THE EFFECT OF ASSISTED AND RESISTED SPRINT TRAINING ON ACCELERATION AND VELOCITY IN DIVISION IA FEMALE SOCCER ATHLETES

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ABSTRACT

Upton, DE. The effect of assisted and resisted sprint training on acceleration and velocity in Division IA female soccer athletes. *J Strength Cond Res* 25(10): 2645–2652, 2011—This investigation evaluated the effects of a 4-week, 12-session training program using resisted sprint training (RST), assisted sprint training (AST), and traditional sprint training (TST) on maximal velocity and acceleration in National Collegiate Athletic Association (NCAA) Division IA female soccer athletes ($n = 27$). The subjects, using their respective training modality, completed 10 maximal effort sprints of 20 yd (18.3 m) followed by a 20-yd (18.3 m) deceleration to jog. Repeated measures multivariate analyses of variance and analyses of variance demonstrated significant ($p < 0.001$) 3-way interactions (time × distance × group) and 2-way interactions (time × group), respectively, for both velocity and acceleration. Paired *t*-tests demonstrated that maximum 40-yd (36.6-m) velocity increased significantly in both the AST ($p < 0.001$) and RST ($p < 0.05$) groups, with no change in the TST group. Five-yard (4.6-m), 15-yd (13.7 m), 5- to 15-yd (4.6- to 13.7-m) acceleration increased significantly ($p < 0.01$) in the AST group and did not change in the RST and TST groups. Fifteen- to 25-yd (13.7- to 22.9-m) acceleration increased significantly ($p < 0.01$) in the RST group, decreased significantly ($p < 0.01$) in the AST group, and was unchanged in the TST group. Twenty-five to 40-yd (22.9- to 36.6-m) acceleration increased significantly ($p < 0.05$) in the RST group and remained unchanged in the AST and TST groups. It is purposed that the increased 5-yd (4.6-m) and 15-yd (13.7-m) accelerations were the result of enhanced neuromuscular facilitation in response to the 12-session supramaximal training protocol. Accordingly, it is suggested that athletes participating in short distance acceleration events (i.e., ≤15 yd; ≤13.7 m) use AST protocols, whereas athletes participating in events that require greater maximum velocity (i.e., >15 yd; > 13.7 m) should use resisted sprint training protocols.

KEY WORDS supramaximal sprint training, overloaded sprint training, speed, speed training

INTRODUCTION

Soccer is a sport wherein athletes spend approximately 80–90% of their performance time at a low to moderate intensity and the remaining 10–20% in intermittent bouts of high-intensity running and very high-intensity running (2,3,17). The bouts of high-intensity and very high-intensity running occur about every 90 seconds, last approximately 2–4 seconds, and are most often associated with critical match-related skills such as separating from or closing on an opponent (21). Therefore, to be successful in soccer, the athlete must possess the ability to cover short distances quickly. Maximum velocity is frequently associated with successful performance in field sports; however, during competition, the athlete rarely covers the necessary distance to achieve top speed. Accordingly, the ability to accelerate, defined as the rate of change in velocity, is more important to successful performance than maximum velocity (8). Murphy et al. (18) have defined acceleration as the rate of change in velocity as measured by sprint performance over distances of 5 or 15 yd (4.6 or 13.7 m), whereas velocity reflects the speed over a longer distance, typically 40 yd (36.6 m). This “first-step” quickness is a skill that both coaches and athletes desire. The 2 most frequently used field methods of increasing acceleration and velocity are resisted (1,8,11,12,22) and assisted sprint training (AST [4,6,9,19]).

Resisted sprint training (RST) includes gravity-resisted modalities, such as uphill or upstairs sprinting, and modalities designed to create an overload effect such as the parachute, sled, harness, or weighted vest. The objective of the overload is to elicit a greater neural activation and to increase the recruitment of fast-twitch muscle fibers. Prior literature has suggested that RST increases unloaded stride length and thereby sprint speed by increasing the muscular force output of the hip and knee extensors and the gluteus maximus (1,8,22). However, the beneficial carryover effects

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of RST on sports performance are inconclusive. Previous investigators have demonstrated both no improvement (5) and improvement (11) in unresisted sprint performance in response to RST. Thirteen training sessions with either a vest weighted at 18.5% of the athlete's body mass or towing a sled weighted at 10% of body mass failed to produce improvements in 18.3- to 54.9-m sprint time or velocity when compared to unresisted sprint training (5). Conversely, Harrison and Bourke (11) investigated the effect of resisted sled towing on acceleration and maximum speed in male rugby players and found that loads of approximately 13% of body mass resulted in significantly improved static start 5-m sprint times. Neither the control group nor the resisted sled group improved in 10- and 30-m static start sprint times, and there was no significant difference between the groups, suggesting that traditional rugby sprint training is as effective as resisted sled towing in improving sprint speed at these distances. Lockie et al. (13) suggest coaches use loads equal to 12.6–13% of an athlete's body mass for resisted sled towing. These percentages result in the athletes achieving a submaximal velocity equivalent to approximately 90% of their maximum velocity.

