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Research article

THE EFFECTS OF A 4-WEEK STRENGTH AND CONDITIONING PROGRAM ON STRENGTH, POWER, AND THROWING VELOCITY FOR JUNIOR VARSITY AND VARSITY HIGH SCHOOL WATER POLO PLAYERS

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Abstract. *This study investigated the effects of a 4-week strength and conditioning program on the strength, power, and throwing velocity of male junior varsity and varsity high school athletes. Six junior varsity and eight varsity water polo players were recruited. Pre- and post-testing included isometric grip and leg/back strength; vertical jump (VJ); 2-kg medicine ball throw; and maximum throwing velocity with a water polo ball. All participants completed a 4-week strength and conditioning program designed to enhance base levels of strength. Data was analyzed via a two-way repeated measures ANOVA ($p<0.05$), including groups as a between-subjects factor measured at two levels (junior varsity, varsity). The within-subject factor (time) represented pre- and post-training measures. Change scores were calculated for each variable; independent samples t-tests ($p<0.05$) compared change scores between groups. There were significant time interactions for grip strength, leg/back strength, VJ, and throwing velocity ($p\leq0.031$). Post hoc analyses showed that the junior varsity group significantly improved grip strength, leg/back strength, and VJ ($p\leq0.019$). The varsity group improved grip strength and throwing velocity ($p\leq0.005$). There were no significant time*group interactions ($p=0.068$-0.156), or significant between-group differences in change scores ($p=0.134$-0.756). Thus, rate of improvement was not different between groups. Nonetheless, a greater adaptive reserve may have existed in the junior varsity group such that they experienced grip strength, leg/back strength, and VJ improvements after a short-term training program. A longer program may be required for varsity athletes to experience pronounced changes in strength and power. Nevertheless, these adaptations could translate into greater throwing velocity.*

Key words: *adolescent, isometric strength, lower-body power, motor skill, vertical jump*

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INTRODUCTION

Sports participation can be critical in the physical development of high school students, and depending on the school, a range of sports may be available. Survey data provided by the National Federation of State High School Associations indicated that 4,534,758 boys and 3,402,733 girls participated in structured high school sports programs (National Federation of State High School Associations, 2019). Regardless of the sport, high school athletes would also benefit from effective strength training and conditioning. Strength and conditioning programs are generally designed to enhance the physical performance and reduce the injury risk of athletes (Howe, Waldron, & Read, 2017), including high school-aged individuals. Resistance training is a common focus for the high school strength and conditioning coach (Duehring, Feldmann, & Ebben, 2009; Reynolds et al., 2012), and the position stand from the National Strength and Conditioning Association highlights a range of potential benefits associated with resistance training for young athletes (Faigenbaum et al., 2009).

There has been some research analyzing the effects of resistance training on high school-aged athletes. For example, Coutts, Murphy, & Dascombe (2004) found that a 12-week resistance training program in teenage rugby league players led to increased muscular strength (measured by the three-repetition maximum [3RM] bench press and back squat), lower-body power (vertical jump), and 20-m sprint speed. Channell & Barfield (2008) documented that 8 weeks of either Olympic lifting or traditional resistance training could improve vertical jump performance in high school football players. A 6-week whole-body resistance training program completed by female high school soccer players led to improvements in 3RM back squat, 3RM hip thrust, vertical and standing broad jump, and the pro-agility shuttle (Millar et al., 2020). In addition to improved muscular strength, power, and resistance to injury, other advantages could include enhanced performance of motor skills (Faigenbaum et al., 2009). Indeed, Millar et al. (2020) also found a 13.2% increase in ball kicking distance in their sample of female high school soccer players. This is especially important given that physical activity and exposure to different motor skills (such as resistance training exercises) during an individual's formative years could influence what they do in their sport. This could be especially useful for younger athletes (i.e., junior varsity athletes) as they generally have less experience than their older counterparts (i.e., varsity athletes).

However, the provision of strength and conditioning for the high school athlete can be variable in its delivery and its quality. There are some schools who will hire strength and conditioning coaches with specific, nationally recognized credentials (e.g., Certified Strength and Conditioning Specialists; CSCS), while others may not take this approach (Duehring et al., 2009). This is notable; as an example, a coach who has a CSCS is expected to follow established guidelines in their practice as it relates to designing safe and effective strength training programs (National Strength and Conditioning Association, 2017). Despite these potential benefits, some schools may not employ a certified strength and conditioning coach; instead, they may use sport coaches or physical education teachers (Reynolds et al., 2012). There are also sport coaches who may not require their athletes to participate in resistance training programs, even if they are available and designed by a certified strength and conditioning coach (Reynolds et al., 2012). Inappropriate application of strength and conditioning programs (or a lack of availability of these programs) could have negative downstream effects for high school athletes. In a survey conducted by Wade, Pope, & Simonson (2014), collegiate strength and conditioning coaches stated that incoming freshmen athletes from high school lacked lower extremity and core strength, flexibility, proper lifting technique, and mental toughness. Wade et al. (2014) suggested that these data collectively showed a lack of collegiate training and sport preparedness of high school athletes. Moreover, strength and conditioning for high school athletes could be even more important given current population trends of reduced physical activity and the impacts on motor skill and movement competency (Robinson et al., 2015; Stodden, Langendorfer, & Roberton, 2009).

