investigator approach, we ensured the precision of both instruments and the subject's anthropometric measurements. These identical measuring tools were previously utilized in a separate study. Following our plan, we utilized an intra-examiner approach to assess the examiner's skill. To accomplish this, thirty-five to forty individuals were surveyed and measured twice, with a one-day interval between sessions.

Statistical Analysis

Various statistical methods were employed to analyze anthropometric data and physical fitness. The data was entered into an SPSS spreadsheet and analyzed using the software's built-in features. Consequently, we utilized various statistical methods to analyze the data. Demographic information, including body mass index, height-to-weight ratio, and other anthropometric metrics, along with fitness and health metrics, were assessed using basic statistical measures such as mean and standard deviation. To compare the pre- and post-intervention data on anthropometric characteristics and physical fitness repeated measures analysis of variance (ANOVA) was applied. The effects of plyometric and strength training on the performance of female sprint races were evaluated using multiple regression analysis on data from both experimental and control groups. All factors were found to be statistically significant at the $P < 0.05$ level.

Table 1

Skinfold measurement of the strength and plyometric training groups of female sprinters of the IUB

Variable	pre data				post data				F	Sig.
	Strength training group		Plyometric training group		Strength training group		Plyometric training group			
	mean	*STD*	*mean*	*STD*	*mean*	*STD*	*mean*	*STD*		
Triceps skinfold (mm)	5.07	0.94	4.59	0.38	4.83	0.68	4.62	0.39	0.63	0.43
subscapular skinfold(mm)	4.97	0.97	4.37	0.57	4.77	0.68	4.61	0.52	3.98	0.06
Biceps Skinfold(mm)	4.94	0.98	4.67	0.55	4.71	1.04	4.36	0.66	1.66	0.21
Iliccrest skinfold (mm)	5.79	1.56	4.61	0.58	4.83	0.82	4.65	0.52	5.28	0.03
Supraspinal Skinfold(mm)	5.34	2.00	4.51	0.64	4.82	0.98	4.40	0.62	3.77	0.06
Abdominal Skinfold(mm)	5.22	1.63	4.27	0.39	4.44	0.95	4.51	0.61	3.30	0.08
frontal thigh Skinfold(mm)	5.19	2.20	4.40	0.63	4.60	0.72	4.31	0.52	2.40	0.13
Medial calf Skinfold (mm)	4.39	0.94	3.67	0.43	4.03	0.55	3.81	0.32	7.96	0.01

Significant difference at p<0.05   skinfold measurement mm (millimeter)*

Table 2 revealed a significant difference between the experimental and control groups in Comparing pre-and post-data measurements. Specifically, this difference was observed in the iliac crest skinfold ($P < 0.03$) and medial calf skinfold ($P < 0.01$).

Table 2

Girth measurements of strength and plyometric training groups of IUB female sprinter

Variable	pre-data				post data				F	Sig.
	Strength training group		Plyometric training group		Strength training group		Plyometric training group			
	mean	*STD*	*mean*	*STD*	*mean*	*STD*	*mean*	*STD*		
Arm girth relaxed (cm)	18.21	1.58	19.25	1.04	19.63	1.36	18.82	1.25	4.97	0.03
Arm girth flexed (cm)	19.42	1.45	20.46	0.92	20.55	1.29	19.59	1.07	9.15	0.01

waist girth(cm)	68.08	7.20	67.76	4.03	68.08	7.20	67.76	4.03	0.02	0.88
hip girth(cm)	73.57	6.53	76.06	4.12	72.93	7.74	76.14	3.43	2.97	0.10
thigh girth(cm)	38.95	4.80	39.99	4.95	40.43	4.98	40.91	4.68	0.27	0.61
calf girth(cm)	27.75	3.83	28.66	1.38	28.47	3.09	27.52	2.86	0.00	0.98
total arm length (cm)	44.75	3.84	43.82	8.09	44.54	7.52	44.49	3.12	0.10	0.75
Total leg length(cm)	77.57	4.94	71.37	17.70	74.59	3.51	76.37	3.98	0.83	0.37

Significant different level at p<0.05   girth measurement cm (centimeter)*

Table 3 revealed a significant difference between the experimental and control groups in
Comparing pre-and post-data measurements. Specifically, this difference was observed in

Arm girth relaxed ($P < 0.03$), arm girth flexed ($P < 0.01$).

