Original Research

Effects of Exercise Sequence in Resistance-Training on Strength, Speed, and Agility in High School Football Players

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ABSTRACT

International Journal of Exercise Science 6(2) : 126-133, 2013. Manipulating variables in a training program (e.g., sets, reps, lifts, sequence, etc.) is designed to maximize strength and power performance. Due to the complexity of designing resistance-training programs, changing one variable could potentially set an athletic team apart from others in performance. The purpose of this study was to investigate if exercise sequence could influence the development of strength, speed, and agility. This study compared two specific types of exercise sequences: traditional, which performs the prescribed exercises in a traditional or blocked manner (by completing every set of an exercise before moving to the next); and, circuit, which performs the prescribed exercises in a circuit or alternating manner (by completing the first set of each prescribed exercise, then going to the second set of each exercise). Thirty-nine adolescent athletes from two separate high school football teams completed identical six-week resistance-training programs with the only difference being the sequence of the exercises. Each group tested pre- and post-intervention on hang clean, bench, squat, 40-yard dash, and pro agility. A strength index was used to measure overall strength gained by dividing the sum of the three lifts by total body weight. The results demonstrated that the only significant difference between groups occurred with hang clean. Both circuit and traditional groups made significant but equal gains when compared independently pre- to post-intervention. These results suggest that if strength gains are desired, then either a circuit or traditional style of exercise sequence will produce equal results regardless of beginning level of strength.

KEY WORDS: Weight training variation, summer football training, traditional versus circuit training

INTRODUCTION

In the 1950's Coach Al Roy was one of the first to introduce weight training to high school and college athletes with positive results including decreased injuries, and increased speed. Ever since then resistance training has remained an integral component for sports teams. Scientific investigations have shown that significant benefits such as increased power (3, 4), kicking performance (20) vertical jump (2), overhead throwing velocity (19), and explosive strength (14) can be gained from the systematic and proper application of resistance-training principles (5, 6, 12, 15). It has also been established that neurological adaptations are the primary cause for improvements in strength within the first 3-4 weeks of resistance training (3, 4, 11, 13). Muscle hypertrophy, the increase in the size and function of a muscle fiber, is commonly seen in weeks 8-12 from the start of the training program (9, 16, 17).

Periodization is the systematic process of planned variations in a strength-training program over a training cycle and usually refers to manipulating the amount of rest between sets, number of sets, or number of repetitions within each set (7, 8, 10). The manipulation of variables in a training program is designed to maximize strength and power. Due to the complexity of designing a resistance-training program, one variable could potentially set an athletic team apart from others in performance (12).

There is a paucity of research focusing on the effects of exercise sequence and its relationship to strength, agility, and power outcomes with adolescents. Landin and Nelson (2007), examined three different variations of exercise sequence in a partial strengthening program focusing on an upper extremity of the body, specifically, the elbow in untrained men. Landin and Nelson compared three exercise sequences; blocked or traditional manner of strength training (completion of all sets of the exercise before continuing to another exercise), alternating (completing one set of each exercise in a circuit or alternating manor), and semi-blocked to a single set program using untrained adult men. The results revealed significant gains in strength for all groups from pre-test to post-test in all exercises. The only sequence that showed significant improvement from the single set program was the blocked regimen while performing the arm curl exercise. Where Landin and Nelson left-off, the current study has attempted to elucidate further the effects of exercise sequence in both upper and lower body exercises and in high school football players instead of adult males. Related to this research methodology and to further support the current research question related to younger athletes, Pearson et al. (2000) recommended that young athletes should typically perform 6-12 repetitions for each exercise and have a training frequency of 2-3 days per week of resistance training. Pearson also suggests that young athletes can adhere to many of the same principles as adult resistance-training programs.

The current study focuses on the effects of exercise sequence on adolescent male athletes who participate in high school football. The purpose of this study was to investigate whether one exercise sequence outperforms another (traditional blocked in which all sets of an exercise are completed before beginning a different exercise versus circuit training which required completion of one set of all exercises before repeating additional sets) by measuring pre- to post-differences in strength, speed, and agility. Thus, this study focuses on two specific types of exercise sequences, one of the many variables that are modifiable within a resistance-training program.

