Predicting Throwing Performance with Field Tests

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ABSTRACT

The purpose of this study was to investigate whether training-induced changes in muscle power evaluated with easy-to-use field tests are linked with performance in the shot put, discus, hammer and javelin after long-term training. Ten well-trained throwers participated in a 20-week training programme for winter competition. Measurements taken before and after the programme included competitive shot put throws, seated medicine ball throws, standing long jump, 30m sprint, countermovement jumps on a force platform with various loads, and body composition analysis. Significant increases were observed for competition throwing performance and for most of the power tests ($P < 0.05$). Significant correlations were found between the training-induced increases in competition throws and the increase in performance in the shot put tests ($r = 0.68$-0.76, $P < 0.05$), as well as in the seated medicine ball throw ($r = 0.89$, $P = 0.004$). The results of the study suggest that increases in muscle power measured with easy-to-use field tests may predict the increases in competition throwing performance anticipated with long-term training and therefore that these tests can be useful for coaches without regular access to laboratory testing.

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Introduction

Success in the throwing disciplines of athletics depends largely on muscle power production, which is mainly determined by three factors: 1) the muscle mass volume, 2) the percentage of type II (fast twitch) fibres in the protagonist muscles and 3) the neuromuscular activation level during an effort[1]. This power may be developed with power training or in combination with strength training[2,3] and throwers regularly perform resistance training programmes to induce specific neuromuscular adaptations and increase their muscular power output. However, little data exists regarding the link between training-induced changes in muscle power and changes in competition discipline throwing performance. In part, this reflects the limited access of athletes to sports performance laboratories where power tests to evaluate physical ability can be conducted.

The data that is available includes a recent study of well-trained shot putters, in which the subjects experienced a significant increase in countermovement jump (CMJ) power after 12 weeks of training (approximately by 8.9%) with a concomitant increase in competition discipline throwing performance of 4.6%. Furthermore, during the competition phase a significant correlation was found between shot put performance and the CMJ power (r = 0.70)[4]. Data from another study, this time of university-level throwers, revealed that when muscle power measured with mid-thigh pulls increased by 21.8% shot put performance increasing by 5.5%. However, no correlation was found between muscle power and throwing performance after eight weeks of training[5].

Working around their available access to sports performance laboratories, most coaches recognise that field tests for power, such as standing long jump and short sprints, are well related to throwing performance. Indeed, MORROW *et al.* found significant correlations between shot put performance and both the standing long jump (r = 0.69) and the 20-yard sprint (r = -0.64) in a group of well-trained shot putters[6]. Unfortunately, although it would be of great importance for coaches, it is difficult to find comparative data and further information on these and similar easy-to-use field tests.

The purpose of this study was to investigate a possible link between training-induced changes in muscle power (as evaluated with field tests) and changes in competition discipline throwing performance. We hypothesised that muscle power as expressed in field tests would strongly correlate to throwing performance.

Methods

Experimental approach

Ten throwers followed 20 weeks of periodised training aimed at maximising throwing performance in the February competition period. The measurements of the parameters described below were taken both before (October = T1) and after (February = T2) the training period and statistically compared. Additionally, correlation analysis was used to investigate a possible link between the percentage increase in competition discipline throwing performance and the percentage increase in power performance tests.

Athletes

Ten well-trained athletes, five males (age 22.8±4.9years, body mass 88.3±13.7kg, body height 1.81±0.04m) and five females (age 18.8±0.8 years, body mass 74.7±11.4kg, body height 1.67±0.6m) with a mean 5.6±1.7 years training experience participated in the study. The group comprised four hammer throwers (1 male and 3 female), two discus throwers (1 male and 1 female), three javelin throwers (2 males and 1 female), and one male shot putter. Each participant read and signed a consent form. All procedures were approved by the School of Physical Education and Sport Science at the University of Athens and performed in accordance with the principles outlined in the Declaration of Helsinki. Before joining the experiment, all athletes were examined by a trained physician and found to be healthy (i.e., no injuries). During the training period no athletes received any medication or nutritional supplements.

Training

All the athletes completed a four-week general preparatory phase before the 20-week training period of the study, as a recovery from the long summer competition phase. The 20-week training period was designed according to the principles of periodisation[7,8,9]. It was separated into four training periods (mesocycles), each with a specific training goal and each comprising five microcycles. The main aim of the first mesocycle was to enhance muscle hypertrophy, of the second was to enhance muscle

Table 1: Training volume, training intensity and training frequency of resistance training during the 20-week training period