Assisted or supramaximal sprint training includes gravity-assisted modalities, such as downhill sprinting, and external tools such as high speed towing using a harness or stretch tubing and a parachute release while at a maximum speed. It has been shown that these overspeed training techniques improve velocity by increasing unassisted stride frequency (19). Six weeks of downhill training at a 3° slope increased both 35-m maximum running speed and stride frequency with no change in stride length (19). Ebben et al. (9) demonstrated that running downhill at a slope of 5.8° produced a 6.4% decrease in 10-yd (9.1-m) split time and a 7.09% decrease in 40-yd (36.6 m) sprint time as compared to flatland running. Assisted towing at approximately 40–50 N produced a significant increase in stride length with no change in stride frequency during towing (6). Investigators have demonstrated significant increases in stride length during assisted towing at 3.8 and 4.8% of body mass with a trend toward increases in stride frequency as towing force magnitude increased (4). However, these studies only examined the acute effects of downhill running or assisted towing, and the question regarding the unassisted performance benefits in response to a longer duration training intervention remains unclear.

Because coaches and athletes may lack access to an optimally sloped hill to provide either uphill or downhill training, manufacturers have developed several training aids to provide resistance or assistance to the athletes' sprint training program. Two such devises that are commercially available are The Trainer® (Perform Better, Cranston, RI, USA) and the Speed Harness™ (Power Systems, Knoxville, TN, USA). These devices provide a steady adjustable resistance (The Trainer®) that the athlete must overcome in the execution of the sprint, or they provide assistance (Speed Harness™) to the athlete's sprint training, thereby allowing the athlete to achieve supramaximal sprints. The theory upon which manufacturers base the efficacy of these products is that sprint speed is the product of stride length and stride frequency, and accordingly increasing one or both of these components without negatively impacting the other will result in an increase in speed. Although the literature associated with the acute effects of these types of training tools is somewhat conflicted as to the possible beneficial or detrimental outcomes on performance, the literature associated with the direct performance enhancement benefits in response to chronic training with these tools is lacking. Accordingly, investigation as to the performance enhancement capabilities of the longer-term use of these training modalities is warranted. Specifically, training programs addressing the chronic application of AST and RST protocols and their effect on the sport specific performance variables of acceleration and velocity.

Therefore, the aim of this investigation was to determine the effects of a 4-week, 12-session training program using RST or AST as compared to traditional sprint training (TST) on 5-yd (4.6-m) and 15-yd (13.7-m) acceleration and 40-yd (36.6-m) maximal velocity in elite collegiate Division IA female soccer athletes. It is hypothesized that both AST and RST, as compared to TST, will produce greater improvements in acceleration and maximal velocity over the 4-week, 12-session sprint training program. Thus, the secondary question addressed in this study was, of the 2 training modalities, assisted vs. resisted, will one prove to be superior in improving acceleration and maximal velocity. This study seeks to provide coaches and athletes with relevant information regarding the availability and efficacy of training tools that can increase acceleration and maximum velocity.

METHODS

Experimental Approach to the Problem

This investigation required subjects to perform 40-yd (36.6-m) speed tests before and after a 4-week, 12-session intervention period. The investigator obtained split times at 5 yd (4.6 m), 15 yd (13.7 m), and 25 yd (22.9 m). Based upon their 5-yd (4.6 m) sprint velocity, subjects were listed in rank order from fastest to slowest and then randomly match divided into 1 of 3 groups: AST, RST, and TST. Accordingly, there was no significant preintervention period difference in sprint velocity between the groups at this or any other distance. The subjects then participated in 12 sprint training sessions specific to their respective group. The training sessions occurred at nonconsecutive practice sessions during the first 30 minutes of the team practice. All subjects participated in the identical technical soccer practice after the sprint training. The technical soccer practice occurred 6 $d \cdot wk^{-1}$ over the 4-week time period and was comprised of approximately 1.5 hours of ball handling skills, defensive drills, offensive drills, and small-sided games.