METHODS

Participants

Thirty-nine athletes in two groups participated in this study. TRAD (n=16; 16±2 years) and CIRC (n=23; 16±1 year) were two separate high-school football teams recruited for this study. One school team did the traditional method (TRAD) and the other school participated in the circuit method (CIRC).

Protocol

The current study consisted of six weeks of resistance training with each of two participating high school football teams performing the same resistance-training program during their summer workouts. Exercise sequence was the only variable between the two teams that was not the same throughout the two programs (one school doing traditional and the other doing circuit). After receiving institutional human subjects review board approval, all subjects signed an assent form after having parent or guardian sign an informed consent. The exercise sequences were as follows: the TRAD group performed the prescribed exercises in a traditional otherwise known as blocked manner (by completing every set of an exercise before moving to the next) and the CIRC group performed the prescribed exercises in a circuit or alternating manner (by completing the first set of each prescribed exercise then going to the second set of each exercise). The only exception in the circuit sequences is that they were instructed to complete all sets of hang cleans, in a traditional manner, before they started lifting in the desired circuit manner. The reason for completing hang clean in a traditional manner first is due to the information provided by the American College of Sports Medicine (2002) and Fleck and Kraemer (2004), which revealed benefits for power and explosive exercises being implemented at the beginning of a workout due to the neuromuscular system being in a non-fatigued state and is capable of higher rates of force production and contractile velocities. This also reduces risk of injury due to the explosive nature of hang cleans (7).

Each group lifted three days a week (Mondays, Tuesdays, and Thursdays) in their high school's weight room. The resistance-training program for this study, with the exception of the hang cleans, utilized an undulated periodization approach geared towards enhancing sports performance. The weight for hang cleans was progressed in a linear manner to gradually build up the resistance for the athletes due to their inexperience with performing this exercise. Each work out was designed towards a total body approach, having lifts that targeted each body section. Exercises in this program were all multiple-joint exercises requiring synergy to occur among different muscle groups. The program consisted of a mixture of Olympic and traditional style exercises. Rest time between sets was not tightly controlled nor was other physical activity outside of football practice. Although this may have affected results it was the desire to keep this study as close to "real world" experience as possible. Athletes were advised to eat a balanced diet and encouraged to drink appropriate amounts to offset sweat and maintain reduced thirst however there was not a registered dietitian assigned to either group.

Excluding hang cleans; all exercises consisted of three sets with the total volume progressing in an undulated manner. Hang cleans were placed at the beginning of the workout for each day it was performed, with a total of five sets with the reps not exceeding three. During the first four weeks, hang cleans were referred to as "speed cleans" to emphasize bar speed and utilized lighter weight to help develop proper form and technique.

Exercise resistance for each work out was predetermined for hang cleans, bench, and squat based on each individual's multiple rep max pretest. For all other exercises involving free weights, the athletes were instructed to use an appropriate amount of resistance in order to perform only the required number of repetitions for that given set. Athletes were instructed to perform each set of inverted rows and pull-ups to max.

Testing Procedures: For group subject descriptive purposes, body mass (Detecto beam scale) and body fat using a bioelectrical impedance analysis (Omron HBF-306) was assessed before and after the intervention (See Table 1). Hang clean, bench, squat, speed, and agility were also measured pre and post intervention.

Table 1. Group Descriptive Statistics.