One of the barriers for why sport coaches may not have their athletes participate in strength and conditioning programs is a perception of lack of time to train (Duehring et al., 2009; Reynolds et al., 2012). This is despite the potential benefits to numerous aspects of athletic performance (Faigenbaum et al., 2009). Therefore, more research is needed to analyze the general effectiveness of high school strength and conditioning programs administered by an appropriately educated coach. In addition to this, research in high school-aged athletes tends to focus on training programs ranging from 6 weeks (Millar et al., 2020; Noyes et al., 2012) to 12 weeks (Coutts et al., 2004). However, previous research in high school-aged athletes has shown that 4 weeks is enough time for an appropriate training program to lead to improved squat technique (Dobbs et al., 2021), the Functional Movement Screen (Boucher et al., 2021), and 36.6-m sprint times (Hammett & Hey, 2003). However, there is no research that has documented whether a 4-week strength and conditioning program can improve traditional measures of strength, power, and motor skill in high school athletes. It would be useful to demonstrate whether sport-specific fitness and skill performance could improve with a short-term training program. This would document that even the provision of 4 weeks of specific strength and conditioning could be beneficial for the high school athlete. Further, it would be beneficial to note whether junior varsity and varsity athletes respond different to short-term structured strength and conditioning programs. This would be beneficial considering that an appropriate strength and conditioning program could not only influence qualities such as strength and power, but motor skill performance as well (Millar et al., 2020).

Therefore, this study investigated the effects of a 4-week strength and conditioning program administered by a certified strength and conditioning coach on the strength, power, and throwing velocity of junior varsity and varsity male high school water polo players. This was a convenience sample of athletes who were available for pre- and post-testing prior to their competition season. The researchers were not involved in the design of the training program but administered the pre- and post-testing sessions. It was hypothesized that there would be improvements in strength, power, and throwing velocity for both the junior varsity and varsity groups. However, the improvements would be greater for the junior varsity group.

METHODS

Participants

Participants were recruited from the junior varsity and varsity water polo teams from one high school in southern California. This was a sample of convenience from this high school relative to access and availability of athletes during the pre-season period from March-May 2022. Twenty-one water polo players were available for this study. All participants received a clear explanation of the study, including the risks and benefits of participation. Following this, consent and assent forms were given to potential participants to take home to their parents/guardians. Parents/guardians were provided contact details for the researchers to have any questions they may have answered. A parent/guardian completed the consent form, while the participant completed the assent form. Fifteen players returned consent and assent forms and were included in this study. However, participants were excluded if they did not complete the pre- and post-testing sessions, and one participant did not complete post-testing. The results in final sample of 14 participants (age: 15.57 ± 0.94 years; height: 177.26 ± 6.60 cm; 77.06 ± 16.18 kg); 6 in the junior varsity group (age: 14.83 ± 0.41 years; height: 177.38 ± 6.31 cm; 79.48 ± 20.14 kg), and 8 in the varsity group (age: 16.13 ± 0.84 years; height: 177.16 ± 7.25 cm; 75.24 ± 13.70 kg). The sample size in each of the groups was similar to previous training studies (Lockie, Murphy, Callaghan, & Jeffriess, 2014a; Lockie et al., 2012; Millar et al., 2020). G*Power software (v3.1.9.2, Universität Kiel, Germany) was used to confirm post hoc that the sample size of 14 (with groups of 8 and 6 participants) was sufficient for a repeated measures analysis of variance (ANOVA) with within-between interactions such that data could be interpreted with a small effect level of 0.35 (Hopkins, 2004), and a power level of 0.90 when significance was set at 0.05 (Faul, Erdfelder, Lang, & Buchner, 2007). The methodology and procedures used in this study were approved by the institutional ethics committee (HSR-19-20-511). The research was conducted in agreement with the recommendations of the Declaration of Helsinki.

Procedures

Approximately one week before the two days of testing, players had an informal familiarization testing day to understand what was expected of them for each test and for the testing administrators to make sure equipment was working properly. Testing was conducted within two approximate 60-minute sessions during the pre-season at a southern California high school; pre-testing in the week prior to the training intervention, and post-testing in the week after the intervention. Both testing sessions were conducted at approximately 4 p.m. in the weight room at the high school. Test selection and order were conducted in collaboration with the school’s strength and conditioning director and coaches, with consideration given to time constraints and sport coach priorities. Prior to data collection, the participant’s age, height, and mass were recorded. Height was measured using a stadiometer (Health O Meter, Ontario, Canada); body mass was recorded using electronic digital scales (Tanita Corporation of America, Inc., Illinois, USA). The head coach took the participants through their standard warm-up prior to testing. The participants were placed in two groups, and either completed the grip strength and leg/back dynamometer tests (strength station), or the vertical jump (VJ) and seated medicine ball throw (MBT) tests (power station). Following completion of both tests, participants switched to the other station. Participants rotated through in the same order for both stations, which ensured sufficient recovery periods for each participant. Testing circuits have been used in previous research (Collins et al., 2022; Lockie et al., 2021; Lockie et al., 2020a; Lockie et al., 2018a; Lockie et al., 2020d). Furthermore, all the tests conducted in this study were short-duration assessments. After completing the strength and power stations, the participants completed the maximum throwing velocity test outside the weight room. For each test in this study, three trials were completed with the average used for analysis. The procedures for the individual tests will be detailed hereafter.