Subjects

Collegiate Division IA female soccer players ($n = 27$) with a mean age, height, body weight, and percent fat of 19.6 ± 0.9 years, 166.9 ± 5.9 cm, 63.4 ± 6.9 kg, and 20.7 ± 4.0%, respectively, recruited from the Texas Christian University (TCU) Women's Soccer team, served as subjects. All subjects were in excellent cardiorespiratory condition, with a mean $\dot{V}O_2max$ of 46.1 ± 4.6 $ml\cdot kg^{-1}\cdot min^{-1}$, free of injury, capable of completing the rigorous sprint training program, and had completed at least 1 full year of competitive Division IA soccer. The demographic variables, age, height, body weight, percent fat, and $\dot{V}O_2max$, did not change during the intervention period of the study. The TCU Institutional Review Board for the use of Human Subjects approved the details of this study and all related informational and consent documentation before any data collection. In accordance with the Institutional Review Board's policies for use of human subjects in research, the investigator informed all subjects as to the benefits and possible risks associated with the participation in the study and all subjects signed a written informed consent document indicating their voluntary participation. Additionally, as a member of an athletic team, each subject received medical approval before the onset of any testing and training.

Procedures

This investigation was conducted during the summer preseason-training program with all subjects having completed 6 weeks of conditioning before the onset of the experimental period. The 6-week conditioning program comprised resistance training and a running program. The resistance training program consisted of 2 nonconsecutive days per week of total body resistance training. All players completed the same routine, with the resistance adjusted for individual player strength, which progressed from larger muscle groups (i.e., legs) to smaller muscle groups (i.e., biceps) finishing with abdominal exercises. Approximately 3–6 exercises were performed per major body segment (i.e., legs, midupper back, chest, shoulders, arms, lower back, abdominals) and the routine required approximately 50 minutes to complete. The running program was executed 5 $d\cdot wk^{-1}$ with all players running the same distances each day. The required time to complete the assigned distance was adjusted based upon the player's one-mile time such that all players were working at the same relative intensity. The running program consisted of a long interval day (i.e., 200–800 m), a short interval day (i.e., 50–200 m), a fixed distance high-intensity day (i.e., 3 miles), a moderate over distance day (i.e., 4–5 miles), and a long slow over distance day (i.e., 5–8 miles).

To control for wind and ambient temperature, the investigator conducted all testing at an indoor soccer facility with an artificial surface. The training programs were conducted at the TCU outdoor soccer complex. The TCU athletic training staff was present during all training and provided the subjects with consistent access to fluids.

Before testing, all subjects completed, as a group, an identical warm-up routine comprised of jogging, static and dynamic stretching, and sprints of increasing intensity. After the warm-up, which lasted approximately 20 minutes, the subjects completed 2 sprint trials over the 40-yd (36.6-m) distance. The subjects were tested in ascending order, by player number, thereby providing 5 minutes of recovery time between maximal trials. The between-trial intraclass correlation coefficient of 0.98 indicates a high intraindividual consistency from trial to trial. The fastest trial for each subject was used in statistical analysis.

An infrared beam timing system (Brower Timing Systems Speed Trap II, Salt Lake City, UT, USA), accurate to within 0.01 seconds per manufacturer's specifications, was used to determine sprint times. The infrared beam sensors were attached to tripods, raised to a height of 0.9 m above the ground, and placed in pairs 1 m apart. The first pair was placed at the starting line and additional pairs were placed at 5 yd (4.6 m), 15 yd (13.7 m), 25 yd (22.9 m), and 40 yd (36.6 m). All subjects started from a completely motionless, self-selected, 2-point standing position immediately behind the starting line. Subjects began the sprint at their own initiative. The subject initiated timing by interrupting the beam at the starting line. Split times, in seconds, were recorded as the subject crossed the timing gates at 5 yd (4.6 m), 15 yd (13.7 m), 25 yd (22.9 m), and 40 yd (36.6 m). Velocity ($m\cdot s^{-1}$) was calculated with the following equation: Velocity = (Distance/Time). Average acceleration ($m\cdot s^{-2}$) was calculated with the following equation (10): Average Acceleration = $[(\text{Velocity}_2 - \text{Velocity}_1) \div (\text{Time}_2 - \text{Time}_1)]$. The same testing protocol was followed for the postintervention period testing session and both the pre and posttesting sessions were conducted at the same time of the day.

After the completion of the preintervention period testing, the investigator listed the subjects, based on their 5-yd (4.6-m) sprint velocity, in rank order from fastest to slowest and then randomly match divided them into 1 of 3 groups: AST (3.77 ± 0.11 $m\cdot s^{-1}$), RST (3.79 ± 0.16 $m\cdot s^{-1}$), and TST (3.70 ± 0.29 $m\cdot s^{-1}$). There was no significant difference in velocity between the groups at the preintervention period testing at this or any other distance. This procedure insured that the groups were evenly matched at the onset of the intervention period and, in that all subjects had participated in at least 9 years of elite level competitive soccer including at least 1 year of competition at the Division IA level all subjects had a similar potential for gain as the result of the training intervention. The subject numbers for the AST, RST, and TST groups were 8, 9, and 10, respectively.

