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Effects of a Specialized Strength and Conditioning Program on the Fitness and Motor Skill Performance of High School Girls Softball Athletes

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ABSTRACT

There is a high demand for strength and conditioning programs for high school athletes. However, the delivery of programs for girls can be inconsistent. Accordingly, many high school athletes have turned to private strength and conditioning coaches. The purpose of this study was to examine the effects of different private strength and conditioning program training frequencies (1, 2, 3+ sessions per week) on linear speed (0-9.14 m and 0-18.29 m sprint intervals), lower-body power (standing broad jump [SBJ]), hitting velocity, throwing velocity, and lower-body strength (3RM front squat, 3RM hexagonal bar deadlift [HBD]) in high school girls softball players. Retrospective analysis was conducted on 30 high school softball athletes (age=~15 years) from a strength and conditioning facility that specializes in training softball athletes. The athletes came from various high schools and completed an 8-week strength and conditioning program, with different weekly session frequencies (1 [G1W], 2 [G2W], or 3+ [G3+W] sessions per week). Data was analyzed via a 2 (pre-post) by 3 (G1W, G2W, G3+W) mixed factorial ANOVA ($p<0.05$). Post hoc tests were performed using the Bonferroni adjustment procedure. All groups experienced significant improvements in the 0-9.14 m sprint interval ($p=0.021$), SBJ ($p<0.001$), hitting velocity ($p=0.006$), 3RM front squat ($p<0.001$), and 3RM HBD ($p<0.001$). The results showed that an 8-week strength and conditioning program completed by high school girls softball athletes can improve fitness and motor skill performance, regardless of training frequency. These data support providing high school girls with access to properly structured and supervised strength and conditioning programs.

Keywords: adolescent, hitting velocity, lower-body strength, standing broad jump, sprint acceleration.

INTRODUCTION

Survey data from 2021-2022 indicated that 7,618,054 high school students, of which 3,000,000 were girls, participated in sports (43). Such high numbers of sport participation have led to the demand for strength and conditioning programs. Strength and conditioning programs are generally designed to enhance physical performance and reduce an athlete's risk of injury (9), in which research suggests can occur in high school-aged individuals. For example, Channell and Barfield (6) documented how eight weeks of either Olympic lifting or traditional resistance training improved vertical jump (VJ) performance in male high school football players. Sáez de Villarreal et al. (55) detailed how a 7-week plyometric, strength, and change-of-direction training program on basketball-specific performance measures in male high school players led to improvements in the sit-and-reach, VJ, 20-m sprint, and 10-m zig-zag sprint. Millar et al. (41) found a 6-week whole-body resistance training program completed by female high school soccer players led to improvements in strength (measured by the three-repetition maximum [3RM] back squat and 3RM hip thrust), power (VJ and standing broad jump [SBJ]), change-of-direction speed (pro-agility shuttle), and motor skill performance (ball kicking distance).

For high school athletes, it is important to document not only the influence a strength and conditioning program can have on fitness, but also motor skill performance (41,64). Physical activity and exposure to different motor skills during an individual's formative years can influence physical activity across the lifespan (16). Individuals that display better motor competence during adolescence tend to be more physically active during adulthood, which can impact an individual's health outcomes (16,20). There are not only potential short-term impacts to fitness and skill performance, but lifelong impacts following an effective strength and conditioning program. However, there may be inconsistent provision and access of strength and conditioning for the high school athlete, depending on their sport and school.

Pote and Christie (47) surveyed 24 university and high school level cricket coaches and reported that strength and conditioning practices that followed industry standards were often not being used. Further, Pote and Christie (47) identified coaches as not being properly trained or certified in order to implement proper strength and conditioning practices to their programs. Although this study was conducted in South Africa, the results do have application to the training environment for high school athletes in the United States of America. Indeed, the results from Pote and Christie (47) were supported by a survey conducted by Reynolds et al. (52). In their sample of high school strength and conditioning coaches, Reynolds et al. (52) found only 2 out 10 coaches of female athletes, and 9 of 19 coaches of male athletes, were found to hold appropriate certifications. Depending on the school, strength and conditioning may also not be prioritized (51) or embedded within the high school curriculum (14), which provides less training opportunities for athletes. A lack of priority for strength and conditioning is especially a concern for girls high school athletes (51). Thus, athletes participating in training programs implemented by coaches without proper qualifications could ultimately have negative results within their training and sports performance in general. As a result of the inconsistent delivery of strength and conditioning at the high school level, athletes may seek out supplemental programs in addition to what may be provided during school.

There are many private facilities that provide strength and conditioning services to athletes coming from a range of different sports and ages (16). Clients (i.e., athletes and parents of athletes) pay for a service that provides strength and conditioning programs, typically delivered by trained coaches specific to the needs of the athletes. While there is no research to suggest that coaches at high schools or private facilities differ in their education or qualifications, private training facilities may provide athlete's with the dedicated time, attention, and facilities that could help with their physical development. Many programs will also provide pre- and post-testing following training blocks to track the progress of athletes. Moreover, private facilities can often deliver programs created based on the frequency of times per week an athlete is able to attend. Frequency of training can vary for high school athletes due to several factors, including parental financial budgets, school classroom demands, and whether the athletes are also using private coaches specific to their sport (e.g., coaches hired to develop sport-specific skills such as hitting and pitching). Regardless, appropriate program design and proper supervision by qualified professionals are critical to an effective training program (29). Many of the benefits associated with resistance training are attainable for children and adolescents who follow age-specific guidelines (16). To the author's knowledge, there is no research that has demonstrated the effects private strength and conditioning programs have on the fitness and motor skill performance of high school athletes. Moreover, there has been no published scientific literature that has detailed effective strength and conditioning programs designed specifically for high school girls softball players. There is also no research that has determined whether there are changes in fitness and motor skill performance based on the frequency of training.