	CIRC		TRAD	
	Pre	Post	Pre	Post
Mass (kg)	90.53 ± 15.13	90.28 ± 15.13	74.69 ± 21.18	75.77 ± 21.26
Body Fat (%)	21.87 ± 7.41	19.95 ± 7.56	20.05 ± 9.28	18.61 ± 7.23

The weight of hang clean, bench, and squat measured through a one-rep max were combined to generate a strength index (SI) for each athlete. SI equals the sum of the lifts divided by the total body weight of the athlete. A 40-yard dash was used to measure speed, and a pro agility drill (PA) (athlete sprints to one side for 5 yards touching the line and turns and sprints back for 10 yards touching another line, then turns and sprints 5 yards through the line where they originally started) measured agility. The testing schedule for pre-and post-tests went as follows: day one (PowerPoint presentation explaining program, height, weight, and body fat assessment); day two (40-yard dash, hang clean, and bench); and, day three (PA and squat).

To keep consistency between groups for the depth while squatting, athletes were instructed to go parallel, having the center of their thigh reaching parallel with the ground. An "up call" was given for each parallel squat during testing weeks to ensure proper depth was reached. If parallel was not reached, that repetition was not awarded to the athlete. For each running test, the athletes were given two attempts, with the fastest time recorded. While performing the PA athletes ran one trial starting towards their left and the other attempt towards their right. To keep accuracy while measuring agility, athletes were instructed to touch each outside line; failure to do so resulted in the athlete performing the trial again.

Table 2. Prescribed Exercises.

DAY 1	DAY 2	DAY 3
Hang clean	DB snatch	Hang clean
Power jerk	Upright row	Push press
Bench press	Front squat	Back Squat
DB split squat	Military Press	Incline bench
Inverted rows	Weight Lunges	Weighted step-ups
	Pull ups	

Training Sessions: Each group started the six-week training program the week following the pre-intervention testing. Prior to each workout, the athletes completed a plate warm-up, which also served as the cardiovascular warm-up, consisting of the following exercises performed in a continuous manner for eight reps per exercise: up-right row; good mornings;

bent row; squat to press; and, alternating lunges with twist. Exercises for each day were as appears in Table 2.

Weighted lunges alternated from front, sides, and back each week. Weighted step-ups also alternated from front to sides each week, designed to help get lateral movement patterns involved into their training regimens. One of two different series of abdominal exercises were performed on the first and third days of every week at the end of each workout.

Statistical Analysis

Two-tailed t-tests assuming unequal variances were conducted to determine if significant differences between groups existed before the intervention took place and also to determine any significance between selected parameters as a result of training. T-tests were conducted for paired samples of pre and post measurements separately for each group for SI, clean, squat, bench, 40, and PA. Analysis of Covariance (ANCOVA) models were fit to test for effects of CIRC and TRAD. Alpha level for this study was determined a priori at 0.05.

RESULTS

The results of the pre-assessments conducted to determine if the groups were starting at an equal level revealed significant differences with the group performing CIRC having significantly greater results in hang clean, squat, bench, and agility (see Table 3).

When comparing the pre to post gains made separately within CIRC and TRAD, significant strength gains (based on t-tests) were observed in all strength measures pre to post, as indicated in Table 4. There was also a significant difference regarding hang cleans when comparing the two exercise sequences. However, this was not a result of the defined exercise sequence prescribed.

Table 3. Pre-intervention descriptives.

	CIRC	TRAD	p-value
SI	3.69 ± 0.50	3.42 ± 0.73	0.16
Hang Clean (kg)	99.75 ± 11.29	71.82 ± 16.19	<0.05*
Squat (kg)	136.71 ± 19.11	99.80 ± 26.60	<0.05*
Bench (kg)	92.73 ± 14.25	77.78 ± 18.42	<0.05*
40 (s)	5.16 ± 0.35	5.43 ± 1.43	0.11
PA (s)	4.61 ± 0.23	4.92 ± 0.45	<0.05*

Note: * denotes significant difference $p < 0.05$

Table 4. Pre-to-post differences within groups.

Variable	CIRC			TRAD		
	Pre	Post	Difference	Pre	Post	Difference
SI	3.69	3.78	0.09*	3.42	3.57	0.15*
Hang Clean (kg)	99.75	101.55	1.80*	71.82	78.24	6.42*
Squat (kg)	136.71	140.17	3.46*	99.80	107.07	7.27*
Bench (kg)	92.73	94.55	1.82*	77.78	78.07	0.29*
40 (s)	5.16	5.17	0.01	5.43	5.45	0.02
PA (s)	4.61	4.65	0.04	4.92	4.99	0.07

Note: * denotes significant difference $p < 0.05$.

