Alterations in strength characteristics for isometric and dynamic mid-thigh pulls in collegiate throwers across 11 weeks of training

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Aim. **The purpose of this study was: 1) to investigate the alterations and relationships among training variables, performance variables, and physiological variables and 2) investigate the effects of strength training on potentiation complexes.**

Methods. **The study enrolled nine D-1 collegiate throwers and four control subjects. The throwers participated in an 11-week resistance training and throws program. Resistance training volume load and throwing volume were recorded for 11 weeks. Measurements of maximal strength (isometric mid-thigh pulls) and dynamic mid-thigh pulls (DMTP) across a spectrum of loads: Males-60kg, 140kg, 180kg, 220kg, 140kg, 30% isometric peak force (IPF), Females- 60kg, 80kg, 100kg, 120kg, 80kg, 30% IPF), were measured at weeks 1, 7, and 11. The control group was tested for isometric maximum strength at T1 (week 1) and T3 (week 11)**

Results. **The throwers increased at each time point in isometric peak force (IPF), allometrically scaled IPF (IPFa), and isometric impulse. The throwers strength (IPF and IPFa) was significantly greater than the controls and the throwers experienced statistically significant changes in maximum strength from T1 to T3 when compared to the controls. The throwers demonstrated statistically significant changes in total load variables (variable for load 1+ load 2 + load 3 etc.) for DMTPs.**

Conclusion. **As a whole these data suggest a potential for increased performance capabilities specific to throwing. Some data trends indicate that potentiation can occur as a result of performing a heavy pull before a lighter one. However, increasing maximum strength as a result of focusing on strength training did not enhance this potentiation effect.**

Key words: Strength - Athletes - Physical education and training.

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Monitoring the training process of an athlete is crucial in understanding how an athlete is responding to various training stimuli and whether alterations or changes need to be made to the training plan.[1] Quantification of training is a necessary step in understanding training outcomes. Quantification allows relationships to be established between the training program and physiological and performance variables.

Track and field throwing events rely heavily on a throwers ability to produce high levels of force over a short period of time.[2] Stone *et al.*[3] explain that elite throwers are among the strongest, most powerful, and explosive of all strength power athletes. Properly training the variables of strength, power, and explosiveness over time can result in a shift of the force-velocity curve and potentially improve throwing performance.[3, 4]

Several sport scientists have recently proposed periodization models that modify the traditional/classical approach in a manner "fitting" modern competition schedules.[3, 5-8] Evidence suggests that resistance training programs using progressive phases that emphasize specific characteristics produce superior results.[9, 10] Conceptually, these data indicate that a progression of training, leading to a strong athlete potentiates further increases in power and perhaps speed. For example transitions from strength-endurance to basic strength to strength-power protocols produces superior adaptations compared to simply emphasizing power development constantly.[9] Consequently, Block periodization or Long-term Phase potentiation which exploits the concept that each phase of training potentiates the next phase of training has led to an increased emphasis on the meso-cycle level of periodized programs.[3, 5, 7]

The present study followed Division 1 (D-1) USA collegiate throwers over a period of an 11-week fall semester preparation-phase block form of periodized training. Conceptually, it is important to understand the underlying physiological mechanisms of any training program model. This understanding aids the coach/sport scientist in making better choices in manipulating variables in formulating the training model. These underlying mechanisms can be associated with the manipulation of variables during training. Volume and intensity alterations and their effects on performance variables (*e.g.*, neuromuscular) are a key component in understanding the effects of the training process.

Additionally, in recent years there has been considerable interest in acute exercise potentiation through the use of potentiation complexes.[11] Some evidence indicates that stronger athletes can achieve greater acute potentiation effect.[12] Thus gains in maximum strength as a result of structured training may enhance the performance of a potentiation complex.

Alterations in performance variables were tracked over time. A better understanding of physiological and performance adaptations to a training program can assist the throws coach in constructing a more optimal periodization plan. Thus, the purpose of the present study was: 1) to investigate the alterations among training variables and strength-related characteristics and performance variables during a fall preparation phase in Division I (D-1) collegiate throwers; 2) to investigate the effects of strength training on dynamic mid-thigh pull potentiation complexes.[11]

Materials and methods

All testing took place in the Exercise and Sport Science Laboratory on the campus of East Tennessee State University in accordance with East Tennessee State University Institutional Review Board permission. All subjects read and signed informed consent documents pertaining to all testing procedures.

Subjects

Nine D-1collegiate throwers (age=19.9±1.1 y; Ht=181.8±10.6 cm; BdM=105.5±20.8 kg; % fat=22.8±5.8) and four control subjects (age=23.6±4.1 y; Ht=175.1±7.4 cm; BdM=83.0±13.6kg; % fat=28.0±8.9) participated in the study. These athletes had a resistance training background ranging from 2- 4 years at the collegiate level. The ability level of the throwers (6 male and 3 female) ranged from conference champions and contending NCAA Division I regional qualifiers to conference non-scorers. Throwing performance (taken from NCAA sanctioned meets) ranged from 10.98m to 16.9m in the shot put and 12.03m to 18.6m in the 35 lb. weight throw. The throwers were instructed not to change their dietary habits during the study. The control subjects (3 males and 1 female) were sedentary individuals and were instructed not to change their dietary habits and to remain sedentary throughout the study.