Table 3

Breadth measurements strength and plyometric training groups of IUB female sprinter

Variable	pre-data				post data				F	Sig.
	Strength training group		Plyometric training group		Strength training group		Plyometric training group			
	mean	STD	mean	STD	mean	STD	mean	STD		
chest breadth(cm)	32.08	1.24	32.14	1.02	32.54	1.13	32.17	1.09	0.23	0.63
hip breadth(cm)	33.89	2.07	33.25	1.84	34.11	2.30	32.97	2.19	2.29	0.14
Elbow breadth(cm)	3.70	3.80	3.77	0.31	3.40	3.00	3.84	0.42	0.62	0.44
knee breath(cm)	5.10	081	5.17	0.77	4.90	4.20	5.27	0.83	0.09	0.77
shoulder breadth(cm)	32.12	1.93	31.81	1.83	32.81	2.45	31.52	2.43	1.21	0.28

Significant different p<0.05   Breadth measurement cm (centimeter)*

Table 4

physical fitness measurements strength and plyometric training groups of IUB female sprinter

Variable	pre data				post data				F	Sig.
	Strength training group		Plyometric training group		Strength training group		Plyometric training group			
	mean	STD	mean	STD	mean	STD	mean	STD		
Flexibility cm	21.93	3.92	18.67	2.38	24.73	4.51	20.20	2.46	10.52	0.00
Speed sec	24.60	8.48	24.80	5.51	22.53	8.19	23.47	5.42	6.94	0.01
Agility sec	14.98	3.68	17.16	2.60	13.50	2.91	16.34	2.45	4.10	0.05
Leg explosive strength cm	156.07	7.64	154.47	6.73	159.40	8.27	158.53	6.46	1.34	0.26
Muscular endurance counts	17.67	5.09	20.13	3.64	19.00	4.52	21.80	3.76	0.95	0.34
Reaction time cm	18.53	5.04	16.93	4.76	15.53	4.53	14.53	4.42	1.19	0.28
Balance min	1.71	0.54	1.64	0.50	2.00	0.50	1.90	0.56	0.04	0.84

*Significant different p<0.05**

Table 5 revealed a significant difference between the experimental and control groups in Comparing pre-and post-data measurements. Specifically, this difference was observed in

Flexibility ($P < 0.00$), speed ($P < 0.01$), and agility ($P<0.0$).

Table 5

Kinematic analysis of the 100-meter start of strength and plyometric training groups of female sprinter

Variable	pre-data				post data				*F*	*Sig.*
	Strength training group		Plyometric training group		Strength training group		Plyometric training group			
	mean	*STD*	*mean*	*STD*	*mean*	*STD*	*mean*	*STD*		
Elbow joint stance position	174.27	7.72	173.58	7.54	173.82	7.10	176.00	8.55	2.42	0.13
Right ankle joint stance position	114.54	2.94	116.86	3.74	114.50	2.82	183.17	2.62	0.99	0.33
left ankle joint stance position	123.62	3.34	126.49	3.53	124.33	2.79	125.15	3.61	9.01	0.01
Hip joint stance position	36.79	3.87	40.61	3.91	36.74	3.73	39.05	4.35	2.19	0.15
Trunk angle stance position	34.00	3.59	36.33	5.16	33.53	2.53	36.60	4.63	0.80	0.38
Elbow joint mid-stance position	168.25	9.91	165.13	4.21	169.33	9.13	164.07	4.62	3.57	0.07
leg joint mid-stance position	120.85	7.32	125.73	9.30	123.01	7.03	122.43	9.01	14.52	0.00
Hip angle mid-stance	39.67	5.73	38.33	6.11	38.33	5.22	35.67	4.22	2.41	0.13
Elbow angle joint running phase	168.33	9.02	162.74	8.14	165.91	9.19	160.85	8.42	0.74	0.40
knee angle running phase	127.27	5.69	130.00	4.81	125.81	5.00	128.85	4.96	0.19	0.67
Trunk angle running phase	36.33	5.38	39.93	5.84	35.60	4.61	37.80	5.06	2.47	0.13

Significant difference at level p>0.05

Table 6 revealed a significant difference between the experimental and control groups in Comparing pre-and post-data measurements. Specifically, this difference was observed in the Left ankle joint stance position (P < 0.01), and leg joint mid-stance position (P < 0.00).