Therefore, this study involved the retrospective analysis of data collected by staff working for a private strength and conditioning facility who specialized in training softball players. The use of participants from a private facility prohibited the inclusion of a control group, as all participants were paying for a training program. Although the approach of using existing datasets meant the researchers did not have input into the tests selected or the training program design, this also meant that the study investigated real-world data from a program specific to high school athletes currently in practice. What this also meant is that the results were reflective of adaptations that could be expected from girls high school athletes. The purpose of this study was to examine the effects of different strength and conditioning training frequencies (1, 2, or 3+ sessions per week) on linear speed (18.29-m sprint), lower-body power (SBJ), softball-specific skill performance (hitting and throwing velocity), and lower-body strength (3RM front squat and 3RM hexagonal bar deadlift [HBD]) in high school girls softball players. Each participant completed an 8-week training program administered by facility staff and were tested on their athletic performance before and after the program. It was hypothesized high school athletes who attend strength and conditioning classes more frequently will significantly improve their linear speed, lower-body power, hitting velocity, throwing velocity, and lower-body strength more than those who attend less frequently.

METHODS

Participants

This study involved the analysis of retrospective data collected as part of standard practice by staff from a private facility. Participants over 18 years of age provided consent for their data to be analyzed (two participants were 18 years old at the time of the study), while those under 18 years of age provided their assent for their data to be analyzed and their parents/guardians provided their consent. This resulted in a de-identified sample of convenience dataset data of 34 high school girls softball athletes (age = 14.91 ± 1.00 years; height = 166.35 ± 6.91 cm; body mass = 63.21 ± 9.59 kg) being provided to the researchers. The girls came from different high school programs and played a range of different positions; these factors were not considered in this study. Inclusion criteria from the datasets were for participants who were enrolled in high school, played softball, attended the private facility, provided consent/assent, were free of any medical issues or injuries that may have hindered their participation or performance, and adhered to their training program with at least an 87.5% attendance rate (55,63). The 87.5% attendance rate was equivalent to missing only one week within the participant's respective training program. The study was approved by the Institutional Review Board (HSR-22-23-112) and conformed to the recommendations of the Declaration of Helsinki (68).

Protocols

Although this study involved archival data analysis, the testing procedures adopted by the facility staff are detailed below. Staff used pre- and post-testing to track progress for athletes, and the testing sessions had a duration of 45-60 minutes each. Pre-testing was conducted within the week prior to the start of the training program; post-testing was completed in the week following the end of the 8-week program. All testing was conducted on-site in the afternoon or evening, typically after 5:00pm. Prior to each session, athletes completed a 5-10-minute dynamic warm-up consisting of dynamic exercises, mobility exercises, and fundamental movement skills. The researchers did not have input into the selection or conduct of the tests; they were, however, standard practice within this facility. As this facility specialized in softball, staff also included softball-specific hitting and throwing tests. The tests were performed in the order presented hereafter, which followed industry guidelines (40). As explained in previous research (37), due to time constraints, between-trial recovery periods of about 60 seconds (s) were allotted for the sprint, jump, hitting, and throwing trials. Though potentially not ideal, short-duration power events may not completely deplete phosphagen stores (50), which can then be recovered very quickly (56). Moreover, any potential issues with fatigue were limited with the analysis of the best trial for each test event (37).

18.29-m (20-yard) Sprint

An 18.29-m sprint measured linear speed using established procedures (34,36). Sprints were conducted outside the facility on a blacktop surface. Timing gates (Dashr Motion Performance Systems, Lincoln, USA) were positioned at 0 m, 9.14 m, and 18.29 m to measure the 0-9.14 and 0-18.29 m intervals. The height of each gate was approximately 0.73 m. This gate height was used due to the structure of the tripods that were included as part of the timing gate system, as well as recommendations for a gate height that is similar to hip height in the participants for sprint testing (66,69). Moreover, the same gate height was used for pre- and post-testing to allow for the longitudinal comparisons (11). Participants used a two-point stance behind a start line marked 0.5-m behind the first timing gate. On the start command, the participant sprinted through the gates. Three trials were performed and the best trial was analyzed.

Standing Broad Jump (SBJ)

The standing broad jump (SBJ) provided an indirect measure of horizontal lower-body power and was performed using established procedures indoors on turf (33,34,36). The participant started with their toes behind the start line and performed a countermovement to jump as far forwards as possible and land with both feet. Distance (perpendicular line from the start line to the back heel) in meters was measured by a tape measure. Each participant performed three trials and the best trial was examined.

Hitting Velocity

Hitting velocity was quantified using a portable hitting tracker (Hitting 2.0, Rapsodo®, St. Louis, USA). The portable hitting tracker used camera and radar technology to measure and analyze swing metrics (49). The focus of this study was ball exit velocity (i.e., batted ball velocity), which was referred to as hitting velocity in this study. The procedures adopted were similar to previous methods (65), and manufacturer guidelines were used to set up the tracker (49). The tracker was placed 0.35 m from the front of home plate at ground level. Participants performed 3-5 minutes of practice hits off a batting tee that sat on home plate. Each athlete set the tee to their preferred height, which remained consistent throughout all trials. Though there may be technique differences between hitting a ball off a tee and from a toss or pitch (65), staff at the facility preferred to use more standard, controlled conditions for hitting. A standard 0.18-kg softball and the participant's own composite bat were used for hitting. Although bats made with different materials could influence hitting velocity (39), the staff preferred that each individual used their own equipment. This was done to maximize performance during the hitting test. Following the practice hits, athletes hit the softball off the batting tee with maximum effort three times with about 60 s rest separating each hit. Hitting velocity was measured in kilometers per hour before being converted to meters per second (m/s) for data analysis. The best hitting velocity trial was evaluated.