Grip Strength

Grip strength provided a measure of upper-body strength (Ruprai, Tajpuriya, & Mishra, 2016), and has been used previously to assess strength in adolescents (Hager-Ross & Rosblad, 2002). A hand grip dynamometer (Takei Scientific Instruments, Niigata City, Japan) measured strength in each hand with procedures adapted from the literature (Lockie et al., 2021; Lockie et al., 2020c; Lockie et al., 2020d). Participants kept their testing arm by their side and squeezed the handle as hard as possible for approximately 2 s. The left hand was tested first for all participants. The average for both hands were summed together to provide the grip strength metric.

Isometric Leg/Back Strength

Leg and back isometric strength were measured by a leg/back dynamometer (Fabrication Enterprises, Inc., New York, USA) (Dawes et al., 2019; Dawes et al., 2017; Lockie et al., 2020b; Lockie et al., 2020c). The participant was positioned on the dynamometer so their arms were extended and both hands were on the handle placed at the mid-thigh (knee angle of ~110°) (Dawes et al., 2019; Dawes et al., 2017; Lockie et al., 2020b; Lockie et al., 2020c). From here, while maintaining proper spinal alignment and their feet flat on the base, participants pulled the handle upward as hard as possible by attempting to extend the hips and knees.

Vertical Jump (VJ)

The VJ was used to indirectly measure lower-body power via a jump mat (Just Jump, Probotics Inc., Huntsville, USA) (Lockie et al., 2016; Lockie et al., 2018b; McFarland, Dawes, Elder, & Lockie, 2016). The participant stood on the jump mat, before completing a countermovement and jumping as high as possible. No preparatory step was used, and no restrictions was placed on the countermovement range of movement or arm swing used. Participants were to maintain extended legs during flight, before landing on both feet. Within the jump mat software, VJ height was calculated in inches before being converted to cm for this study.

Seated Medicine Ball Throw (MBT)

The seated MBT indirectly measured upper-body power (Lockie et al., 2021; Lockie et al., 2018a; Lockie et al., 2020d). Participants sat with their head, shoulders, and lower back against a concrete wall, and projected a 2-kg medicine ball (Champion Barbell, Dallas, USA) as far as possible using a two-handed chest pass (Lockie et al., 2021; Lockie et al., 2018a; Lockie et al., 2020d). The perpendicular distance from the wall to the where the ball first contacted the ground was taken using a standard tape measure (Apex Tool Group, Sparks, USA).

Throwing Velocity

Throwing velocity was included because it has been used to measure motor skill competence (Stodden et al., 2009) and is an essential skill for water polo (Botonis, Toubekis, & Platanou, 2019; McCluskey et al., 2010; Smith, 1998; Vila et al., 2009). There are few studies that have investigated the effects of resistance training programs on motor skill performance in teenage athletes (Millar et al., 2020). Throwing trials were performed outdoors, and velocity was measured by a radar gun (Stalker Sport 2, Stalker/Applied Concepts, Texas, USA). An adaptation was made for this study whereby the participants threw a standard water polo ball (Hydro Grip Size 5, KAP 7 International, Inc., Irvine, USA) as fast as possible with the dominant hand from behind a start line, with one stride towards the target (Freeston et al., 2016). A researcher was positioned approximately 40 feet (12.19 m) in front of the participant with the radar gun to measure throwing velocity in kilometers per hour (km/hr). The radar gun was aimed at the ball release point, and this positioning was similar to previously published research (Callaghan et al., 2021; Callaghan et al., 2019).

Training Program

The program completed by the two groups is shown in Table 1. All athletes completed the same program, with individual modifications made relative to the loading used for different exercises. The strength and conditioning coach who designed the programs for the junior varsity and varsity athletes had an accredited certification with a national organization. Accordingly, they were required to adhere to codes of practice relative to the safe and effective design of resistance training programs (National Strength and Conditioning Association, 2017). The program followed traditional periodization principles (Haff, 2016), whereby the primary goal was to develop a foundation of strength and set-up the athletes for future phases of training (e.g., power development). Due to circumstances outside the control of the strength and conditioning coach (Spring break and the coach had jury duty), there was a 2-week break in-between the first 2 weeks and last 2 weeks of the program. Nonetheless, this program provides a real-world example of strength and conditioning at the high school level. Three sessions were completed in the first three weeks of the program (Monday, Tuesday, and Thursday). In the fourth week, only two sessions were completed (Tuesday and Thursday). Each training session was approximately 45-60 minutes and was a mix of compound and isolation exercises. Supersets and circuits were featured throughout the program. As previously noted, the researchers did not have input into the design of the program; exercise selection and program design were entirely up to the discretion of the strength and conditioning coach.

Table 1 Training program completed by the junior varsity and varsity groups. The letters and numbers indicate whether exercises were completed as part of a superset, tri-set, or circuit. LWP: Linear weight progression. 1RM: One-repetition maximum.