Experimental design: throwers

Prior to the initiation of the study, the throwers executed a 4-week period of moderately high volume, moderate intensity (loading) resistance, conditioning and throwing period. This 4-week period consisted of 3 x 5 (1 x 5 down set) repetitions in the weight room using a 3 week increasing load and 1 week unloading scheme. Additionally, there was a moderate to high volume of ball throws (2-3 days per week).

This study was viewed as a hypothesis generating study. The investigation was a longitudinal time series study, analyzing physiological and performance changes over 11 weeks of training in 9 D-1 collegiate throwers. Daily training outcomes were recorded and "monitored" while the throwers executed a periodized throws and resistance training and conditioning program (*e.g.*, various weighted medicine ball throws, sprints) that was structured and sequenced with the objective of enhancing strength characteristics to potentially optimize performance for the upcoming indoor conference championships and produce an initial foundation for training for the outdoor season. A series of three testing periods of 2 days in duration were implemented periodically during the study (weeks 1, 7, and 11) in order to measure strength and strength related characteristics.

The measurements included body composition, isometric mid-thigh pulls, and dynamic pulls from mid-thigh (males: 60kg, 140kg, 180kg, 220kg, 140kg, 30% isometric peak force (IPF) females- 60kg, 80kg, 100kg, 120kg, 80kg, 30% IPF). Alterations in these performance variables were tracked over time and relationships with training variables were established. Tests were part of a sport monitoring program and all athletes were familiar with the performance tests used in this study. The control subjects performed only the isometric tests and were familiarized with the isometric tests two weeks before initial testing.

Methodology

A unique aspect of this observational study was involved using competitive athletes in their normal environment during a preparation period of training. The study began approximately 12 weeks before the start of the indoor track and field season and continued to the beginning of the indoor season. The performance tests were integrated into the athletes training program to help manage fatigue and maintain the goals of each block of training. Testing took place on Wednesdays in order to better fit their training plan because Wednesday was comprised of mostly weightlifting pulling movements. The initial testing sessions (T1) were implemented during the first week of the study in order to obtain baseline data. Test session 2 (T2) took place during the 7^{th} week of the study and test session 3 (T3) took place during the 11^{th} and last week of the study. This coincided with the start of the indoor track and field season. The throwers had their first official NCAA indoor meet at the end of the last week of the investigation.

Testing times corresponded closely with normal resistance training session times. On Monday of each test week a series of measurements involving physical, and anthropometric, data were collected and analyzed. Wednesday involved performance measurements. Performance measurements took place both in the morning and afternoon and consisted of isometric mid-thigh pulls (AM) and dynamic mid-thigh pulls (PM). During the morning session maximum strength was measured using an isometric mid-thigh clean pull, which was performed on a 0.91m x 0.91m force plate (Rice Lake, WI; sampling rate of 1000 Hz) in a custom-designed power rack. The apparatus and standard pulling position was established based upon previously published data (Haff *et al.*, 2005). The athletes' hands were attached to the bar using weightlifting straps and standard athletic tape. This test was chosen because of its time efficiency, high reliability and validity.

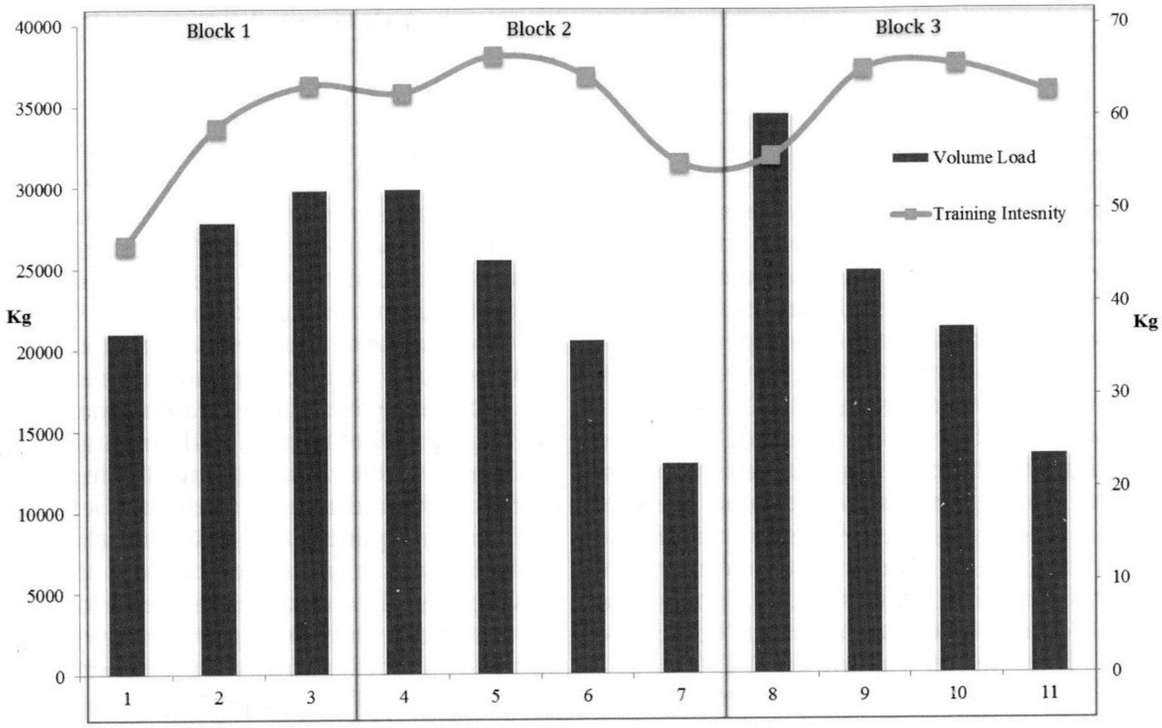

Figure 1.—Average volume load and training intensity per week. Note: As a result of testing on week 11, very few throws were performed during week 11, thus only 10 weeks are presented.