Table 7

100-meter speed among the strength and plyometric training groups after eight weeks of training groups

Variable	pre data				post data				*F*	*Sig*
	Strength training group		Plyometric training group		Strength training group		Plyometric training group			
	Mean	STD	Mean	STD	mean	STD	mean	STD		
Time (sec)	13.31	1.18	14.48	1.50	11.74	1.03	12.41	1.08	5.16	0.03

Significant difference at level p>0.05 Time (sec)*

Table 7 revealed a significant difference between the experimental and control groups in Comparing pre-and post-data measurements. Specifically, this difference was observed in the time of ball speed (P<0.03).

Discussion

The primary goal of this study was to evaluate the physical characteristics of female athletes.

Coaches and scouts could evaluate the potential of female sprinters by comparing their body measurements to those of individuals in the control group. This study utilized a variety of skinfold measurements, such as triceps, subscapular, biceps, iliac crest, supraspinal, abdominal, front thigh, and medial calf, along with various anthropometric measurements, physical fitness tests, and resistance training factors to evaluate volleyball performance. The test subjects were assessed on multiple physical attributes, including their proficiency in various breathing exercises (chest, hip, elbow, and knee), arm span, seated height, right-hand grip strength, left arm girth, as well as their speed, agility, flexibility, vertical jump, and other factors (Klupfel et al., 2014).

In a 100m sprint race, female athletes generally start in a starting stance, move into a mid-stance position, and then commence running. A key finding in the study is the statistically significant variation in the average distance covered by each athlete. The study suggests that experienced sprinters use larger hip joint angles compared to the control group, potentially enhancing their performance (Peter et al., 2006). Trained sprinters seem adept at utilizing these angles effectively. Coaching plays a role in determining front ankle joint angles, showing differences in sprinting techniques among athletes. Notably, well-trained athletes exhibit lower front ankle angles compared to plyometric-trained ones (Murphy et al., 2003). Coaching advice emphasizes maintaining bent legs during positioning. Training significantly impacts individual performance, but no substantial differences were found in elbow-angle postures. Forearm motion occurs around each joint's midpoint, supporting the recommendation for flexed elbows in sprinting.

In the control group, variations in knee angles during mid-stance are natural due to individual biomechanics and technique, resulting in a wide range of angles among sprinters. When comparing. joint angles across different skill levels, distinct positions have been observed within subgroups of faster sprinters. These positions include sprinters with more flexed hips in the front and back legs, respectively, between the strength and plyometric training groups (Ramirez-Campillo et al., 2020), those with more extended back knees, and those with more flexed front knees (Schot et al., 1992). In this study, the strength training group showed an increase in the right knee joint angle compared to the plyometric training group. Additionally, athletes in the strength training group exhibited reduced ankle joint angles and extended trunk angles compared to those in the plyometric training group during mid-stance. During the running phase, the leg's hip, knee, ankle joints, and trunk angles are subject to various angular velocities. limiting ankle dorsiflexion range in the early stance has been shown to enhance power generation during the first stance, requiring increased strength in the plantar flexor muscles, and resulting in a firmer ankle (Bograd et al., 2019). Knee extension of the leg, during the running phase, begins shortly after reaching a midpoint between exiting the rear block and making initial contact. Concurrently, the hip of the stance leg starts extending slightly before ground contact, continuing this extension throughout the stance phase. Higher extension of the torso was observed during the increase in speed (Schot et al., 1992; Marques et al., 2015). Both plyometric training and strength increase consistency rhythm, and running speed (Widodo et al., 2023). Both training programs assist female athletes in increasing stride length and frequency further increasing speed. This study supports the findings of previous studies (Weldon et al., 2003; Bograd et al., 2019), that the skinfold of the abdomen and frontal thigh is higher which may reduce speed.

Conclusion

This study assesses the influence of plyometric training on the body composition, physical fitness, performance, and angular kinematics of female sprinters. The participants were university athletes who participated in college, school, and intervarsity-level competitions. Finally, it was concluded that both plyometric and strength training reduces body fats in the trunk and thighs which are associated with increasing the speed of athletes, especially female athletes. In comparison, plyometric training more effectively assists female athletes in increasing knee height during running which increases speed in competitions (Jaksic et al.,2023). On the other hand, strength training increases muscle mass which is associated with increasing the support for getting ground reaction force to increase sprinter speed. Finally, both training programs may be useful for a female young sprinter in increasing speed during competition.

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