Week 1					
Session 1 (Monday)		Session 2 (Tuesday)		Session 3 (Thursday)	
Exercise	Sets x Repetitions	Exercise	Sets x Repetitions	Exercise	Sets x Repetitions
A1. Prone Y's, T's	2 x 8	A1. Low Pogo Jumps	1 x 20 @ 10 lbs	A1. Superman	2 x 8
A2. Quadruped T-Spine Rotations	2 x 8	A2. Goblet Squat	1 x 10 @ 10 lbs	A2. Shoulder Taps	2 x 8
A3. Fire Hydrant	2 x 8	A3. Single Leg Pogo	1 x 10 @ 10 lbs	A3. Push-up	2 x 5

B1. Front Squat	8, 6, 4, LWP+0	A4. Plate Overhead Lunge	1 x 10	B1. Bench Press	8, 6, 4, 2 @ 65%, 75%, 80%, 83% 1RM
B2. Bird Dog Row	3 x 8	A5. Romanian Deadlift to Goblet Squat	1 x 10	B2. Hamstring Marches	3 x 12
C. Front Squat	1 x 5	B1. Trap Bar Deadlift	3 x 5 @ 45, _, _ lb	C. Bench Press	1 x 5 @ 85% 1RM
D1. Wide-grip Pull-ups	3 x 5	B2. Plank	3 x 1 @ 50 seconds	D1. Band Hamstring Curl	3 x 12
D2. In-Outs	3 x 10 @ 25 lbs	C1. Trap Bar Deadlift	3 x 5	D2. Banded Triceps Pushdown	3 x 20
E1. Half-kneeling Dumbbell Shoulder Press	3 x 6	C2. Inverted Row	3 x 5	D3. Pull-up	3 x Maximum
E2. Dumbbell Bicep Curls	3 x 15 LWP+5	D1. Trap Bar Deadlift	3 x 8	E1. Incline Triceps Extension	15, 12, 10, @ 25, _, _ lbs
		D2. Barbell Shrug	3 x 1	E2. Dumbbell Half-kneeling Low-to-High Chop	10, 8, 6 @ 15, _, _ lbs
		E1. Band W's	3 x 10	E3. Band Pull-apart	3 x 20
		E2. Leg Raises	3 x 10		
Week 2					
Session 1 (Monday)		Session 2 (Tuesday)		Session 3 (Thursday)	
A1. YTW	2 x 8	A1. Thoracic Rotations (Side Lying)	2 x 6	A1. Cossack Squat	3 x 10 @ 25 lbs
A2. ATG Split-squat	2 x 6 @ 5 lbs	A2. Shoulder Taps	2 x 6	A2. Band W's	3 x 10
A3. Single-leg Pogo	2 x 10	A3. Band Pull-apart	2 x 8	A3. Copenhagen Plank	3 x 8 @ 3 seconds
B1. Front Squat	3 x 8 @ 50, 60, 65% 1RM	A4. Pallof Press	2 x 8	B1. Inverted Row	3 x 8
B2. Half-kneeling Dumbbell Shoulder Press	3 x 8	B1. Bench Press	3 x 8 @ 50, 60, 70%	B2. Side Plank with Hip Abduction	3 x 10
C1. Front squat	3 x 5 @ 70% 1RM	B2. Trap Bar Deadlift	3 x 5 LWP+5	B3. Reverse Plank Marches	3 x 10
C2. Landmine Anti-rotation	3 x 8	C1. Bench Press	3 x 8 @ 50, 60, 70% 1RM	C1. Partner Nordic Hamstring Curl	3 x 5 @ 3 seconds
D1. Wide-grip Pull-ups	3 x 1 @ 30 seconds	C2. Trap Bar Deadlift	3 x 5 LWP+5	C2. Pull-up	3 x 8

D2. In-outs	3 x 10 @ 25 lbs	D1. Bird Dog Row	10, 8, 6, LWP+2.5, 5, 10	C3. Zottman Curls	3 x 10
D3. Dumbbell Bicep Curls	3 x 15 LWP+5	D2. Scap Push-up	3 x 6		
		E1. Incline Triceps Extension	3 x 12 LWP+2.5		
		E2. Side Plank Rotation	3 x 8 @ 2.5. lbs		
Week 3					
Session 1 (Monday)		Session 2 (Tuesday)		Session 3 (Thursday)	
A. Front Squat	8, 8, 6 @ 50, 60, 65% 1RM	A1. Wide-grip Pull-ups	4 x 5 @ 3 secondsA2.	A1. Hang Snatch Warm-up	1 x 1
B. Front Squat	3 x 6 @ 70, 75, 75% 1RM	A2. Dumbbell Bicep Curls	15, 12, 10, 8 LWP+5	A2. Hang Clean Warm-up	1 x 1
C1. Wide-grip Pull-ups	3 x 8 @ 30 seconds	A3. Toe Touches	4 x 15 @ 25 lbs	B1. Bench Press	3 x 8 @ 50, 60, 70% 1RM
C2. Hollow Body Holds	3 x 45 seconds @ 25 lbs			B2. Side Plank with Shoulder Eccentrics	3 x 6
C3. Dumbbell Bicep Curls	3 x 12 LWP+5			C. Bench Press	3 x 8 @ 75% 1RM
				D1. Inverted Row	3 x 8
				D2. Dumbbell Triceps Extension	3 x 10
				E1. Barbell Bicep Curl	3 x 8
				E2. Leg Raises	3 x 15
Week 4					
		Session 1 (Tuesday)		Session 2 (Thursday)	
		A. Hang Clean Warm-up	1 x 1 @ 45 lbs	A1. Romanian Deadlift	3 x 8 @ 50, 60, 65% 1RM
		B. Hang Clean	4 x 5	A2. Bird Dog Row	3 x 8
		C1. Front Rack Split-Squat	3 x 8 @ 20, 30, 35% 1RM	B1. Romanian Deadlift	3 x 6
		C2. Landmine Anti-rotation	3 x 8 @ 25, _, _ lbs	B2. Bird Dog Row	3 x 6
		D1. Front Rack Split-Squat	3 x 6 @ 40, 45, 45% 1RM	C1. Incline Bench Press	8, 6, 6 @ 35, 35, 45% 1RM
		D2. Landmine Half-kneeling Shoulder Press	3 x 8	C2. Side Plank with Shoulder Eccentrics	3 x 8
		E1. Strict Bodyweight Pull-up	3 x 6	D1. Bench Press	3 x 5 @ 50% 1RM