The intervention period consisted of 12 training sessions conducted over the 4-week period immediately preceding the fall competitive season. This 4-week time period coincided with the preseason-training time frame occurring before the beginning of classes and the start of regular season matches. Previous investigators have implemented training protocols ranging from 12 sessions over 6 weeks (11) to 24 sessions over

8 weeks (22). The present investigation implemented a 12 session over 4 week protocol to coincide with the prematch training time period associated with Division IA soccer, and to insure appropriate recovery intervals between training sessions. To ensure that all subjects were comfortable with the training modalities, 2 days before the beginning of the intervention period the subjects were given 2 orientation sessions with their respective training modality. The training sessions were conducted at 8:00 AM or 6:00 PM and occurred during the first 30 minutes of nonconsecutive practices, thereby providing approximately 48 hours between the training stimuli. After a 20-minute group warm-up routine comprised of jogging, static and dynamic stretching, and sprints of increasing intensity, the subjects, using their respective training modality, completed 10 maximal effort sprints of 20 yd (18.3 m) followed by a 20-yd (18.3-m) deceleration to jog.

Subjects in the AST group were attached, at the level of the xiphoid process, to one end of the Speed Harness™ (Power Systems, Knoxville, TN, USA) by a shoulder harness. The opposite end of the Speed Harness™ was attached to a waist belt on one of the research assistants. The Speed Harness™ at a 100% stretch (10-yd/9.1-m) results in 45 N of assistive force on the subject; at a 300% stretch (20 yd/18.3 m), the assistive force on the subject is equal to 90 N. Before the start of the assisted sprint, the Speed Harness™ was stretched to a distance of 20 yd (18.3 m), thereby creating a mean initial assistive force equal to 14.7 ± 1.6% of body mass. As the subject sprinted the 20 yd (18.3 m), the assistive force provided by the Speed Harness™ was reduced such that the mean assistive force at the completion of the 20-yd (18.3-m) sprint was 7.4 ± 0.8% of body mass. The subjects began the sprint in a self-selected, 2-point upright standing start position. After confirming that the subject was ready, the research assistant initiated the sprint by accelerating over a 10-yd (9.1 m) distance followed by a 10-yd (9.1-m) jog to insure that tension remained on the Speed Harness™ throughout the 20-yd (18.3 m) sprint by the subject. The initial movement by the research assistant initiated the assisted sprint of the subject who then supramaximally sprinted the 20 yd (18.3 m) followed by a 20-yd (18.3 m) deceleration to jog. The subjects completed 10 assisted sprint repetitions with 3 minutes of recovery between each repetition.

The Trainer® (Perform Better) was used to produce the resistance for the RST group. This product provides a resistance scale for calibration, thereby allowing the investigator to select the desired resistance. Resistance for the subjects in the RST group was set at 12.6% of body mass, thereby producing a sprint speed equal to approximately 90% of maximal speed. The Trainer® was attached to a stationary pole, the subjects in the RST group were attached to the "work line" of The Trainer® by a waist belt, and the 40-yd (36.6-m) "control line" of The Trainer® was extended in front of the subject to the right of their running path. On command, the subject began the 20-yd (18.3-m) sprint from a self-selected, 2-point upright stance; after the 20-yd (18.3-m) maximal effort sprint, the subject completed a 20-yd (18.3-m) deceleration to jog. The subjects completed 10 resisted sprint repetitions with 3 minutes of recovery between each repetition.

Subjects in the TST group performed 10 maximal effort 20-yd (18.3-m) sprints followed by a 20-yd (18.3-m) deceleration to jog. On command, the subject began the sprint from a self-selected, 2-point stance. Each subject completed 10 maximal sprint repetitions followed by 3 minutes of recovery between each repetition. The investigator repeatedly encouraged the subjects in all group to execute a maximum effort on every repetition. The training program characteristics are summarized in Table 1.

Statistical Analyses

Demographic information, including age, body weight, and $\dot{V}O_2max$, and standing sprint split information, including velocity ($m \cdot s^{-1}$) and acceleration ($m \cdot s^{-2}$), were recorded for each participant and entered into SPSS (version 17) for analysis. All variables met normality assumptions using

TABLE 1. Training program descriptive characteristics.*

	AST	RST	TST
Product	Speed Harness®	The Trainer®	None
Assistive/resistive force	14.7% of Body mass	12.6% of Body mass	None
Sprint distance (m)	13.7	13.7	13.7
Deceleration jog distance (m)	13.7	13.7	13.7
Repetitions	10	10	10
Rest between reps (min)	3	3	3
Training program duration (wks)	4	4	4
Sessions	12	12	12
Recovery between session (h)	≥48	≥48	≥48

*AST = assisted sprint training; RST = resisted sprint training; TST = traditional sprint training.

a Kolmogorov–Smirnov test ($p < 0.01$). Differences among the 3 groups (AST, RST, and TST) on the demographic variables of age, height, weight, percent fat, and VO_2max were tested using 1-way analysis of variance (ANOVA). No significant difference occurred in the demographic variables during the intervention period of the study ($p > 0.05$).