The test has shown strong correlations with a number of other performance characteristics in previous studies.[13-16]

The standardized warm-up protocol before entering the power rack warm-up consisting of 25 jumping jacks followed by 1x5 repetitions with a 20kg bar followed by 3x5 mid-thigh pulls at 30% of their previously established 1RM power clean. Each athlete was given two practice isometric mid-thigh pull trials at submaximal efforts (50% and 75% effort). Following the practice trials, athletes performed 2 trials with approximately 1 minute rest between pulls. Athletes were explicitly instructed to perform the pull "as hard and fast as possible". If peak force varied more than 250N between trials it was repeated[17]. The trials were averaged for analysis. Customized Labview software (National Instruments Co., Austin, TX) was used to determine the isometric peak force (IPF), instantaneous forces at 50, 90, and 250 ms, isometric RFD (IRFD) during the first 200ms of each pull, and isometric Im (0 ms to PF). Previous testing in our lab (N.>200) has consistently produced a high test-retest reliability for: IPF, ICC$\alpha \geq 0.98$ and IRFD, ICC$\alpha \geq 0.95$. Similar reliabilities for IPF and IRFD were noted for this study (ICC$\alpha \geq 0.95$; N.=9) However, isometric impulse (Im) reliability was lower ICC$\alpha \geq 0.66$ (N.=9) but acceptable.

In the afternoon the throwers performed dynamic mid-thigh pulls at various loads. Athletes were positioned initially for the dynamic tests exactly as they were for the isometric tests. Velocity was measured by using two multi-turn potentiometers with spring retractable cables suspended from the top of the right and left sides of the custom-designed power rack and attached to both ends of the bar. The athlete stood in the power position (knee angle 120-130°, hip angle 160-170°, trunk was nearly vertical) while standing on a 0.91m x 0.91m force plate (Rice Lake, WI; sampling rate of 1000 Hz). Six dynamic performance trials were performed with two attempts at each trial, the loading scheme is based on Stone *et al.* [11] (and it is as follows: Males 30% IPF, 60kg,

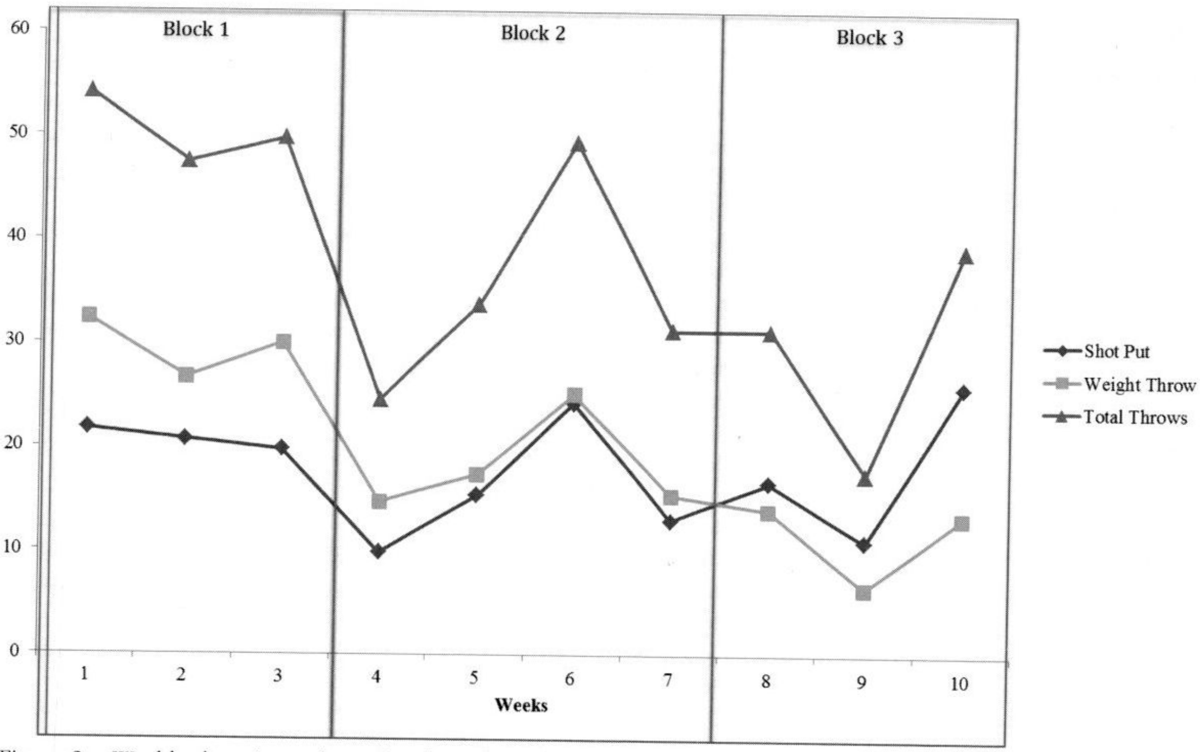

Figure 2.—Weekly throwing volume (total number of repetition).