	E2. Single-arm Overhead Farmer's Walk	3 x 20 yards	D2. Russian Twist	3 x 10
	F1. Banded Triceps Pushdown	3 x 15	E1. Reverse Grip Barbell Bicep Curl	3 x 10
	F2. Dumbbell Half-kneeling Low-to-High Chop	3 x 8 @ 30 lbs	E2. Leg Raises	3 x 15
			E3. Cable Rope Bicep Curl	3 x 12

Statistical Analysis

Statistical analyses were processed using the Statistics Package for Social Sciences (Version 27; IBM Corporation, New York, USA). Descriptive statistics (mean ± standard deviation [SD]) were calculated for the pre- and post-test data. Normality of the data was evaluated by visual analysis of Q-Q plots (Callaghan et al., 2020; Jeffriess et al., 2015; Orjalo, Callaghan, & Lockie, 2020; Orjalo, Lockie, Balfany, & Callaghan, 2020) and the Kolmogorov-Smirnov test (Ghasemi & Zahediasl, 2012; Lockie, Orr, & Dawes, 2022). Following the training period, data was analyzed via a two-way repeated measures ANOVA ($p < 0.05$), including groups as a between-subjects factor measured at two levels (junior varsity and varsity) (Bloomfield, Polman, O'Donoghue, & McNaughton, 2007; Lockie et al., 2014a; Lockie, Schultz, Callaghan, & Jeffriess, 2014b; Spinks, Murphy, Spinks, & Lockie, 2007). The within-subject factor (time) represented the pre- and post-training measures. As only two repeated measures were employed, the assumption of Mauchly's test of sphericity was not applicable (Lockie et al., 2014a; Lockie et al., 2014b; Spinks et al., 2007). All other repeated measures ANOVA assumptions were considered, with the Levene statistic used to determine homogeneity of variance. If a significant F ratio was detected, post hoc tests were performed using the Bonferroni adjustment procedure. Effect sizes (d) were also derived for the pre- to post-test comparisons within each group, where the difference between the means was divided by the pooled SD (Cohen, 1988). A d less than 0.2 was considered a trivial effect; 0.2 to 0.6 a small effect; 0.6 to 1.2 a moderate effect; 1.2 to 2.0 a large effect; 2.0 to 4.0 a very large effect; and 4.0 and above an extremely large effect (Hopkins, 2004).

In order to further investigate between-group comparisons, change scores were calculated for each variable for the junior varsity and varsity groups (Cocke, Dawes, & Orr, 2016). Change scores were calculated as the difference between the post-test and pre-test data (Cocke et al., 2016). Independent samples t-tests compared the change scores between the groups ($p < 0.05$). Levene's test for equality of variances were checked to determine whether equal variances were to be assumed for each variable or not. Effect sizes were also calculated for the change score comparisons.

RESULTS

The Kolmogorov-Smirnov data for the junior varsity group indicated all pre- and post-test variables were normally distributed (p = 0.200). With regards to the varsity group, all pre- and post-test variables were normally distributed (p = 0.103-0.200) except for leg/back strength (p = 0.029-0.037). However, visual analysis of the Q-Q plots indicated no outliers, so it was deemed appropriate to use parametric statistics. There was a significant main effect for time (F(1, 12) = 31.539, p < 0.001), but not time*group (F(1, 12) = 2.295, p = 0.156) for combined grip strength. Post hoc analyses indicated that both groups significantly improved this metric following the training intervention (moderate effects for both groups), although the varsity group was stronger at both time points. For leg/back strength, there was a significant main effect for time (F(1, 12) = 6.781, p = 0.023), but not time*group (F(1, 12) = 3.311, p = 0.094). Post hoc data revealed that the junior varsity group significantly improved their leg/back strength (moderate effect), but the varsity group did not (trivial effect). The varsity group was superior in leg/back strength in the pre-test (p = 0.040), but not the post-test (p = 0.185). With regards to the VJ, was a significant main effect for time (F(1, 12) = 17.638, p = 0.001), but not time*group (F(1, 12) = 2.585, p = 0.134). Post hoc analyses revealed that the junior varsity group significantly improved their VJ (moderate effect); the varsity group did not (small effect). The varsity group had a higher VJ in the pre-test (p = 0.009), but not the post-test (p = 0.095). There were no significant interactions for time (F(1, 12) = 2.746, p = 0.123) or time*group (F(1, 12) = 3.768, p = 0.076) for the MBT. As there was no significant interaction for time, post hoc analyses for the effects of training were not considered for the MBT. There was, however, a small effect for the increase in MBT distance for the junior varsity group. The varsity group had a trivial decline in MBT distance from pre- to post-test. The varsity group had a greater MBT distance for the pre-test (p = 0.016) but not the post-test (p = 0.104). Lastly, for throwing velocity there was a significant main effect for time (F(1, 12) = 5.996, p = 0.031), but not time*group (F(1, 12) = 4.013, p = 0.068). Post hoc calculations indicated that the varsity group significantly improved their throwing

Table 2 Descriptive (mean ± SD) data for the junior varsity and varsity groups pre- and post-training for combined grip strength (GS), leg/back strength (LBS), vertical jump (VJ), medicine ball throw (MBT), and throwing velocity (TV).