Changes in velocity and acceleration were analyzed separately. To test for changes from pre to postintervention, repeated measures multivariate analyses of variance (MANOVAs) were conducted with time (2 levels: preintervention, postintervention) and distance (4 levels: 5, 15, 25, and 40 yd; 3 levels: 5–15, 5–15, and 5–40 yd; 3 levels: 15–25, 15–40, and 25–40 yd) as within-subjects factors and group (3 levels: AST, RST, and TST) as the between-subjects factor. Distance was included in the analyses to account for the overlap in variance in split measurements. In each analysis, the investigator followed a significant 3-way interaction (time × distance × group) with a series of repeated measures ANOVAs, with time (2 levels: preintervention, postintervention) as the within-subjects factor and group (3 levels: AST, RST, and TST) as the between-subjects factor for each of the 4 distances. For analyses with significant interactions (time × group), simple effects were tested using paired *t*-tests between the pre and postintervention scores for each of the 3 groups individually. All significant findings are discussed in terms of $p \leq 0.05$. In addition, partial eta (η^2) is reported as an index of effect size.

RESULTS

The purpose of this study was to determine if AST or RST provided a significant advantage, as compared to one another and to TST, in the enhancement of velocity and acceleration in Division IA female soccer athletes. Separate repeated measures MANOVAs were conducted for velocity and acceleration. Additionally, within velocity and acceleration 3 separate repeated measures MANOVAs were conducted: (a) the absolute distances of 5 yd (4.6 m), 15 yd (13.7 m), 25 yd (22.9 m), and 40 yd (36.6 m); (b) the intervening distances of 5–5 yd (4.6–13.7 m), 5–25 yd (4.6–22.9 m), and 5–40 yd (4.6–36.6 m); and (c) the intervening distances of 15–25 yd (13.7–22.9 m), 15–40 yd (13.7–36.6 m), and 25–40 yd (22.9–36.6 m).

Velocity

Repeated-measures MANOVAs, with the use of the Wilks Lambda criterion, demonstrated significant 3-way interactions (time × distance × group) for (a) the absolute distances $F(6,44) = 6.641$, $p < 0.0001$, $\eta^2 = 0.475$; and the intervening distances; (b) $F(4,46) = 3.251$, $p < 0.02$, $\eta^2 = 0.294$; and (c) $F(4,46) = 3.977$, $p < 0.008$, $\eta^2 = 0.362$. Subsequent repeated measures ANOVAs with the Huynh–Feldt epsilon adjustment revealed significant 2-way interactions (time × group) for 5 yd ($p < 0.0001$, $\eta^2 = 0.742$), 15 yd ($p < 0.0001$, $\eta^2 = 0.719$), 25 yd ($p < 0.001$, $\eta^2 = 0.465$), 40 yd ($p < 0.003$, $\eta^2 = 0.376$), 5–15 yd ($p < 0.042$, $\eta^2 = 0.237$), 5–40 yd ($p < 0.007$, $\eta^2 = 0.278$), 15–25 ($p < 0.038$, $\eta^2 = 0.239$), 15–40 yd ($p < 0.01$, $\eta^2 = 0.321$), and 25–40 yd ($p < 0.02$, $\eta^2 = 0.301$). There was no significant interaction at the 5–25 yd (4.6–22.9 m) distance ($p > 0.05$, $\eta^2 = 0.063$). To clarify the nature of the interactions, simple effects were tested using paired *t*-test between pre and postintervention scores for each of the 3 groups individually. Table 2 presents the pre and postintervention group means, *SD*s, and their associated level of significance.