140kg, 180kg, 220kg, 140kg, Females 30% IPF, 60kg, 80kg, 100kg, 120kg, 80kg). This loading scheme was designed to produce PVs that were approximately the same between men and women.[11] In this study the loading scheme produced PV differences of ≤ 0.1 m x s^{-1} between males and females. Employing dynamic mid-thigh pulls and using this specific loading scheme [11] as a strength-power potentiating complex allows the assessment of: 1) variables (*e.g.*, peak force, peak power, peak velocity) across the power spectrum and 2) the possibility of performance potentiation (*i.e.*, heavy movements potentiating lighter performances.[11]

Training protocol

The development of the training program was a collaborative effort and involved input from the strength and conditioning coach, as well as the throws coach. Multiple sources in the literature served as its foundation.[3, 7, 9, 18, 19] The development of the training protocol was constrained to the limitations of the throwers class schedule, weight-room schedule, and practice times coordinated with the throws coach. The throwers lifted 4 days a week for 11 weeks, 3 of the lifting days occurred twice a day. Throwing practices occurred 2 to 4 times a week, total throw volume (number) per each practice was calculated (Figures 1, 2).

Although indoor track and field is a season, it is unlike many team sports in that every competition is not of equal importance. For this group of athletes, the major competition of the indoor season is the conference championships. Thus, the throwers overall program was designed to peak the athletes for this event (March 2010). Because the experiment only continued until the start of the indoor season, the study primarily involved the preparation period preceding the season as well the beginning phase of the competitive season. The primary objective of this preparation phase was to raise the work capacity and strength levels of the athletes (accumulation phase).

The resistance training program was sequenced with a series of three 3-4 week concentrated loads (summated micro cy-

TABLE I.—*Training exercise.*

Block	Time of day	Monday	Wednesday	Friday	Saturday
1	AM	Back Squat Standing Press	Power Snatch (40-60kg) Clean Grip Shrug Clean Grip Mid-thigh Pull	Back Squat Standing Press	Power Snatch Ball Throws Pull-ups
	PM	Bench Press Dumbbell Front Raise	Power Snatch Clean Grip Shrug (50% of AM) Clean Grip PK?	Bench Press Dumbbell Front Raise	
2	AM	Back Squat Push Press	Power Snatch (40-60kg) Clean Grip Shrug Clean Grip Mid-thigh Pull Clean Grip Stiff Leg Deadlift	Back Squat Push Press	Power Snatch Ball Throws
	PM	45° Incline Bench Press Dumbbell Front Raise	Power Snatch Clean Grip Shrug (50% of AM) Power Clean (70-75%) Clean Grip Stiff Leg Deadlift	45° Incline Bench Press Dumbbell Front Raise	
3	AM	Back Squat Push Jerk	Power Snatch (40-60kg) Clean Grip Shrug Clean Grip Mid-thigh Pull	Back Squat Push Jerk	Power Snatch Ball Throws
	PM	10° Incline Bench Press Dumbbell Front Raise	Clean Grip Shrug (50% of AM) Power Clean (75-80%) Clean Grip Stiff Leg Deadlift	10° Incline Bench Press Dumbbell Front Raise	

cles) of training. These concentrated loads (CL) were based on Stone *et al.*[3] in which 1 CL lasts roughly a month consisting of a primary adaptation objective. This periodization method is similar in construction to "Block" and "Phase Potentiation" models of periodization which encompass several concentrated loads and periods of accumulation, transmutation, and realization.[3, 5, 8, 19] The approach of this model is to take advantage of training after-effects that can potentiate adaptations in the subsequent phase of training.[3, 5]

The beginning of the preparatory phase focused on a short period of higher volume and less technical work with an emphasis on strength endurance, while the end of the preparatory phase there was a shift towards a focus on strength and a small increase in technical work. The first phase of training consisted of a strength-endurance concentrated load (CL1) moving to a strength emphasis (CL2), while during CL3 the emphasis remained focused on strength, but with additional variations in exercises and volume load and a somewhat greater emphasis n power production. Table I illustrates the exercises and Table II shows the set and repetitions for the target sets (warm-up sets are not shown, but all warm-up sets were recorded and used in volume load data analyses) and down sets. Exercises were chosen in concert with the set/repetition scheme in an attempt to achieve the goals and objectives of each CL (Tables I, II).

Alterations in relative intensities were incorporated into the weekly training structure to produce heavy and light days. Similar programs have been used successfully with collegiate throwers.[20] Figure 1 shows the strength training volume load (repetitions x sets x load), the average training intensity (average load/week) for the 11 weeks and the throwing volumes. It should be noted that weeks 1, 7, and 11 include the data from the dynamic pull session which "artificially" alters the training loading. The training was designed by coaches such that high volumes of resistance training would not interfere with a higher volume of throwing.