Throwing Velocity

Throwing velocity was measured by a portable pitching tracker (Pitching 2.0, Rapsodo®, St. Louis, USA). This equipment has been used in recent studies (13), and manufacturer guidelines were followed for set-up (48). The tracker was placed 4.70 m from the front of home plate. A line was marked 13.11 m from home plate where participants would throw from. Participants performed 3-5 minutes of warm-up throws into a net placed behind home plate. Participants were permitted to step before throwing the ball, but one foot had to remain on the throwing line. A 0.18-kg softball was used for throwing. After the warm-up throws, participants threw into the target with maximum effort three times with 60 s rest separating each throw. Each trial was measured in kilometers per hour before being converted to m/s, with the best trial studied.

3RM Front Squat

Two lower-body strength tests were used by staff, with the first being a 3RM front squat. A 3RM was used for safety considerations relative to young athletes (9,10). The front squat was adopted by staff to alleviate concerns about lower back and knee stress (3,21). To perform the front squat, the feet of the participant were positioned about shoulder-width apart, with their toes pointed forward or slightly outward (9). The bar rested above and behind the anterior deltoids on the upper clavicle region and the participant descended until the tops of their thigh were parallel with the floor for a successful repetition. To obtain the 3RM, athletes worked their way up to this load by first starting with a weight they could lift comfortably for at least 5 repetitions. The weight was increased by 10-20% for two more sets of 3-5 repetitions, followed by 3RM testing sets until failure. A between-attempt rest interval of 2-3 minutes was provided.

3RM Hexagonal Bar Deadlift (HBD)

The 3RM HBD was the second lower-body strength test. The movement was similar to that previously described (35). The same loading scheme and rest periods used during the front squat test was also applied for the HBD. A successful HBD repetition occurred when the athlete was standing within the frame of the bar via hip and knee extension and shoulder retraction (35).

Training Program

Training programs were designed entirely by staff at the facility, who were all Certified Strength and Conditioning Specialists (CSCS), which is the certification provided by the National Strength and Conditioning Association. The program encompassed exercises typically used within strength and conditioning programs for athletes, with modifications made specific to the high school-aged population and sport of the participants. Training staff at the private facility followed a program template for their athletes who signed up for their programs, which typically run for eight weeks. With an appropriate program, eight weeks should be a sufficient time period to obtain improvements in different athletic performance measures (6,15,41,63). Prior to the program, participants (usually with their parents) signed up for a certain number of sessions per week (typically 1-4 sessions per week). For every day athletes visited the training facility, they completed a 5-10 minute dynamic warm-up, 10-15 minutes of speed and agility drills, and 30-40 minutes of structured resistance training, adapted to the individual as needed. The dynamic warm-up varied by day but generally consisted of a range of dynamic exercises, mobility exercises, and fundamental movement skills (Tables 1 and 2). The speed or agility drills also varied by day and alternated between a linear or lateral focus (Tables 1 and 2).

The resistance training program, which also included plyometrics, was structured as 2 x 4-week blocks with four different workouts per week that repeated each week until the next block began with a new set of workouts. For weeks 1 to 8, the 2 structured blocks were as follows: Weeks 1-4 had a strength focus consisting of high intensity and low volume exercises (Table 3); weeks 5-8 had a power focus consisting of a higher intensity and lower volume exercises (Table 4). Workout intensity for the athletes was gauged with the use of a 0-10 rating of perceived exertion scale (19). This tool enabled athletes to monitor their effort when performing exercises in order to help them self-assess if they should increase or decrease the amount of weight. Any missed sessions could be made up at the end of the week and/or the following week. Class sizes ranged from five participants to as many as 40 participants. Two-to-three coaches were present at each session to ensure the coach-to-athlete ratio was at least 1:15 (recommended ratio for supervising high school athletes) but never exceeding 1:20 (59). Training sessions were all conducted in the evenings from 5:00-9:00pm. All participants completed the assigned session for the training day, regardless of their training frequency.

Statistical Analysis

All statistical analyses were computed using the Statistics Package for Social Sciences (version 28.0; IBM Corporation, NY, USA). Descriptive statistics (mean ± standard deviation [SD]) were calculated for each variable. Facility staff collected pre- and post-test data, and only those athletes who met the inclusion criteria were analyzed. Athletes were grouped into those who completed 1 session (G1W), 2 sessions (G2W), or 3+ sessions (G3+W) per week. Data was analyzed via a 2 (time; pre and post) by 3 (G1W, G2W, and G3+W) mixed factorial analysis of variance (ANOVA) ($p < 0.05$). As only two repeated measures were employed, the assumption of Mauchly's test of sphericity was not applicable (31-33,58). All other repeated measures ANOVA assumptions were considered, with the Levene statistic used to determine homogeneity of variance, and partial eta squared (ηp^2) effects sizes were reported. If a significant F ratio was detected, post hoc tests were performed using the Bonferroni adjustment procedure. To provide additional descriptive analysis, change scores, calculated as the difference between the pre- and post-test data, were derived for each variable for each group (7,54,64).

RESULTS

Following review of the data provided by facility staff, 30 participants (age = 14.90 ± 1.00 years; height = 166.53 ± 6.98 cm; body mass = 62.08 ± 8.72 kg) met the inclusion criteria, and their data was analyzed. This resulted in 6, 17, and 7 athletes being allocated to the G1W, G2W, and G3+W groups, respectively. Pre- and post-test data is shown in Table 5, while change score data is displayed in Table 6. For age, the main effect of time was significant ($F(1,27) = 7.604$, $p = 0.010$, $\eta p^2 = 0.220$), as the participants got older over the course of the study. The time by group ANOVA was not significant ($F(2,27) = 0.346$, $p = 0.710$, $\eta p^2 = 0.025$), although the main effect between groups was significant ($F(2,27) = 4.592$, $p = 0.019$, $\eta p^2 = 0.254$). The G3+W group was significantly older than the G2W group ($p = 0.040$).