TABLE 2. Mean velocity ($m \cdot s^{-1}$) ± *SD*.*†

	AST		RST		TST	
Distance	PRE	POST	PRE	POST	PRE	POST
5 yd (4.6 m)	3.77 ± 0.11	4.15 ± 0.11‡	3.79 ± 0.16	3.79 ± 0.16	3.70 ± 0.29	3.68 ± 0.30
15 yd (13.7 m)	5.18 ± 0.12	5.39 ± 0.10‡	5.16 ± 0.21	5.13 ± 0.16	5.07 ± 0.30	5.09 ± 0.31
25 yd (22.9 m)	5.78 ± 0.15	5.90 ± 0.13‡	5.74 ± 0.22	5.77 ± 0.18	5.68 ± 0.31	5.70 ± 0.32
40 yd (36.6 m)	6.25 ± 0.17	6.33 ± 0.15‡	6.20 ± 0.23	6.26 ± 0.21‖	6.19 ± 0.33	6.20 ± 0.34
5–15 yd (9.1 m)	6.37 ± 0.19	6.47 ± 0.19‡	6.30 ± 0.28	6.26 ± 0.22	6.25 ± 0.36	6.28 ± 0.34
5–25 yd (18.3 m)	6.66 ± 0.20	6.66 ± 0.17	6.60 ± 0.25	6.63 ± 0.19	6.60 ± 0.34	6.62 ± 0.35
5–40 yd (32.0 m)	6.90 ± 0.22	6.89 ± 0.18	6.82 ± 0.26	6.92 ± 0.23‡	6.85 ± 0.36	6.87 ± 0.35
15–25 yd (9.1 m)	6.99 ± 0.35	6.88 ± 0.38‖	6.92 ± 0.34	7.09 ± 0.30‖	6.93 ± 0.44	6.98 ± 0.47
15–40 yd (22.9 m)	7.14 ± 0.32	7.08 ± 0.28	7.06 ± 0.30	7.16 ± 0.28‖	7.13 ± 0.40	7.13 ± 0.39
25–40 yd (13.7 m)	7.25 ± 0.30	7.23 ± 0.26	7.24 ± 0.32	7.31 ± 0.31‖	7.28 ± 0.43	7.24 ± 0.40

*AST = assisted sprint training; RST = resisted sprint training; TST = traditional sprint training.
†Significance based on paired *t*-test between pre and postintervention scores for each of the 3 groups individually.
‡$p < 0.001$.
‖$p < 0.05$.

Table 3. Mean acceleration ($m\cdot s^{-2}$) ± *SD*.*†

Distance	AST PRE	AST POST	RST PRE	RST POST	TST PRE	TST POST
5 yd (4.6 m)	3.12 ± 0.18	3.58 ± 0.20‡	3.15 ± 0.26	3.15 ± 0.28	3.01 ± 0.44	2.99 ± 0.48
15 yd (13.7 m)	1.96 ± 0.09	2.12 ± 0.08‡	1.95 ± 0.16	1.92 ± 0.12	1.88 ± 0.22	1.89 ± 0.23
5–15 yd (9.1 m)	0.94 ± 0.08	1.01 ± 0.09§	0.95 ± 0.10	0.94 ± 0.10	0.94 ± 0.14	0.95 ± 0.13
15–25 yd (9.1 m)	0.46 ± 0.10	0.38 ± 0.11§	0.44 ± 0.08	0.51 ± 0.07§	0.46 ± 0.10	0.47 ± 0.11
25–40 yd (13.7 m)	0.25 ± 0.05	0.23 ± 0.04	0.24 ± 0.04	0.30 ± 0.04‖	0.27 ± 0.05	0.26 ± 0.05

*AST = assisted sprint training; RST = resisted sprint training; TST = traditional sprint training.
†Significance based on paired *t*-test between pre and postintervention scores for each of the 3 groups individually.
‡$p < 0.01$.
§$p < 0.01$.
‖$p < 0.05$.

Acceleration

Previous studies have suggested that sports-specific acceleration represents the rate of change in velocity over shorter distances (18); accordingly, the accelerations analyzed were those covering the following distances: 0–5 yd (0–4.6 m), 0–15 yd (0–13.7 m), 5–15 yd (4.6–13.7 m), 15–25 yd (13.7–22.9 m), and 25–40 yd (22.9–36.6 m). Repeated measures MANOVAs, with the use of the Wilks Lambda criterion, revealed a significant 3-way interaction (time × distance × group) for the absolute distances $F(6,44) = 10.661$, $p < 0.0001$, $\eta^2 = 0.592$ and the intervening distances $F(4,46) = 17.497$, $p < 0.0001$, $\eta^2 = 0.583$. Repeated measures ANOVAs with the Huynh–Feldt epsilon adjustment showed significant 2-way interactions (time × group) for 0–5 yd ($p < 0.0001$, $\eta^2 = 0.767$), 0–15 yd ($p < 0.0001$, $\eta^2 = 0.741$), 5–15 yd ($p < 0.008$, $\eta^2 = 0.302$), 15–25 yd ($p < 0.002$, $\eta^2 = 0.406$), and 25–40 yd ($p < 0.009$, $\eta^2 = 0.361$). To clarify the nature of the interactions, simple effects were tested using paired *t*-test between pre and postintervention scores for each of the 3 groups individually. The pre and postintervention group means, *SD*s, and their associated level of significance are presented in Table 3.