TABLE II.—*Training volume and intensity by microcycle.*

Block	Week	Target Sets						Down Sets		
		Sets	Repetitions	Intensity				Sets	Repetitions	Intensity
				Monday	Wednesday	Friday	Saturday			
1	1	3	10	70-80%	70-75%	70-75%	80-85%			
	2	3	5	85-90%	75-80%	80-85%	80-85%	3	10	50%
	3	3	5	90-95%	80-85%	80-85%	80-85%	3	10	50%
2	4	5	5	80-85%	70-75%	70-75%	80-85%			
	5	3	5	85-90%	70-75%	80-85%	80-85%	1	5	50%
	6	3	3	90-95%	80-85%	80-85%	80-85%	1	5	50%
	7	3	3	80-85%	80-85%	70-75%	70-75%	1	5	50%
3	8	3	10	80-85%	70-75%	75-80%	80-85%			
	9	3	5	85-90%	75-80%	80-85%	80-85%	1	5	50%
	10	3	3	90-95%	80-85%	80-85%	80-85%	1	5	50%
	11	3	2	95-100%	80-85%	85-90%	80-85%	1	5	50%

Note: intensity for and down target loads are based upon estimated RM values for sets and repetitions per week (Stone and O'Bryant 1987; Stone *et al.* 2007).

Statistical analyses

Data were analyzed using the statistical Package for the Social Science (SPSS) 17.0 (SPSS Inc., Chicago, IL, USA). Multiple (1 x 3) repeated measure analysis of variance (ANOVA) were used to determine if statistically significant differences existed between the measurement times for all throwers tested. Additionally, multiple (1 x 2) ANOVAs were used to determine if statistically significant differences existed between the measurement times for all control subjects tested. For the dynamic pulls multiple (3 x 5) ANOVAs were calculated to determine if statistically significant differences existed between different loads for the throwers dynamic mid-thigh pulls, while paired samples tests were used to determine if significant differences existed between different loads within the same testing session. Paired comparisons were adjusted with a Holm's sequential Bonferroni follow-up to control for type I error. Differences between male and females were determined using partially adjusted t-tests: differences between males and females were determined by repeated measures ANOVA[21]. Additional analyses were performed using effect size (η^2) and the coefficient of variation for the percent gain over time and 95% confidence intervals.[22] Where appropriate, data were allometrically scaled to help obviate body mass differences among individuals and between sexes using the following equation: absolute value/body mass$^{0.67}$.[1, 17]

Results

Neither the controls nor the throwers statistically changed body mass or body composition over the investigation. Additionally there were no statistical differences for performance markers for the control. Conversely the throwers exhibited increases in strength and power over the duration of the 11-week training period. The directions and percent changes of variable alterations across time were quite similar, thus males and females were analyzed as one group.[17]

Group means, standard deviations, and statistical differences over time for the throwers isometric mid-thigh pulls are shown in Table III. Isometric impulse showed a statistical increase across time and T1 was different from T3 (Holm's Bonferroni). Isometrically scaled peak force (IPFa) displayed a moderate effect size and a substantial % gain (7.5%). The control group failed to demonstrate any statistical changes. The throwers change over time for Im and IPFa was significantly greater than the control groups ($P \leq 0.05$).

TABLE III.—*Throwers isometric force-time curve assessment results.*

Variable		Testing Session 1	Testing Session 2	Testing Session 3	p-value	T1 *vs* T3	
		Mean± SD	Mean± SD	Mean± SD		η^2	% Δ
Peak Force	N	6133.0± 1506.0	6349.0± 1530.0	6472.0± 1498.0	0.21	0.36	5.5
Allometrically Scaled Peak Force	N/ $kg^{0.67}$	267.0± 40.0	278.0± 43.0	287.0± 39.0	0.08	0.52	7.5
Force at 50 ms	N	1700.0± 486.0	1726.0± 616.0	1586.0± 422.0	0.48	0.19	-6.4
Force at 90 ms	N	2241.0± 707.0	2277.0± 857.0	2094.0± 502.0	0.56	0.15	-6.6
Force at 250 ms	N	4100.0± 1222.0	3978.0± 1236.0	4006.0± 840.0	0.54	0.16	-2.3
Rate of Force Development	N/s	11502.0± 4102.0	11413.0± 4242.0	11111.0± 2621.0	0.91	0.03	-3.4
Impulse		12763.0± 4139.0	17667.0± 6505.0	21276.0± 5866.0	0.005*	0.78	66.7

Statistically significant =*.