Table 1. Linear and lateral dynamic warm-ups with speed and agility drills for training block 1.

Linear	Lateral	Linear	Lateral
Dynamic (20 yards down and back)			
Jog Back pedal 2-1 Forward run 2-1 Back pedal	Back pedal Cross in front run Shuffles with arm crossovers Carioca	Forward skip with arm circles Backward skip with arm circles Forward carioca Backward carioca	Lateral jacks Carioca with spins Shuffles with backside spin Cross behind run
Mobility			
Good mornings with forward reach 90/90 Transitions Yoga-ups Snapdowns	Squats Birddogs Adductors stretch with toe taps High plank rotations 2 to 1 Snapdowns	Body circles Glute bridges Supine leg swings Bear crawl Snapdowns with split stance landing	Lateral lunge sways All 4's hip abduction Glute bridge with diagonal reach Yoga up with toe taps Rotational snapdowns
Skill development (10 yards down and back)			
Forward/backward pogo hops A march A skips High knees Primetimes Continuous broad jumps (5+) Prone start sprints	Lateral pogo hops Lateral A march Lateral A skips 2 shuffle sticks 5-yard change-of-direction shuffles to sprint Lateral start sprints	1 leg pogo hops A march A skips High knee double switches Dribble bleeds Falling start sprints	Lateral 1 leg pogo hops Lateral A march Lateral A skips Lateral broad jumps Hip turn to sprint Half kneeling lateral start sprints
Speed/Agility			
Ramp sprints (4-6) Prone 10-yard races (4-6)	Medicine ball fake throws (jab step and 1-2 shuffles) 10-yard mirror drill	20-yard Medicine ball sprints (2-3) 3 (10-yard) zone sprints (3-4)	3-cone reaction drill

Table 2. Linear and lateral dynamic warm-ups with speed and agility drills for training block 2.

Linear	Lateral	Linear	Lateral
Dynamic (20 yards down and back)			
Forward skips with arm cross-overs Backward skips with arm crossovers Cross behind run Cross in front run	Cross in front run Carioca Shuffles with frontside spin Shuffles with backside spin	Forward gallop Backward gallop 2-1 back pedal Forward carioca	Lateral jacks Carioca with spins Cross behind run Shuffles
Mobility			
Squat to hamstring stretch All 4's hip abduction All 4's opposite pickups Snapdowns	Curtsy lunge with rotation Inchworm Lateral bearcrawl 2-1 snapdowns	Ankle rocker to hamstring stretch Lateral lunge with rotation Forward/backward bearcrawl Rotational snapdowns	Spiderman lunge with rotation 1 leg glute bridge Serratus walks Snapdowns to vertical jump
Skill development (10 yards down and back)			
Ankle hops A march A skips Dribbles (small, medium, large) Forward skip races Half kneeling start sprints	Lateral 1 leg pogo hops Lateral A march Lateral A skips Crossover sticks Crossover to sprint Lateral 4-point start sprint	Staggered pogo hops A march A skips Broad jumps (5+) Prone start sprints	Zig zag pogo hops Lateral A march Lateral A skips Heidens Shuffle races Shuffle to sprint
Speed/Agility			
Wall runs (5-7 minutes): 1 switch and 2 switches Resisted sprints (4-6)	Speed/Agility: Resisted shuffles (2-3 each direction) Shuffle Races	Speed/Agility: Medicine ball sprints (3-4) Flying 10's (3-5)	Speed/Agility: Square drill

Table 3. Training block 1 (4-week mesocycle). Exercises performed as supersets (i.e., A1-A2-A3). e: each side.

		Exercises	Week 1	Week 2	Week 3	Week 4
Day 1	A1	Barbell Front Squat	4x5	4x5	4x5	4x5
	A2	Depth Jump	4x3	4x3	4x3	4x3
	A3	1/2 Kneeling Kettlebell Weight Shift	3x6e	3x6e	3x6e	3x6e
	B1	Dumbbell Step Up	3x6e	3x6e	3x6e	3x6e
	B2	Weighted Plank	3x30s	3x30s	3x30s	3x30s
	C1	Split Squat Landmine Press	3x8e	3x8e	3x8e	3x8e
	C2	Chest Supported Dumbbell Row	3x10	3x10	3x10	3x10
	D1	Feet Elevated Hip Bridge with Alternate Hip Flexion	2x10e	2x10e	2x10e	2x10e
	D2	Prone External Rotation	2x10e	2x10e	2x10e	2x10e
Day 2	A1	Trap Bar Deadlift	4x5	4x5	4x5	4x5
	A2	Tipple Broad Jump	4x1	4x1	4x1	4x1
	A3	Quadruped Reach Under to Rotation	3x8e	3x8e	3x8e	3x8e
	B1	Goblet Reverse Lunge to Knee Drive	3x8e	3x8e	3x8e	3x8e
	B2	1/2 Kneeling Plate Rotations (both positions)	3x5e	3x5e	3x5e	3x5e
	C1	Band Assisted Pull Up	3x8	3x8	3x8	3x8
	C2	Alternate Dumbbell Floor Press	3x8e	3x8e	3x8e	3x8e
	D1	Side Plank Row	2x10e	2x10e	2x10e	2x10e
	D2	Wall Supported 1 Leg Calf Raise	2x10e	2x10e	2x10e	2x10e
Day 3	A1	Barbell Split Squat	4x5e	4x5	4x5	4x5e
	A2	Heiden with Stick	4x3e	4x3e	4x3e	4x3e
	A3	Straight Leg Adductor Squeeze (8-10 lbs.)	3x20s	3x20s	3x20s	3x20s
	B1	Heels Elevated Goblet Squat	3x8	3x8	3x8	3x8
	B2	Medicine Ball Deadbug with Diagonal Reach (4-8 lbs.)	3x6e	3x6e	3x6e	3x6e
	C1	Hand Release Push Up	3x8	3x8	3x8	3x8
	C2	Ring Row	3x10	3x10	3x10	3x10
	D1	Stability Ball Leg Curl	2x20	2x20	2x20	2x20
	D2	Wrist Pronation and Supination	2x10e	2x10e	2x10e	2x10e
Day 4	A1	Rotational Scoop Toss (4-6 lbs.)	3x5e	3x5e	3x5e	3x5e
	A2	Double Contact Hurdle Jumps	3x5	3x5	3x5	3x5
	B1	Barbell Romanian Deadlift	4x5	4x5	4x5	4x5
	B2	Prone Y	3x10e	3x10e	3x10e	3x10e
	C1	Goblet Rear Foot Elevated Split Squat	3x8e	3x8e	3x8e	3x8e
	C2	1 Arm Resistance Band Row with Opposite Arm Reach	3x10e	3x10e	3x10e	3x10e
	D1	Goblet Lat Lunge	3x6e	3x6e	3x6e	3x6e
	D2	Supine Medicine Ball Chest Pass (6-8 lbs.)	3x5	3x5	3x5	3x5