Discussion

The objective of this study was twofold: first, to determine if AST or RST were superior to TST in improving 40-yd (36.6-m) maximal velocity and 5-yd (4.6-m) and 15-yd (13.7-m) acceleration; and second, of the 2 training modalities, assisted vs. resisted, will one prove to be superior in improving acceleration and maximal velocity in Division IA female soccer athletes. As hypothesized in response to 12 training sessions over a 4-week time period, maximum velocity, as measured by the 40-yd sprint, was significantly improved as the result of both assisted ($p < 0.001$) and resisted ($p < 0.05$) sprint training and remained unchanged ($p > 0.05$) in the TST group; however, the nature of this improvement differed between the 2 training modalities (i.e., assisted vs. resisted). In the AST group, the greatest increase in velocity occurred in the first 5 yd (4.6 m) of the sprint, whereas the RST group had the greatest increase in velocity during the 15- to 25-yd (13.7- to 22.9-m) segment of the 40-yd (36.6-m) sprint. Acceleration increased significantly ($p < 0.001$) in the AST group in the first 5 yd (pre = 3.12 ± 0.18 $m\cdot s^{-2}$; post = 3.58 ± 0.20 $m\cdot s^{-2}$), and during the subsequent 10 yd from 5 to 15 yd (pre = 0.94 ± 0.08 $m\cdot s^{-2}$; post = 1.01 ± 0.09 $m\cdot s^{-2}$), and decreased significantly ($p < 0.01$) during the 10-yd interval from 15 to 25 yd (pre = 0.46 ± 0.10 $m\cdot s^{-2}$; post = 0.38 ± 0.11 $m\cdot s^{-2}$). In the RST group, acceleration remained unchanged pre to postintervention over the first 15 yd of the sprint and increased significantly ($p < 0.01$) from 15 to 25 yd (pre = 0.44 ± 0.08 $m\cdot s^{-2}$; post = 0.51 ± 0.07 $m\cdot s^{-2}$) and from 25 to 40 yd ([$p < 0.05$] pre = 0.24 ± 0.04 $m\cdot s^{-2}$; post = 0.30 ± 0.04 $m\cdot s^{-2}$). In other words, subjects in the AST group increased their acceleration in response to the AST protocol during the initial 15 yd (13.7 m) of the 40-yd (36.6-m) sprint, whereas subjects in the RST group responded to the resisted training protocol with an increase in acceleration during the final 25 yd (22.9 m) of the 40-yd (36.6-m) sprint. Accordingly, the major finding of this study is that although both AST and RST are capable of eliciting a training effect, which results in an unassisted or unresisted increase in short distance maximum velocity (i.e., 40 yd/36.6 m), the segment within the 40-yd (36.6-m) sprint distance wherein this increase occurs differs. That is, the training modalities impact maximal velocity differentially as the result of their effect on the rate of change in velocity, or acceleration, over the total distance covered.

Maximum velocity and acceleration are the product of stride length and stride frequency. Increasing one or both of these components without negatively impacting the other will positively impact maximum velocity. The ability to invoke this increase over a short distance will impact the rate of change in velocity, thereby increasing acceleration.

Investigators have suggested that maximum velocity and the rate of change in velocity are related to muscular force production and neural factors (16).

Harrison and Bourke (11), using a weighted sled RST protocol, found that 12 training sessions over a 6-week period significantly improved unresisted 5-m sprint times with no improvement in 10- or 30-m times. They attributed this improvement in initial acceleration to a significant increase in muscle force development. It has been suggested that an increase in the strength and power of the hip and knee extensors will eventually produce an increase in stride length during unresisted sprinting (7,13). This author proposes that the sled weighted at 13% of the subjects body mass in the Harrison and Bourke (11) study or The Trainer® weighted at 12.6% of the subjects body mass in this study created an overload on, and thereby improved the strength and power of, the muscles used in sprinting. Accordingly, on comparing the 2 training modalities used in this study, the investigator would hypothesize that, if the enhancement of strength and power are the primary contributing factors in the improvement of initial acceleration, the RST group would have the greater increase in acceleration. This outcome did not occur; instead, whereas both the RST and AST groups increased their 40-yd (36.6-m) velocity, only subjects in the AST group, using an elastic-band towing devise (i.e., Speed Harness™) creating a mean initial assistive force equal to 14.7% of the subjects body mass, increased their 5-yd (4.6-m) and 15-yd (13.7-m) acceleration.