TABLE IV.—*Throwers Dynamic Force-Time Curve Variables.*

Variable		Trial	Testing Session 1	Testing Session 2	Testing Session 3	T1 *vs* T3	
			Mean ± SD	Mean ± SD	Mean ± SD	η^2	% Δ
Peak Force	N	1	3338.0 ± 544.0	3347.0 ± 505.0	3420.0 ± 557.0	0.15	2.50
		2	3996.0 ± 806.0	3941.0 ± 825.0	3998.0 ± 794.0	0.00	0.02
		3	4277.0 ± 907.0	4267.8 ± 930.0	4283.0 ± 892.0	0.00	0.60
		4	4491.0 ± 987.0	4424.0 ± 985.0	4529.0 ± 986.0	0.00	0.90
		5	3984.0 ± 823.0	4014.0 ± 796.0	3994.0 ± 805.0	0.00	0.30
0-200 ms Rate of Force Development*	N/s	1	8918.0 ± 1261.0	8066.0 ± 1182.0	8366.0 ± 1440.0	0.40	-6.10
		2	11390.0 ± 1853.0	10533.0 ± 4318.0	12488.0 ± 2576.0	0.49	9.60
		3	12426.0 ± 2337.0	13054.0 ± 2681.0	13239.0 ± 3106.0	0.43	6.50
		4	11878.0 ± 3486.0	12890.0 ± 3055.0	13192.0 ± 3165.0	0.39	11.10
		5	11436.0 ± 2334.0	12318.0 ± 2337.0	12110.0 ± 2448.0	0.40	5.90
Peak Velocity*	m/s	1	2.08 ± 0.30	2.10 ± 0.34	2.23 ± 0.36	0.45	7.20
		2	1.68 ± 0.21	1.78 ± 0.23	1.77 ± 0.23	0.34	5.30
		3	1.51 ± 0.21	1.53 ± 0.21	1.57 ± 0.22	0.39	4.00
		4	1.32 ± 0.20	1.38 ± 0.21	1.38 ± 0.20	0.34	4.50
		5	1.74 ± 0.21	1.77 ± 0.26	1.80 ± 0.24	0.31	3.40
Peak Power*	W	1	3003.0 ± 693.0	3185.0 ± 844.0	3585.0 ± 1193.0	0.60	19.40
		2	3399.0 ± 1016.0	3702.0 ± 1059.0	3695.0 ± 1118.0	0.28	8.70
		3	3397.0 ± 1076.0	3573.0 ± 1149.0	3616.0 ± 1195.0	0.23	6.50
		4	3350.0 ± 1131.0	3470.0 ± 1046.0	3571.0 ± 1192.0	0.29	6.70
		5	3647.0 ± 1089.0	3784.0 ± 1002.0	3916.0 ± 1205.0	0.30	7.30
Impulse**		1	377.0 ± 65.0	401.0 ± 171.0	370.0 ± 67.0	0.00	-1.80
		2	568.0 ± 169.0	554.0 ± 156.0	556.0 ± 139.0	0.14	-2.50
		3	706.0 ± 211.0	691.0 ± 213.0	666.0 ± 211.0	0.19	-5.60
		4	831.0 ± 283.0	798.0 ± 273.0	784.0 ± 265.0	0.17	-5.70
		5	571.0 ± 163.0	617.0 ± 178.0	575.0 ± 150.0	0.00	0.07

Note: *=ANOVA demonstrated statistically significant increases over time (T1<T3) for Peak Force, Rate of Force Development, and Peak Power. **=Impulse decreased significantly over time

Group means, standard deviations, and statistical differences over time for the throwers dynamic mid-thigh pulls are shown for trials 1 (80kg male, 60kg female), 2 (140kg male, 80kg female), 3 (180kg male, 100kg female), 4 (220kg male, 120kg female), and 5 (140kg male, 80kg female) in Table IV.

Based on effect sizes and percent changes (% Δ), trends for improvement in dynamic pulls across time are suggested. In addition

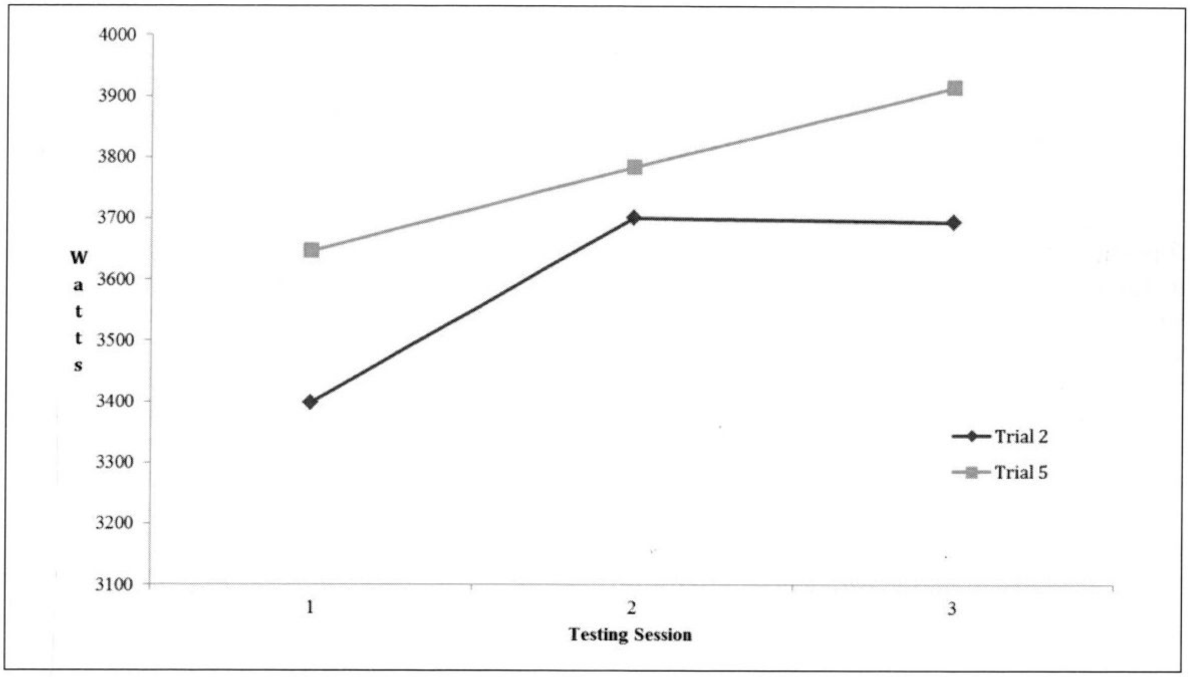

Figure 3.—Peak power data for the dynamic mid-thigh pull trial 5 *vs.* trial 5. Note: Trial 2 *vs.* 5: T1% Δ=7.4 (P=0.006, Holms-Bonferoni adjusted); trial 2 *vs.* 5: T2% Δ=2.2 (P=0.05, Holms-Bonferoni adjusted); trial 2 *vs.* 5: T3% Δ=6.0 (P=0.06, Holms-Bonferoni adjusted).