	Junior Varsity (n = 6)				Varsity (n = 8)			
	Pre	Post	p	d	Pre	Post	p	d
GS (kg)	63.56 ± 4.80	74.00 ± 15.45*	0.019	0.91	83.75 ± 18.15§	101.92 ± 14.81ɸ*	<0.001	1.10
LBS (kg)	105.84 ± 25.26	119.70 ± 26.97*	0.013	0.53	137.59 ± 25.67§	140.05 ± 26.63	0.560	0.09
VJ (cm)	41.62 ± 10.15	49.16 ± 10.14*	0.002	0.74	54.91 ± 5.76§	58.28 ± 8.68	0.071	0.46
MBT (m)	5.16 ± 0.87	5.63 ± 0.78	na	0.57	6.48 ± 0.88§	6.44 ± 0.90	na	0.04
TV (km/hr)	59.28 ± 6.92	59.55 ± 7.48	0.773	0.04	65.45 ± 5.98	68.13 ± 7.23*	0.005	0.40

§ Significantly (p < 0.05) different from the junior varsity pre-test data.
ɸ Significantly (p < 0.05) different from the junior varsity post-test data.
* Significant (p < 0.05) change from pre- to post-test.
na Post hoc analyses were not considered for this variable.

velocity post-testing (small effect), while the junior varsity group did not (trivial effect). There were no significant differences between the groups for the pre- ($p = 0.099$) or post-test ($p = 0.051$) throwing velocity.

Change score data were also used to analyze between-group differences following the training protocols, and these are shown in Table 3. Equal variances were assumed for all variables except VJ. There were no significant differences between the junior varsity and varsity groups in any of the change scores. There was a moderate effect for the greater change in grip strength experienced by the varsity group compared to the junior varsity group. All other effects were trivial-to-small.

Table 3 Change score data (mean ± SD) for the junior varsity and varsity groups for combined grip strength, leg/back strength, vertical jump, medicine ball throw, and throwing velocity.

	Junior Varsity ($n = 6$)	Varsity ($n = 8$)	p	d
Combined Grip Strength (kg)	10.33 ± 8.91	18.33 ± 9.64	0.134	0.868
Leg/Back Strength (kg)	9.07 ± 13.92	6.05 ± 12.31	0.674	0.233
Vertical Jump (cm)	4.57 ± 7.30	5.60 ± 3.11	0.756	0.195
Medicine Ball Throw (m)	0.33 ± 0.48	0.07 ± 0.58	0.379	0.494
Throwing Velocity (km/hr)	1.16 ± 2.97	2.01 ± 2.18	0.548	0.334

Discussion

This study provided a preliminary investigation of the effects of a 4-week structured strength and conditioning program on the strength, power, and throwing velocity of junior varsity and varsity male high school water polo players. It was hypothesized that the training program would improve strength, power, and throwing velocity, with performance changes being greater in the junior varsity group. The study results provided some credence to this concept, and supported previous research in high school-aged athletes that showed 4 weeks of specific training can improve movement capabilities and neuromuscular coordination (Boucher et al., 2021; Dobbs et al., 2021; Hammett & Hey, 2003). In the current study, this occurred even though there was a two-week break in the middle of the program due to extenuating circumstances (Spring break and absence of the strength and conditioning coach due to jury duty). The junior varsity group significantly improved their grip strength, leg/back strength, and VJ. The varsity group significantly grip strength and throwing velocity. These data suggested some adaptations specific to the junior varsity and varsity groups. However, there were no significant time*group interactions or differences in change scores, which suggested that within this sample there were no differences in the rate of change for any of the variables tested. As will be discussed, the results provide support for structured strength and conditioning programs for high school athletes.

The varsity group significantly outperformed the junior varsity group in all pre-tests except throwing velocity, although the varsity group still had a 10% faster throw. This was expected, with the physiological changes that occur with increased age and maturation during adolescence (e.g., increased strength, muscle mass, neuromuscular development, coordination) (Radnor et al., 2018; Tumkur Anil Kumar et al., 2021). Interestingly, for the post-test data the varsity group was only significantly better in grip strength. This provides some indication that the junior varsity group was able to improve such that their strength, power, and throwing velocity to progress closer to that of their varsity counterparts. Nonetheless, and as previously stated, there was no significant time*group interactions of differences between the change scores. Although commentary on specific aspects of maturation (e.g., skeletal age) are outside the scope of this study, the results do provide some evidence for the value of strength and conditioning in high school athletes. This is reflected in some of the specific results from the current research.