The main effect for time was significant for height ($F(1,27) = 8.580$, $p = 0.007$, $\eta p^2 = 0.241$), which increased during the study. The time by group ANOVA ($F(2,27) = 0.608$, $p = 0.552$, $\eta p^2 = 0.043$), and main effect between groups ($F(2,27) = 2.681$, $p = 0.087$, $\eta p^2 = 0.166$), were not significant. Concerning body mass, the main effect for time ($F(1,27) = 3.654$, $p = 0.067$, $\eta p^2 = 0.119$) and the time by group ANOVA ($F(2,27) = 0.633$, $p = 0.539$, $\eta p^2 = 0.045$) were both not significant. The main effect between groups was significant ($F(2,27) = 4.358$, $p = 0.023$, $\eta p^2 = 0.244$); the G1W group was heavier than the G2W group ($p = 0.039$).

The main effect for time was significant for the 0-9.14 m sprint interval ($F(1,27) = 6.012$, $p = 0.021$, $\eta p^2 = 0.182$), as time decreased from pre- to post-test. This was not the case for the 0-18.29 m sprint interval ($F(1,27) = 0.213$, $p = 0.648$, $\eta p^2 = 0.008$). The time by group ANOVA was not significant for either the 0-9.14 m ($F(2,27) = 2.040$, $p = 0.150$, $\eta p^2 = 0.131$) or the 0-18.29 m ($F(2,27) = 2.317$, $p = 0.118$, $\eta p^2 = 0.147$) intervals. The main effect between groups for the 0-9.14 m interval was significant ($F(2,27) = 3.820$, $p = 0.035$, $\eta p^2 = 0.221$), with the G3+W group being faster than the G2W group ($p = 0.043$). The main effect between groups for the 0-18.29 m sprint interval was not significant ($F(2,27) = 2.859$, $p = 0.075$, $\eta p^2 = 0.175$).

The SBJ improved from pre to post-test across the groups as the main effect for time was significant ($F(1,27) = 14.900$, $p < 0.001$, $\eta p^2 = 0.356$). The main effect between groups was also significant ($F(2,27) = 4.260$, $p = 0.025$, $\eta p^2 = 0.240$), with the G3+W group jumping further than the G2W group ($p = 0.023$). The time by group ANOVA was not significant ($F(2,27) = 0.810$, $p = 0.455$, $\eta p^2 = 0.057$).

Table 4. Training block 2 (4-week mesocycle). Exercises performed as supersets (i.e., A1-A2-A3). e: each side.

		Exercises	Week 1	Week 2	Week 3	Week 4
Day 1	A1	Trap Bar Deadlift (75-80% 1RM)	4x3	4x3	4x3	4x3
	A2	3 Hops for Distance on 1 Leg	4x1e	4x1e	4x1e	4x1e
	A3	Serratus March	3x8e	3x8e	3x8e	3x8e
	B1	1 Arm Dumbbell Rear Foot Elevated Split Squat	3x6e	3x6e	3x6e	3x6e
	B2	1 Arm Resistance Band Lat Pulldown	3x10e	3x10e	3x10e	3x10e
	C1	Valslide Hamstring Curl with Dumbbell	3x10	3x10	3x10	3x10
	C2	Deadbug with Weight	3x8e	3x8e	3x8e	3x8e
	D1	Reactive Supine Medicine Ball Chest Pass (4-8 lbs.)	3x8	3x8	3x8	3x8
	D2	Resistance Band Pull Apart (Rear Deltoids)	2x12	2x12	2x12	2x12
Day 2	A1	Barbell Split Squat (75-80% 1RM)	4x3e	4x3e	4x3e	4x3e
	A2	Step Behind Medicine Ball Rotational Scoop Toss (4-6 lbs.)	4x3e	4x3e	4x3e	4x3e
	A3	Prone Y	3x10e	3x10e	3x10e	3x10e
	B1	Barbell Glute Bridge (315 lbs. max)	3x8	3x8	3x8	3x8
	B2	1/2 Kneeling Dumbbell Lateral Flexion (25 lbs. or more)	3x10e	3x10e	3x10e	3x10e
	C1	1A Dumbbell Floor Press	3x8e	3x8e	3x8e	3x8e
	C2	Ring Row	3x10	3x10	3x10	3x10
	D1	Goblet Valslide Lateral Lunge	2x8e	2x8e	2x8e	2x8e
	D2	Standing Pallof Press	2x10e	2x10e	2x10e	2x10e
Day 3	A1	Barbell Back Squat (75-80% 1RM)	4x3	4x3	4x3	4x3
	A2	Rotational Box Jump	4x2e	4x2e	4x2e	4x2e
	A3	All 4s Hip Abduction	3x10e	3x10e	3x10e	3x10e
	B1	Kickstand Dumbbell Romanian Deadlift	3x8e	3x8e	3x8e	3x8e
	B2	Push Up with Rotation	3x5e	3x5e	3x5e	3x5e
	C1	1 Arm Dumbbell Row	3x10e	3x10e	3x10e	3x10e
	C2	Plank with Alternate Hip Extension	3x8e	3x8e	3x8e	3x8e
	D1	Side Plank with External Rotation (5 lbs.)	3x10e	3x10e	3x10e	3x10e
	D2	PVC Ulnar Deviation	3x10e	3x10e	3x10e	3x10e
Day 4	A1	Kettlebell Swing	3x10	3x10	3x10	3x10
	A2	Spiderman Lunge with T Spine Rotation	3x5e	3x5e	3x5e	3x5e
	B1	Dumbbell Push Press	4x6	4x6	4x6	4x6
	B2	Supine Shoulder Flexion	3x8	3x8	3x8	3x8
	C1	Dumbbell Walking Lunge with Knee Drive	3x6e	3x6e	3x6e	3x6e
	C2	Resistance Band Row with Pause (3s)	3x10	3x10	3x10	3x10
	D1	Lateral Bearcrawl	2x10e	2x10e	2x10e	2x10e
	D2	Mini Band Glute Bridge	2x25	2x25	2x25	2x25