Table V.—*Throwers 30% of Isometric Mid-thigh Pull Trial Force Time Curve Characteristics.*

Variable		Testing Session 1	Testing Session 2	Testing Session 3	p-value	T1 vs T2	
		Mean± SD	Mean± SD	Mean± SD		η^2	% Δ
Peak Force	N	4540.0± 965.0	4533.0± 960.0	4601.0± 990.0	0.46	0.20	1.30
Rate of Force Development (0-200 ms)	N/s	11943.0± 2890.0	12471.0± 2852.0	13190.0± 3147.0	0.15	0.46	10.40
Peak Velocity	m/s	1.31± 0.11	1.32± 0.17	1.28± 0.17	0.73	0.08	2.30
Peak Power	W	3338.0± 986.0	3396.0± 1069.0	3451.0± 1143.0	0.64	0.10	3.90
Impulse		826.0± 254.0	793.0± 270.0	589.0± 278.0	0.024	0.12	4.00

Note: Significant difference = P ≤ 0.05

the sum of values for each variable for each load (Total load variables) at each trial (trial 1 + trial 2 + trial 3 + trial 4 + trial 5), showed statistically significant (Holm's Bonferroni adjusted t-Test) increases for RFD, PV, PP and a decrease for Im (P≤0.05). Additionally, trends suggesting a potentiation effect were noted. For example: trial 2 and trial 5 are the same load; peak power tended to be greater for trial 5 (Figure 3). This same trend (trial 2 *vs.* 5) can be noted for all variables. The trend for a potentiation effect was greater at T1 and T3. However, there was no evidence of a greater potentiation effect across time.

Group means, standard deviations, and statistical differences over time for the throwers dynamic mid-thigh pulls with 30% IPF are shown in Table V. While differences over time did not reach statistical significance, improvements in PF, RFD, and PP were observed, particularly for RFD. Based on a moderate effect size (ES=0.46) and % Δ (10.4%), RFD displayed a trend toward an increase over time. These alterations over time were executed with increased absolute loads since IPF increased over time. Impulse statistically increased across time (T1 > T3).

Discussion

Several important findings resulted from this study. First, the training program appears to have accomplished the main objective of the 3 sequenced CLs by directing the throwers adaptations towards increased strength. Second, gaining maximum strength was associated with enhanced dynamic performance capabilities. Third, some data trends in the present study indicate that potentiation can occur as a result of performing a heavy pull before a lighter one.

Performance

Isometric pulls

Stronger throwers are able to move at higher velocities, thus, increasing the velocity at which the implement is released and enhancing the distance of the throw.[23] Stone *et al.*[20] demonstrated that stronger throwers were able produce more force than weaker throwers (both absolutely and scaled) and that stronger throwers are able to produce force more rapidly than weaker throwers. Swisher (2009 unpublished thesis) observed that peak power output and isometric peak force were both strongly correlated with throwing performance in collegiate shot putters and 35lb weight (15.9 kg) throwers. Indeed, maximum strength, peak power, and rate of force development appear to be central to achieving higher levels of throwing performance. In the present study, the training protocol focused on gaining maximum strength. The decrease in IRFD may be explained because: 1) the focus was on maximum strength development, not explosiveness and 2) these athletes were moderately to well strength-trained. While among weaker athletes, strength endurance work produces both increased IPF and IRFD, we have noted (unpublished data) that among stronger athletes, strength endurance and strength emphasis may not substantially alter IRFD or may even produce a decreased IRFD which is consistent with the observations of Marshall *et al.*[24] among more advanced weight trainers. It was observed that the athletes during testing periods were quite competitive in producing high IPF values and not on explosiveness; thus, the athletes tended to pull longer not necessarily more explosively. This last contention is supported by the increase in isometric impulse with large increases in IPF. Indeed, inspections of the Im raw data indicated a substantially longer (as much as 1-2s) pull from T1 to T3, with the IPF occurring at the end of the pull. This last observation is interesting, as instantaneous forces at 50, 90 and 250 ms showed no change, suggesting that increasing maximum isometric strength was accomplished by being able to increase force over a longer period during a maximum execution.

Dynamic pulls

In the present study the throwers realized increased maximum force output, as well as trends toward increased dynamic RFD and power across the 11 weeks of training. The ability to develop force, explosiveness, and power while loaded is often a limiting factor for performance and are a major differentiating factor of success among throwers.[11, 20] Interestingly, inspection of the force time curves showed that Im also increased in the dynamic pulls; unlike the increase in Im for the isometric pulls this did not appear to be a result of increased time, but more related to increases in force production. As a result of the training protocol the increased force production capabilities indicate that the "fitness" and potentially the preparedness of the throwers had improved over the 11-week period. During the week following the study further tapering took place both in the weight-room and throwing practice. Although other factors could apply, at the opening indoor track and field meet the next week every thrower produced a personal best in one or more events (shot or weight throw). The range for the shot put improved to 11.9-17.3m and the weight throw to 12.6-19.1m.