Due to the unexpected presen of statistically different strength levels at the onset of the study between the CIRC and TRAD groups, t-tests of pre to post differences between the groups could not be conducted. Thus, two Analysis of Covariance (ANCOVA) models were fit to evaluate if the Post SI measure was equal across the CIRC or TRAD grouping, while statistically controlling for the effects of other covariates. The first ANCOVA model included Pre Body Fat, Pre Weight, Age, Attendance, and Pre SI as covariates (see table 5) and the second ANCOVA model only included the Pre SI as a covariate (see table 6). In both models, the Pre SI was the only covariate significant to the model and the CIRC and TRAD grouping were not a significant factor in the Post SI results (see Tables 5 and 6).

DISCUSSION

The results suggest no difference in circuit versus traditional training on any of the strength or performance variables. The significant result of the SI in the ANCOVA indicates a generalization may be made that regardless of beginning level of strength, either method of training will result in

Table 5. ANCOVA with PreBodyFat, PreWeight, Age, Attendance, and Pre SI as Covariates.

		SS	df	MS	F	sig
PostSI Covariates (Combined)		13.343	5	2.669	120.949	.000*
	PreBodyFat	.023	1	.023	1.064	.310
	PreWT	.004	1	.004	.160	.692
	Age	.005	1	.005	.222	.641
	Attendance	.015	1	.015	.691	.412
	PreSI	5.573	1	5.573	252.573	.000*
Main Effects	CIRC/TRAD	0.002	1	.002	.107	.746
Model		13.838	6	2.306	104.535	.000*
Residual		.706	32	.022		
Total		14.544	38	.383		

Table 6. ANCOVA with Pre SI as Covariate.

		SS	df	MS	F	sig
PostSI Covariate	PreSI	13.288	1	13.288	628.798	.000*
Main Effects	CIRC/TRAD	0.42	1	.042	2.000	.168
Model		13.784	2	6.892	326.126	.000*
Residual		.761	36	.021		
Total		14.511	38	.383		

equal improvement in strength. It might also be a possibility that a circuit style of training could actually yield greater results than a traditional approach due to the group performing the circuit sequence starting significantly above the traditional group and yet still yielded significant gains pre to post intervention (see Table 3) (1).

The key finding from the current study was that the effect of exercise sequence was not significantly different between circuit and traditional sequences except when performing hang cleans; in which traditional training had a significant difference over circuit training. This finding is particularly unusual due to the fact that both the circuit and traditional groups performed all sets of hang cleans in a traditional manner before going into their given exercise sequence. Possible explanations for the higher performance on hang cleans may be that the group performing the traditional sequence was a younger group, and the pretest differences revealed that they were significantly weaker than the circuit group, allowing the traditional group to experience greater strength gains.

The “corridor theory” states that too much time between sets of the same exercise may limit overall strength gains because it will prompt the repeated recruitment of the same motor units, thus supporting the use of traditional exercise sequence (21). Landin and Nelson stated that as an exercise is repeated, the nervous system becomes more efficient in its muscle activation patterns (10). Motor unit recruitment follows a progression from small to large, and those regimens that successively stress the same muscle groups may produce greater gains by prompting an earlier recruitment of larger motor units. This could explain why both the circuit and traditional sequence had significant increases in hang clean.

No significant increases were observed in speed or agility in either group, possibly due to the absence of speed, agility, or plyometric programs. The aim of the current study was to observe if either exercise sequences enhanced performance through the means of a 40-yard dash and a pro agility drill. It was observed that neither a circuit nor traditional style of training resulted in a better performance. Although based on the increase in strength one might expect to see an improvement in these performance variables however no specific training was done towards these measures. One might also postulate that there was not enough difference in the strength to elicit the change in performance.