	1st Mesocycle	2nd Mesocycle	3rd Mesocycle	4th Mesocycle (3 First weeks)	4th Mesocycle (2 Last weeks)
Olympic Lifts and Variations (Snatch, Power Cleans, etc.)					
Volume	8 - RM	6 - RM	3/5 - RM	2/4 - RM	1/3 - RM
Intensity	75/80% - RM	80/85% - RM	85/90% - RM	90/95% - RM	85% - RM
Frequency	2 Sessions/Week	3 Sessions/Week	3 Sessions/Week	2 Sessions/Week	1 Sessions/Week
Structural Multi-Joint Exercises (Bench press, Squats, Dead Lifts, etc.)					
Volume	8 - RM	6 - RM	4/5 - RM	2/3- RM	1/2 - RM
Intensity	75/80% - RM	80/85% - RM	85/90% - RM	90/95% - RM	90/95% - RM
Frequency	2 Sessions/Week	2 Sessions/Week	3 Sessions/Week	2 Sessions/Week	1 Sessions/Week
Auxillary Exercises (Shoulder Press, Back Latter, Dumbbells, etc.)					
Volume	10/12 - RM	10 - RM	8/10 - RM	6/8 - RM	6-8 - RM
Intensity	≈75/80% - RM	≈ 80% - RM	≈ 80/85% - RM	≈ 85/90% - RM	≈ 90% - RM
Frequency	2 Sessions/Week	2 Sessions/Week	2 Sessions/Week	2 Sessions/Week	1 Sessions/Week

Table 2: Training volume, training intensity and frequency of competition discipline throws, shot put training throws and plyometric training *(*during the 20-week training period)*

	1st Mesocycle	2nd Mesocycle	3rd Mesocycle	4th Mesocycle (3 First weeks)	4th Mesocycle (2 Last weeks)
Competition Throws (Shot Put, Discus, Hammer, Javelin)					
Volume	80 Throws/Week	100 Throws/Week	120 Throws/Week	100 Throws/Week	60 Throws/Week
Intensity	Moderate to Maximum	Moderate to Maximum	Moderate to Maximum	Maximum	Maximum
Frequency	2 Sessions/Week	3 Sessions/Week	3 Sessions/Week	3 Sessions/Week	3 Sessions/Week
Shot Put Training Throws (Backward, Underhand, etc.)					
Volume	70 Throws/Week	90 Throws/Week	110 Throws/Week	90 Throws/Week	60 Throws/Week
Intensity	Moderate to Maximum	Maximum	Maximum	Maximum	Maximum
Frequency	2 Sessions/Week	3 Sessions/Week	3 Sessions/Week	3 Sessions/Week	2 Sessions/Week
Plyometric Training (Jumping bounds, Standing long jumps, etc.)					
Volume	100 Jumps/Week	120 Jumps/Week	160 Jumps/Week	160 Jumps/Week	120 Jumps/Week
Intensity	Moderate to Maximum	Moderate to Maximum	Maximum	Maximum	Maximum
Frequency	2 Sessions/Week	2 Sessions/Week	2 Sessions/Week	2 Sessions/Week	2 Sessions/Week

strength, of the third was to enhance maximum strength and power and of the fourth was to enhance muscle power production[10]. The resistance exercises comprised structural exercises (bench press and squats), Olympic lifts (power snatch and cleans), and other exercises with dumbbells and machines (Table 1). During the entire training period, all throws were performed to increase the technical skills of the athletes and their performance. To enhance muscle power, plyometric exercises with various jumps and bounds, agility exercises, and short-distance sprints with maximum velocity were performed (Table 2). All exercises were done with maximum movement velocity especially during the fourth mesocycle, when muscle power production was the main focus of training.

Competition throws tests

The subjects performed their specialist competition disciples (shot put, javelin, hammer and discus) at an outdoor facility in accordance with the official rules of the IAAF. The ambient temperature was between 18 and 22°C and the weather was sunny and calm. After a short warm-up (jogging, stretching, 2-4 near maximum-effort throws) athletes performed six throws with maximum effort[11] and with technical feedback provided. The best performance was used for further analysis.

Shot put tests

The following day, all subjects performed four different shot put tests: 1) the backward overhead shot throw, 2) the underhand shot put throw, 3) the front throw with feet in parallel facing the field and 4) the shot-put throw from the power position[12,13]. All athletes were familiar with these tests since these exercises had been part of their regular training regime over the years. Each athlete performed four attempts at maximum effort with a two-minute rest period between attempts. The best performance for each test was used for statistical analysis.

Seated medicine ball throws

Fifteen minutes after the shot put tests the subjects performed seated chest throws using five different medicine balls. They were familiarised with this test during the four-week general preparation phase. The mass of the medicine balls ranged between one and five kilograms. Seated on the floor with their back positioned against the wall and knees straight, forcing them to use their upper extremities only, the athletes performed a maximum throw from the chest[14]. With the balls chosen in random order, the athletes were instructed to throw the them as far as possible. Throwing distance was measured to the nearest centimeter from the wall where the athlete was seated to the nearest mark of where the ball landed. Two efforts were made with each ball with a one-minute rest between efforts. The best performance was used for statistical analysis. The average performance of all ball throws was also calculated and it is presented as the combined seated ball throw.