Potentiating complexes (heavy lifts before light lifts) depend upon an acute fatigue-fitness effect, the underlying mechanisms remain unclear.[11] Possible mechanisms include phosphorylation of myosin light chains or disinhibition of the neuromuscular apparatus.[3, 11] There was some indication of a potentiating effect as a result of lifting heavy loads before lifting a lighter load. Trial 2 and trial 5 in the loading scheme was the same load (140kg males, 80kg females), yet trial 5 typically resulted in greater peak power outputs and peak velocities. This suggests a possible potentiation effect similar to Stone et al.'s[11] findings. However, no training effect over time was noted. Thus simply gaining maximum strength does not appear to enhance the potentiation effect of the exercise used in this study. However it should be noted that no specific potentiation exercises were used during training. It is possible that using a specific potentiation complex as a training exercise may have further enhance potentiating effects.

Periodization aspects

Of importance for athletes, very small alterations in physiology and training performance can make large differences at the competition. It should be noted that the study contained a rather small sample size, lacked elite level throwers, and lasted only 11 weeks, a snap shot in the training life of a thrower. Considering these shortcomings, this "block" periodization protocol indicates a strong potential to enhance the performance of throwers over a longer term. Therefore, future research should test a sample containing more advanced and elite male and female throwers over the course of several years to examine chronic physiological and performance effects of training.

Often studies investigating "newer" periodization models lack a block model to make comparisons or use a block model that when closely examined lack the basic tenets of periodization.[10] Thus, the authors wanted to examine a periodization model that utilizes a block approach and adheres to the basic tenets of periodization. The strength power periodization model implemented in the present study is structurally similar to the phase potentiation methods described by Stone *et al.*,[3, 8] Painter *et al.*[10] and the block periodization model as described by Issurin.[5, 6] Similar past findings, logically sequencing and directing adaptations by manipulating training variables may lead to enhanced performance. Furthermore, the manner in which these training variables are directed dictates the specifics of an athlete's adaptation(s). For example, the 11-week periodization model implemented in the present training study focused on primarily on strength characteristics, thus, the greatest group enhancement occurred within these performance variables.

Conclusions

Using a block type model, emphasizing maximum strength training, resulted in marked increases in maximum strength, as well as trends toward increased RFD and power. While evidence of potentiation (dynamic pulls) was noted during testing, there was no evidence that potentiating effects were enhanced as a result of the 11 week training protocol. It should be noted that the protocol in this study emphasized maximum strength and different protocols emphasizing RFD or power may not produce the same effects.

Riassunto

Alterazioni nelle caratteristiche di forza per i mid-thigh pulls isometrici e dinamici in lanciatori universitari nel corso di 11 settimane di allenamento

Obiettivo. Obiettivo del presente studio è stato quello di: 1) esaminare le alterazioni e le relazioni tra variabili di allenamento, variabili di performance e variabili fisiologiche e di 2) esaminare gli effetti dell'allenamento della forza sui complessi di potenziamento.

Metodi. Lo studio ha reclutato nove lanciatori universitari della prima divisione (D-1) e quattro soggetti di controllo. I lanciatori hanno preso parte a un programma di allenamento della forza e di lanci durato 11 settimane. Il carico di volume dell'allenamento della forza e il volume di lancio sono stati registrati per 11 settimane. Sono state effettuate misurazioni della forza massimale (stacchi isometrici da metà coscia [*mid-thigh pulls*] e stacchi dinamici da metà coscia [*dynamic mid-thigh pulls*, DMTP]) in una serie di carichi: uomini - 60 kg, 140 kg, 180 kg, 220 kg, 140 kg, 30% forza isometrica picco (*isometric peak force*, IPF); donne - 60 kg, 80 kg, 100 kg, 120 kg, 80 kg, 30% IPF) alle settimane 1, 7, e 11. La forza isometrica massimale del gruppo di controllo è stata valutata a T1 (settimana 1) e T3 (settimana 11).

Risultati. I lanciatori hanno mostrato aumenti in ciascun punto temporale nella forza isometrica picco (IPF), nella IPF graduata allometricamente (IPFa) e nell'impulso isometrico. La forza dei lanciatori (IPF e IPFa) era significativamente maggiore rispetto ai controlli e i lanciatori hanno sperimentato variazioni statisticamente significative nella forza massimale da T1 a T3 rispetto ai controlli. I lanciatori hanno mostrato variazioni statisticamente significative nelle variabili di carico totali (variabile per carico 1 + carico 2 + carico 3 ecc.) per i DMTP.

Conclusioni. Nel complesso, i dati suggeriscono un potenziale di aumento delle *performance* specifiche per il lancio. Alcune tendenze dei dati indicano che il potenziamento può verificarsi come risultato di un esercizio intenso prima di uno più leggero. Tuttavia, l'aumentata forza massimale derivante dalla predilezione dell'allenamento della forza non migliora questo effetto di potenziamento.

PAROLE CHIAVE: Forza - Atleti - Educazione fisica e allenamenti.

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