For hitting velocity, the main effect for time was significant ($F(1,27) = 8.968$, $p = 0.006$, $\eta p^2 = 0.249$) and indicated improvement from pre- to post test. The between-group effect was significant ($F(2,27) = 5.182$, $p = 0.012$, $\eta p^2 = 0.277$); the G1W group had a faster hitting velocity than the G2W group ($p = 0.032$). The time by group ANOVA was not significant ($F(2,27) = 0.336$, $p = 0.718$, $\eta p^2 = 0.024$). Regarding throwing velocity, the main effect for time ($F(1,27) = 0.099$, $p = 0.755$, $\eta p^2 = 0.004$) and the time by group ANOVA ($F(2,27) = 0.866$, $p = 0.432$, $\eta p^2 = 0.060$) were not significant. The main effect between groups was significant ($F(2,27) = 5.134$, $p = 0.013$, $\eta p^2 = 0.276$). The G3+W group had a faster throwing velocity than the G2W group ($p = 0.026$).

The main effect for time was significant for both the 3RM front squat ($F(1,27) = 81.802$, $p < 0.001$, $\eta p^2 = 0.752$) and 3RM HBD ($F(1,27) = 12.579$, $p < 0.001$, $\eta p^2 = 0.318$). The time by group interaction was not significant for either the front squat ($F(2,27) = 3.175$, $p = 0.058$, $\eta p^2 = 0.190$) or HDB ($F(2,27) = 1.020$, $p = 0.374$, $\eta p^2 = 0.070$). The main effect between groups was also not significant for either strength test (front squat: $F(2,27) = 2.498$ $p = 0.101$, $\eta p^2 = 0.156$; HBD: $F(2,27) = 2.338$, $p = 0.116$ $\eta p^2 = 0.148$).

DISCUSSION

The purpose of this study was to evaluate a strength and conditioning program completed at a private facility designed for girls high school softball athletes. As athletes training at a private facility may use different training frequencies, depending on their financial commitment, the study focused on performance changes in participants who

Table 5. Pre- and post-test data (mean ± SD) for high schools girls athletes grouped by who trained once (G1W), twice (G2W), or 3+ (G3+W) times per week for 8 weeks in the performance tests (0-9.14 m and 0-18.29 m sprint intervals; standing broad jump [SBJ]; hitting velocity (HV); throwing velocity (TV); three-repetition maximum front squat [3RM FS] and hexagonal bar deadlift [3RM HBD]).

	G1W (n = 6)		**G2W (n = 17)**		**G3+W (n = 7)**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Age (years)	15.33 ± 0.82	15.67 ± 1.21*	14.47 ± 0.51	14.76 ± 0.44*	15.57 ± 1.51	15.71 ± 1.38*
Height (cm)	169.17 ± 7.14	169.50 ± 7.12*	164.06 ± 6.34	164.88 ± 6.27*	170.29 ± 6.70	170.86 ± 6.84*
Body Mass (kg)	69.85 ± 10.37	70.67 ± 10.93	59.92 ± 8.08	59.67 ± 8.05	63.10 ± 3.72	63.18 ± 3.35
0-9.14 m (s)	1.79 ± 0.07	1.79 ± 0.08*	1.86 ± 0.07	1.81 ± 0.05*	1.77 ± 0.09	1.75 ± 0.06*
0-18.29 m (s)	3.09 ± 0.15	3.11 ± 0.16	3.17 ± 0.13	3.13 ± 0.09	3.02 ± 0.14	3.03 ± 0.11
SBJ (m)	1.96 ± 0.14	2.03 ± 0.10*	1.89 ± 0.12	1.93 ± 0.14*	2.08 ± 0.22	2.13 ± 0.22*
HV (m/s)	31.43 ± 2.40	32.02 ± 1.65*	28.76 ± 2.51	29.28 ± 1.89*	30.78 ± 2.83	31.71 ± 2.51*
TV (m/s)	27.03 ± 0.85	26.80 ± 0.67	25.41 ± 1.56	25.40 ± 1.29	27.02 ± 1.91	27.44 ± 2.21
3RM FS (kg)	66.15 ± 12.86	79.38 ± 21.08*	62.83 ± 10.96	70.44 ± 12.09*	71.93 ± 9.14	85.53 ± 12.33*
3RM HBD (kg)	111.13 ± 31.30	113.40 ± 22.36*	93.25 ± 17.88	99.39 ± 17.57*	105.95 ± 11.84	114.37 ± 15.04*

** Significantly ($p < 0.05$) different from the pre-test.*

Table 6. Change scores (mean ± SD) for high schools girls athletes grouped by who trained once (G1W), twice (G2W), or 3+ (G3+W) times per week for 8 weeks in the performance tests (0-9.14 m and 0-18.29 m sprint intervals; standing broad jump [SBJ]; hitting velocity (HV); throwing velocity (TV); three-repetition maximum front squat [3RM FS] and hexagonal bar deadlift [3RM HBD]).