One of the more important things to note from this study is that strength and conditioning coaches faced with choices due to equipment availability and/or time factors should be able to choose whichever method (CIRC or TRAD) that best suits their own schedules. The outcome in a six-week summer training program should be equal.

Further research should be conducted with groups of equal strength, speed, and agility prior to the intervention. While a traditional sequence produced the largest differences in hang clean, both exercise sequences produced significant differences from pre to post intervention, concluding that either sequence gains strength when implemented in a resistance-training program.

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REFERENCES

1. American College of Sports Medicine. Position stand on progression models in resistance exercise for healthy adults. Med Sci Sports Exerc 34: 364-380, 2002.

2. Channell B, Barfield, J. Effect of Olympic and traditional resistance training on vertical jump improvement in high school boys. J Strength Cond Res *22*(5): 1522-1527, 2008.

3. Cormie P, McGuigan M, Newton R. Developing maximal neuromuscular power: part 1—biological basis of maximal power production. Sports Med 41(1): 17-38, 2011.

4. Cormie P, McGuigan M, Newton R. Developing maximal neuromuscular power: part 2—biological basis of maximal power production. Sports Med 41(2): 125-146, 2011.

5. Duehring M, Feldmann C, Ebban, W. Strength and conditioning practices of United States high school strength and conditioning coaches. J Strength Cond Res *23*(8): 2188-2203, 2009.

6. Faignbaum A, Kraemer W, Blimkie C, Jeffreys I, Micheli L, Nitka M, Rowland T. Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. J Strength Cond Res *23*(5): S60-S79, 2009.

7. Fleck SJ, Kraemer WJ. Designing Resistance Training Programs. Champaign: Human Kinetics, 2004.

8. Fleck SJ, Kraemer WJ. Periodization Breakthrough: The Ultimate Training System. New York: Advanced Research Press, Inc, 1996.

9. Gabriel D, Kamen G, Frost G. Neural adaptations to resistive exercise: mechanisms and recommendations for training practices. Sports Med *36*(2): 133-149, 2006.

10. Landin D, Nelson AG. Early phase strength development: A four-week training comparison of different programs J Strength Cond Res *21*(4): 1113-1116, 2007.

11. Moritani T, Devries H. Neural factors versus hypertrophy in the time course of muscle strength gain. Am J Phys Med *58*(3): 115-130, 1979.

12. Pearson D, Faigenbaum A, Conley M, Kraemer W J. The national strength and conditioning association's basic guidelines for the resistance training of athletes. Strength Cond J *22*(4): 14-37, 2000.

13. Sale DG. Strength Training in Children. Youth, Exercise and Sport (pp. 165-222). Indianapolis: Benchmark, 1989.

14. Santos E, Janeira M. Effects of complex training on explosive strength in adolescent male basketball players. J Strength Cond Res *22*(3): 903-909, 2008.

15. Smith M, Melton P. Isokinetic versus isotonic variable-resistance training. Am J Sports Med *9*(4): 275-279, 1981.

16. Staron RS, Karapondo DL, Kraemer WJ, Fry AC, Gordon SE, Falkel JE., et al. Skeletal muscle adaptations during early phase of heavy-resistance training in men and women. J Appl Physiol *76*(3): 1247-1255, 1994.

17. Tesch PA. Skeletal muscle adaptations consequent to long-term heavy resistance exercise. Med Sci Sports Exerc 20(5): 132-134, 1988.

18. Todd T. Al Roy: the first modern strength coach. J Phys Ed Recreation Dance *79*(8): 1-57, 2008.

19. Van den Tillaar R, Marques M. A comparison of three training programs with the same workload on overhead throwing velocity with different weighted balls. Sports Med 41(2): 125-146, 2011.

20. Young W, Rath D. Enhancing foot velocity in football kicking: the role of strength training. J Strength Cond Res 25(2): 561-566, 2011.

21. Zatsiorsky V.M. Science and Practice of Strength Training. Champaign: Human Kinetics, 1995.