Grip strength has direct application to water polo players (Ferragut et al., 2011), as players need to wrestle with their opponents and throw the ball with high velocities (Botonis et al., 2019). Developing grip strength has been recommended for wrestling (Zemke & Wright, 2011) and grip has been related to throwing velocity in elite water polo players (Ferragut et al., 2011). Both groups were able to significantly improve combined grip strength following the 4-week training intervention. Grip strength is required in almost all resistance training exercises where a bar or dumbbell needs to be gripped. As grip strength relates to manual lifting and carrying tasks (Leyk et al., 2007), it is not unexpected that both groups were able to experience improvements in this strength metric. Nevertheless, the results from this study demonstrate that an appropriately designed 4-week strength and conditioning program can significantly improve grip strength on both junior varsity and varsity water polo players.

Isometric leg/back strength has been related to different aspects of physical performance, including dynamic strength (i.e., repetition maximum strength tests) (McGuigan, Newton, Winchester, & Nelson, 2010), jumping (Dawes et al., 2019; McGuigan et al., 2010; Merrigan, Stone, Hornsby, & Hagen, 2021), linear speed (West et al., 2011), and change-of-direction speed (Lockie, Post, & Dawes, 2019; Post, Dawes, & Lockie, 2022; Spiteri et al., 2015). Although high school water polo players may not need to run in their sport, lower-body strength is essential within this sport (Botonis et al., 2019). Previous research in adult law enforcement recruits has shown that a strength and conditioning program that features exercises such as front squats and cleans can improve leg/back isometric strength by approximately 10% (Lockie et al., 2020b). However, the program analyzed by Lockie et al. (2020b) was conducted over a total of 27 weeks. The junior varsity group in this study was able to significantly improve leg/back strength by 13% after 4 weeks. However, the 4-week period was not sufficient for the varsity group to significantly improve isometric leg/back strength. This may relate to the lower leg/back strength and the start of the training intervention for the junior varsity group, and these athletes may have had a larger adaptive reserve for improvement (Muehlbauer, Gollhofer, & Granacher, 2012). Nonetheless, the data from this study demonstrated that even a short-term strength and conditioning program can lead to improved lower-body strength in junior varsity athletes. Future research should investigate the effects of longer-term strength and conditioning programs on high school athletes.

Lower-body power is essential quality for water polo players (De Siati et al., 2016; McCluskey et al., 2010; Smith, 1998), in addition to many athletes in general, so it would be very beneficial for a short-term strength and conditioning program to improve this quality in high school athletes. The junior varsity group significantly improved VJ by 18% following the 4-week training intervention. Lower-body strength relates to VJ performance (Dawes et al., 2019; McGuigan et al., 2010; Merrigan et al., 2021), so the improved leg/back strength for the junior varsity group likely contributed to the enhanced jump performance. The larger adaptive reserve for the junior varsity athletes would also be a factor (Muehlbauer et al., 2012), especially considering the VJ results for the varsity group. The 6% VJ increase experienced by the varsity group was not a significant change, and this may mean the 4-week period was not sufficient to improve the jump in these participants. However, technique and coordination is also an important part of being able to translate force production into an effective jump (Hudson, 1986; Vanezis & Lees, 2005), and this can be developed through appropriate periodization (Haff, 2016). Indeed, the primary goal of this 4-week program was strength as opposed to power, so this could also form part of the reason why there was not a significant VJ increase for the varsity group. Future studies should investigate long-term strength and conditioning programs for high school athletes, with periodization plans to develop strength and power. This could especially be impactful for older high school athletes.

The MBT provides a measure of upper-body power (Lockie et al., 2021; Lockie et al., 2018a; Lockie et al., 2020d). There was no significant interaction for time in this study, so post hoc analyses were not considered for either the junior varsity or varsity groups. The upper-body push actions for the MBT are somewhat dissimilar to upper-body actions required in water polo, such as for the swimming stroke and overhead throwing (Botonis et al., 2019; Smith, 1998). This could have affected the results seen in this study. Further to this, power was not the primary focus of the strength and conditioning program completed by the athletes in this study. Nevertheless, it should be noted that there was a 9% increase in MBT distance for the junior varsity group which also had a small effect, which could be somewhat reflective of the results seen for grip strength, leg/back strength, and the VJ. The larger adaptive reserve for the junior varsity group provided more scope for improvement in upper-body power following a short-term strength and conditioning program (Muehlbauer et al., 2012). Further research is needed on whether a long-term strength and conditioning program can influence upper-body power in high school athletes, whether measured by the MBT or some other upper-body test (e.g., bench throw velocity).

Throwing velocity has been used to assess motor skill competence (Stodden et al., 2009), and is an essential skill for water polo (Botonis et al., 2019; McCluskey et al., 2010; Smith, 1998; Vila et al., 2009), so has direct application for the participants in this study. The junior varsity group did not significantly improve their throwing velocity following the 4-week training intervention. In contrast, the varsity group had a significant 4% increase in throwing velocity after training. This supports previous research by Millar et al. (2020), who found 6 weeks of resistance training could improve kicking distance in female high school soccer players. The neuromuscular development of the varsity group may have left them better equipped to facilitate and adaptations from the strength and conditioning program (e.g., greater grip strength) into the more complex skill of throwing. Age can be a factor in being able to translate resistance training adaptations into throwing performance (Martínez-García et al., 2021). Additionally, motor skill development for high school athletes is very important. Individuals that display better motor competence during childhood or adolescence tend to be more physically active during adulthood, which can greatly impact health outcomes (Robinson et al., 2015; Stodden et al., 2009). The increase in throwing velocity by the varsity athletes is an important result, as these data indicate that a structured strength and conditioning program can improve a sport-specific motor skill in high school athletes. Notwithstanding the potential fitness benefits that can result from a training program (Faigenbaum et al., 2009), the current results also provide a counterpoint for coaches who feel more training time should be dedicated to sport-specific skill development (Duehring et al., 2009; Reynolds et al., 2012). Motor skill performance could be positively influenced by an effective strength and conditioning program. Prospective studies should investigate a longer-term strength and conditioning program on motor skill performance in high school athletes, as more time may be required for younger athletes (i.e., junior varsity) to experience positive adaptations.