	G1W (n = 6)	**G2W (n = 17)**	**G3+W (n = 7)**
Age (years)	0.33 ± 0.51	0.29 ± 0.47	0.14 ± 0.38
Height (cm)	0.003 ± 0.008	0.008 ± 0.010	0.006 ± 0.011
Body Mass (kg)	0.82 ± 1.49	0.75 ± 1.35	0.08 ± 1.53
0-9.14 m (s)	-0.01 ± 0.04	-0.05 ± 0.05	-0.02 ± 0.04
0-18.29 m (s)	0.02 ± 0.07	-0.04 ± 0.07	0.003 ± 0.04
SBJ (m)	0.08 ± 0.07	0.04 ± 0.07	0.05 ± 0.06
HV (m/s)	0.59 ± 1.20	0.52 ± 1.07	0.93 ± 1.20
TV (m/s)	-0.23 ± 0.72	-0.01 ± 1.03	0.42 ± 0.79
3RM FS (kg)	13.23 ± 11.33	7.61 ± 4.60	13.61 ± 3.70
3RM HBD (kg)	2.27 ± 14.27	6.14 ± 5.60	8.42 ± 4.67

trained either once (G1W), twice (G2W), or 3+ times (G3+W) per week. It was hypothesized athletes who attended more strength and conditioning training sessions per week would improve their linear speed, lower-body power, hitting velocity, throwing velocity, and lower-body strength more than those who attended less frequently. This hypothesis was not supported. The results demonstrated a resistance training program completed with different training frequencies could all improve lower-body strength, 0-9.14 m sprint performance, SBJ, and hitting velocity, with no differences in how each group improved in these tests. It is possible the physical growth of the participants may have influenced changes to test performance (2), as the athletes were older and taller by the end of the study (although maturation was not directly assessed). In relation to this, the G2W group could have had greater capacity for improvements as they were younger than the G3+W group, lighter than the G1W group, and had lesser performance in several of the tests (0-9.14 m sprint interval, SBJ, hitting and throwing velocity) compared to the other groups. Nonetheless, the current data indicated even athletes who completed one session per week improved qualities important for softball. As will be discussed, the improvements made by all groups in this study express how valuable strength and conditioning programs could be for girls high school athletes.

At its core, resistance training programs are typically designed to improve the strength of the trainees. This was no different from the program designed by the private facility training staff for the girls high school softball athletes in this study. Significant improvements were seen in all groups for the 3RM front squat and 3RM HBD from pre- to post-test, with increases of approximately 8-14 kg and 2-8 kg, respectively. Previous research has shown resistance training programs can influence adolescents' lower-body strength as measured by the 3RM front squat (increase of ~6-10 kg) (9) and hexagonal bar deadlift (increase of 32.2 kg) (26). Although previous research has shown greater frequency of training has led to superior strength gains in children (15), the results from the current study showed a strength and conditioning program completed either once, twice, or three or more times per week could improve lower-body strength in girls high school softball athletes. Since additional training performed by the athletes outside of the assigned programs was not controlled, it is plausible participants may have been completing supplemental training. Nevertheless, the current data demonstrates how an appropriately designed resistance training program can improve the strength of high school girls. These data support the provision of strength training programs for high school girls, as they can experience positive physical adaptations.

The 0-9.14 m and 0-18.29 m tests measured linear speed over short distances, with an emphasis on the sprint acceleration needed by team sport athletes (30,33). After training, the statistical analysis indicated the participants as a group reduced their 0-9.14 m sprint time. There were several factors that could have contributed to the performance improvement. One of the causes for acceleration ability improvements may be that the athletes got stronger (8); as previously discussed, all groups increased their 3RM front squat and 3RM HBD. Previous research has shown improving strength can contribute to improvements in linear speed in adolescent athletes (10,28,55). Further, the program included linear sprint drills (31-33) and resisted sprinting (27,31,58), which can both improve sprint acceleration capabilities in athletic populations. The results show the value of strength and conditioning in improving sprint acceleration in high school girls athletes.

Nonetheless, the participants collectively did not significantly improve in the 0-18.29 m sprint interval from pre- to post-test, which was also reflected in the change score data. Speed over this distance involves the athlete transitioning from acceleration towards maximum velocity sprinting (12,38). Most team sport athletes, including softball players, emphasize speed over short distances that emphasize acceleration (30). While this study's linear speed drills focused mostly on acceleration technique with distances ranging from 0-18.29 m (i.e., 20 yards), strength and conditioning coaches may need to incorporate linear speed drills emphasizing longer-distance (>18.29 m) sprints into their programs to see greater improvements in speed over distances that approach maximum velocity. Additionally, for high school girls, there could also be a need for sprint technique development for sprints over longer distances (42). Future studies should investigate whether strength and conditioning programs could influence the sprint technique of high school girls.

The SBJ was assessed to indirectly measure lower-body leg power (34,36). With training, all groups collectively had a significant improvement in their SBJ from pre- to post-testing. Across the groups, the average increase was from about 4-8 cm. There were several factors that could have contributed to this SBJ performance enhancement. Firstly, the training program was focused on building strength and power, while also emphasizing motor skill development. Previous research has shown improving strength can enhance SBJ performance in adolescent athletes (46,67). Strength training has also displayed increases in rate of force development (1,23). An increase in rate of force development could have also attributed to the significant increase in SBJ. Furthermore, plyometrics were incorporated into the training regimen for the participants. Plyometric training has been shown to improve jumping power in previous studies involving children and adolescents (4,25), which is supported by the results of the current study. Notably, the SBJ has been used in previous studies as a measure of motor skill performance (60,61), and the participants from this study were able to improve this motor skill. These results are important considering the potential impact that better motor skill performance during adolescence could impact physical activity later in life (53).