An examination of the acute effects of an elastic-band towing device on sprint kinematics in male and female sprinters revealed that this method significantly increased stride length and the horizontal distance from the center of mass of the foot to the center of mass of the body but did not affect stride frequency (6). The authors thus concluded that the elastic-band towing devise might not be a sprint specific towing devise. This study does not support this finding. Primary differences between the 2 investigations include the subject characteristics, the duration of the study, and the assistive towing force. Research has documented that the sprinting style differs between the 2 subject populations; as compared to the sprinter used in the Corn and Knudson (6) study, the field-sport athlete used in this study sprints with a lower center of gravity and exhibits less knee flexion during recovery and lower knee lift (8). The duration of the study period, a single session evaluating only the acceleration kinematics with and without assisted towing vs. 12 sessions, eliminates the ability to assess the existence of a training effect produced by the longer-term use of the training modality. Lastly, the assistive towing force used in the acute study was approximately 50% of that used in this study, approximately 6.5% of body mass as compared to a mean initial assistive force of 14.7% of body mass. Significant increases in stride length have been demonstrated using assistive towing forces equal to 3.8 and 4.7% of body weight with a trend to increasing stride frequency as the towing force magnitude increased (4). However, this study (6), as with many, only investigated the acute effects of assisted towing as a means of supramaximal sprint training, and it is therefore difficult to extrapolate this information into a longitudinal outcome regarding the enhancement of sports-specific performance. This study did not measure stride length or stride frequency; however, the longitudinal effects of supramaximal sprint training revealed significant improvements in 5-yd (4.6-m) and 15-yd (13.7-m) velocity and acceleration in the AST group but not in the RST group. The effect sizes (20) in the AST group were large; ES = 3.45, 1.75, 2.56, and 1.78 for the 5-yd (4.6-m) velocity, 15-yd (13.7-m) velocity, 5-yd (4.6 m) acceleration, and 15-yd (13.7-m) acceleration, respectively. It is suggested that unlike resisted training, assisted training does not impose strength enhancement demands; accordingly, the sports-specific enhancements found in short distance velocity and acceleration in this study are more attributable to neurological adaptations as opposed to strength improvements.

Investigators have demonstrated that maximal integrated electromyographic (EMG) activity is higher during the acceleration phase as opposed to the constant speed phase of a sprint implying that the neural activation of a sprinter achieves its maximum in this phase (15). Mero et al. (16) found a significant correlation between stride frequency and the relative changes in integrated EMG in the breaking phase between maximal and supramaximal runs, suggesting that the increased neural activation in the supramaximal sprint had a positive effect on stride frequency. In an acute assessment of stride rate comparing supramaximal sprinting, produced by a "rubber rope" at an assistive force of 45–50 N, to maximal sprinting, stride frequency was shown to be significantly greater in supramaximal as compared to maximal sprinting (14). Additionally, stride frequency remained elevated in the unassisted maximal effort sprint executed after the supramaximal trial, suggesting an immediate neuromuscular adaptation to the supramaximal effort (14). A comparison of field sport athletes grouped as fast or slow, based upon their 15-m velocity, revealed that the fast group had a significantly lower ground contact time and a significantly increased stride frequency (18). This study concluded that fast acceleration times were the result of decreased ground contact times and increased stride frequencies. Accordingly, although this study did not directly measure stride frequency and ground contact time, the investigator purposes that the increased 5-yd (4.6-m) and 15-yd (13.7-m) accelerations were the result of this scenario as produced by an enhanced neuromuscular facilitation in response to the 4-week 12-session supramaximal training protocol.

PRACTICAL APPLICATIONS

This study demonstrates that both AST and RST produce training adaptations in elite female soccer athletes resulting in significantly improved 40-yd (36.6-m) maximal velocity. Although both AST and RST resulted in greater improvements in 40-yd (36.6-m) maximal velocity as compared to TST, the means by which the outcome occurred differed between the 2 training protocols. Therefore, the incorporation of 1 or the other of these 2 modalities into a speed enhancement training program must be based on the sport-specific demands on the athlete. Assisted, or supramaximal, sprint training increased the 40-yd (36.6-m) velocity by improving acceleration from standing to 5 yd (4.6 m) and from standing to 15 yd (13.7 m). Accordingly, this speed enhancement modality would best be used in athletic populations that participate in events requiring rapid acceleration over distances of 15 yd (13.7 m) or less. The RST protocol resulted in a comparable increase in 40-yd (36.6-m) maximal velocity; however, this improvement occurred as a result of faster acceleration from 15 to 25 yd (13.7–22.9 m) and 25 to 40 yd (22.9–36.6 m). Thus, RST protocols can be used with athletes participating in events that allow the attainment of maximal velocity over distances >15 yd (13.7 m).

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