There are study limitations that need to be acknowledged. The sample size was small (N = 14), and only male athletes from one sport were used in this study. Future research into high school strength and conditioning programs should use larger samples, males and females, and athletes from a range of sports. Nonetheless, this study provided an important step in the analysis of structured strength and conditioning for high school athletes, and the results should be generalizable across other junior varsity and varsity athletes. The training program investigated was only over a short time period of 4 weeks, so future studies are needed to investigate longer-term strength and conditioning programs for high school athletes (e.g., over the course of a semester). As previously noted, there was a two-week break in the middle of the program due to outside factors. Nonetheless, this study provided an analysis of a real-world example of a strength and conditioning within the high school environment. In addition to this, the participants in this study were still able to experience improvements in strength and power even within a less-than-optimal program design. The testing battery adopted in this study was relatively limited, which was due to time constraints and the restrictions placed by the high school strength and conditioning and sports coaching staff. Forthcoming research on high school strength and conditioning would benefit from analyzing other fitness tests (e.g., anaerobic and aerobic capacity, linear and change-of-direction speed) and motor skill assessments (e.g., jumping, landing, kicking).

CONCLUSIONS

This study showed that a 4-week strength and conditioning program could improve the strength, power, and throwing velocity for male high school water polo players. Although there were no significant time*group interactions or differences between change scores, there were some specific adaptations for junior varsity and varsity athletes. The junior varsity group significantly improved their grip strength, leg/back strength, and VJ. The varsity group significantly improved their grip strength and throwing velocity. A greater adaptive reserve may have been present in the junior varsity athletes such that they could experience significant changes in upper-body and lower-body isometric strength, in addition to lower-body power. However, junior varsity athletes may require more time to translate these adaptations into a specific motor skill such as throwing. A longer strength and conditioning program may be required for varsity athletes to experience more pronounced changes in strength and power. Nevertheless, they could translate any changes in these qualities into the specific motor skill measured in this study. Future research should investigate longer-term strength and conditioning programs and how they influence fitness outcomes and motor skill performance in high school athletes.

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EFEKTI ČETVORONEDELJNOG PROGRAMA TRENINGA SNAGE I KONDICIONOG TRENINGA NA SNAGU, SILU I BRZINU BACANJA MEĐU PRVORANGIRANIM I DRUGORANGIRANIM TIMOVIMA VATERPOLISTA SREDNJOŠKOLSKOG UZRASTA

*U ovom istraživanju analizirani su efekti četvoronedeljnog progama treninga snage i kondicionog treninga na snagu, silu, i brzinu bacanja među vaterpolistima srednjoškolskog uzrasta, pripadnika prvorangiranog i drugorangiranog tima. Šest pripadnika drugorangiranog i osam pripadnika prvorangiranog vaterpolo tima regrutovani su za potrebe ovog istraživanja. Pretest i post-test uključivali su izometrijski test hvata i snage nogu/leđa; skok u vis (VJ); bacanje medicinke od 2-kg; i maksmialna brzina bacanja vaterpolo lopte. Svi ispitanici učestvovali su u četvoronedeljnom programu treninga snage i kondicionom treningu kako bi uvećali osnovne vrednosti snage. Podaci su analizirani dvosmernom ANOVA testom sa ponovljenim merama ($p<0.05$), gde je pripadnost grupi bila faktor merenja između ispitanika na dva nivoa (prvorangirani i drugorangirani tim). Vrednosti merenja pre i posle treniranja predstavljale su faktor promene između ispitanika (vreme). Promene u vrednostima izračunate su za svaku varijablu; t-test za nezavisne uzorke ($p<0.05$) poredio je promene u vrednostima između grupa. Značajne interakcije sa vremenom uočene su za snagu hvata, snagu nogu/leđa, i VJ ($p\leq0.019$). Prvorangirana grupa poboljšala je snagu hvata i brzinu bacanja ($p\leq0.005$). Nisu uočene značajne interakcije vreme*grupa ($p=0.068$-0.156), ili značajne razlike između grupa u promeni vrednosti ($p=0.134$-0.756). Samim tim, stopa poboljšanja nije se razlikovala između grupa. Ipak, veća adaptivna rezerva možda je postojala među pripadniciam drugorangiranog tima tako da su među njima uočena poboljšanja za snagu hvata, snagu nogu/leđa i VJ nakon kraćeg programa treninga. Duži program treninga je potreban kako bi prvorangirani tim mogao značajnije da napreduje u pogledu snage i sile. Ipak, ove adaptacije bi mogle da dovedu do veće brzine bacanja.*

Ključne reči: *adolescenti, izometrijska snaga, snaga donjih ekstremiteta, motoričke veštine, skok u vis*