Hitting is a fundamental skill in softball (18). Although there are multiple skills important to hitting the ball successfully in a game (e.g., recognizing type of pitch, tracking ball speed and trajectory, decision-making about when to swing the bat, reaction time, swing technique) (5), a greater ball exit velocity an athlete can generate in their swing relates to a longer distance the ball will travel and less time available for an opponent to react to the ball (44). The results from this study revealed participants collectively improved their hitting velocity following training. The improvements in hitting velocity could potentially be due to the total-body structure of the training program (i.e., use of various lower- and upper-body strength and power exercises). Previous research has shown upper- and lower-body strength and power has a significant relationship with hitting velocity in male high school and college baseball athletes (62). Additionally, all groups significantly increased their lower-body strength measured by both the 3RM front squat and 3RM TBD following training, which could have positively contributed to increased hitting velocity. The change in hitting velocity across each group was a notable result, as this demonstrated how a strength and conditioning program could positively influence a sport-specific motor skills in female high school athletes.

However, skill performance changes were not evident for the throwing velocity test. Throwing is a biomechanically complex skill, where athletes are tasked with sequentially generating and transferring energy from their lower-body to their upper-body in an effort to perform a powerful and accurate throw (17). Previous research has used throwing velocity as a measure of motor skill competence with youth athletes (57,60,61). However, possibly because of skill complexity, throwing velocity did not significantly improve from pre- to post-test for any of the groups, which was reflected in the very small magnitude of change following training for each group. These results are also similar to a study in six adolescent male cricket bowlers, where improvements in strength (measured by the bench press, bent over row, and hexagonal bar deadlift) following a 14-week training program did not translate to faster bowling delivery speed (26). Hislen et al. (26) attributed this in part due to 'lag time', where there was not sufficient time for motor learning strategies to show improvement relative to the strength changes. Similar to the current study, Hislen et al. (26) conducted post-testing in the week after completion of the training program. Another potential limitation to the softball athletes' training program is that the core exercises consisted of mainly multi-joint, structural, lower-body exercises (i.e., squat and deadlift variations). In line with this, it should be noted the program administered by the private facility staff was not expressly targeting throwing velocity, but rather general fitness qualities important for high school softball athletes. The softball athletes in this study may require specific exercises targeting the movements or involved muscles groups for the throwing action. Hermassi et al. (24) found young male handball players who performed 10 weeks of heavy-loaded resistance training, including the upper-body bench press and pull-over exercises, improved their throwing velocity more than those who performed moderate-load resistance training. Future research should investigate the effects of multi-joint, upper-body pushing and pulling exercises on throwing velocity for high school girls.

There are study limitations that should be considered. As stated, maturation was not measured in this study, and the physical development of the participants could have affected the results (2). This study did not include a control group, although this has occurred in other training studies (31-33). A sample of comparable high school softball athletes who were not training was not available for this study, and in real-world situations it would not be plausible to request athletes to not participate in training. Although training history was not provided to the researchers by the facility staff, it is possible it could have influenced the results. Each group had different ages, body sizes, and fitness levels prior to starting the training programs. The researchers had no control over this, as training frequency was governed by the athlete's availability and their parents' financial commitments to the private specialty training. Nevertheless, this meant some groups, such as the G2W group, may have had a greater capacity for improvements within the program compared to the G1W and G3+W groups. As mentioned previously, the researchers did not have input into the tests selected by staff at the private facility. While all tests had an application to softball, the inclusion of upper-body strength (e.g., bench press, pull-ups) (22,24) and change-of-direction speed (e.g., the 505) (45) tests would have been valuable. As noted, for the hitting velocity test, participants used their own bats and hit the ball off a tee, and which may have influenced the resultant technique and ball velocity (39,65). Nonetheless, this was a standard test at the facility with a focus of maximizing performance of the athlete by allowing them to use their own equipment. Moreover, each participant used the same bat and tee for pre- and post-testing. Only three trials were used for the hitting and throwing velocity tests, and it is possible that more trials could have featured a faster batted ball or throwing velocity. Lastly, the sample size was relatively small (N = 30), with an imbalance between groups (G1W: n = 6; G2W: n = 17; G3+W: n = 7), and only included female athletes; which, in turn, could have affected the results observed in this study. Male high school athletes may have responded differently on performance tests compared to their female counterparts. Future research on high school strength and conditioning should include both female and male athletes.

CONCLUSION

The results from this study demonstrated high school girls softball athletes who trained once, twice, or three or more times per week for 8 weeks within a private strength and conditioning facility significantly improved their lower-body strength (3RM front squat and HBD), linear speed over 9.14 m, lower-body power (SBJ), and hitting velocity. Most notably, the results from this study demonstrated a properly structured strength and conditioning program supervised by trained coaches could improve the physical performance of high school girls athletes. These results provide support for providing girls with access to properly structured and supervised strength and conditioning programs. Further, the results from this research showed an 8-week strength and conditioning program in high school athletes can deliver improvements in fitness and motor skills. High school coaches could use strength and conditioning to aid in the advancements of their athletes' fitness and movement competency. Additionally, for younger athletes (such as those in the G2W group), undergoing a greater frequency of training per week could help to close the performance gap between them and their competitors.

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CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

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ETHICAL APPROVAL

The study was approved by the Institutional Review Board (HSR-22-23-112) and conformed to the recommendations of the Declaration of Helsinki (68).

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