Standing long jump

Ten minutes after the seated ball throws, the subjects performed the standing long jump using an arm swing into a standard outdoor sand pit[15]. The ambient temperature was between 18 and 22°C and the weather was sunny and calm. All athletes were familiar with this test since they frequently do long jumps during their training sessions. Three test jumps were given with instructions to maximise performance as much as possible. This was followed by three maximum efforts with a one minute rest between efforts. The distance of the best jump was measured to the nearest centimeter from the take-off point to the mark where the heels landed and was used for statistical analysis. Visual feedback was used to enhance performance. Analysis included the calculation of work production during the jump with the equation: $W = F * S$ (W = work in joules, F = force, which is the body weight in Newtons, S = distance of the long jump in metres).

Sprinting

Fifteen minutes after the standing long jump the subjects performed a 30m sprint from a standing start. After two short distance sprints with sub maximum velocity and some dynamic stretching for the major muscle groups of the lower limbs, two maximum effort sprints were performed with a five-minute rest between.

Time was recorded with a stopwatch starting from the initial movement of the rear leg and ending with the athlete crossing the finish line[16, 17]. The subjects were instructed to accelerate as quickly as possible and maintain maximum speed until the finish line. The fastest time was used for statistical analysis.

Counter movement jumps

The day after the power field tests, the CMJ test was conducted in the laboratory. Three different loads were used: 1) unloaded, using a wooden bar of 100gr, 2) 20kg, using an Olympic barbell and 3) 30% of 1-RM squat[4]. All measurements were performed on a force platform (Applied Measurements Ltd Co. UK, WP800, 80 x 80cm, sampling frequency 1 kHz). After a five-minute warm-up on a stationary bicycle followed by five minutes of stretching the major muscle groups of the lower extremity, three submaximal CMJs with the hands placed on the bars at set positions were performed for each load with increased intensity prior to the tests. After this familiarisation process, two CMJ's with maximum effort were performed for each load (wooden and Olympic bar, and 30% 1RM squat) followed by a three minute rest between each effort. Data from the force platform were recorded and analysed (Kyowa sensor interface PCD- 320A) calculating the maximum vertical jump height and power output during the push off phase. The signal was filtered using a secondary low pass Butterworth filter with a cutoff frequency of 20 Hz. The best jump height performance was used for further analysis.

Body composition analysis

A total body scan was performed on all the subjects using the DEXA (model DPX-L; LUNAR Radiation, Madison, WI, USA) to evaluate lean body mass. All measurements were analysed using the LUNAR radiation body composition program. Analysis included fat mass, bone mineral density (BMD) and lean body mass (LBM) for the whole body, arms, trunk and legs.

Statistical analysis

All data was represented as mean ± SD. Analysis of variance for repeated measures was used to test differences between T1 (Pre) and T2 (Post) in all raw data. Bonferroni confidence interval adjustment compared the main effects between T1 and T2. Effect sizes were calculated using the eta-squared statistic with statistical power calculated to obtain the power of the test. Pearson's r product moment correlation coefficient was used to explore the relationships between training induced changes for all variables. Standard multiple regression analysis was performed for the % change of variables between T1 and T2. Because of the small sample size (n = 10) adjusted R squared was used for the interpretation of the multiple regression analysis results[18]. Within subject variation and reliability was determined for all variables by calculating the confidence limits

Table 3: Intra Class Coefficients for all variables

Variable	ICC	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	N
Backward	0.98	0.92	0.99	13
Underhand	0.92	0.74	0.98	13
Front Throw	0.93	0.80	0.99	13
Power Position	0.94	0.83	0.98	13
Medicine Ball Throw	0.93	0.80	0.98	12
Standing Long Jump	0.96	0.88	0.99	11
Sprinting	0.94	0.76	0.98	11
CMJ	0.91	0.90	0.99	13
DEXA	0.98	0.95	0.99	13

ICC = Intra Class Coefficient, CMJ = Counter Movement Jump; DEXA = Dual X-ray Absorptiometry

(CI 95%) and intra-class correlation (ICC) coefficient and are presented in Table 3. Significance was accepted at $p \leq 0.05$. All statistical analyses were performed using SPSS version 17.0 software (SPSS inc. Chicago, IL, USA).

Results

Training

Performances for the competition discipline throws increased significantly after 20 weeks of training by 13.5±9.8% (P=0.02, η^2= 0.661, Power = 0.960).

Performance in the shot put tests also increased significantly, except for the front throw. Absolute values and joule production for the standing long jump increased by 5.9±3.9% and 5.8±4.9%, respectively, while 30m-sprint performance decreased significantly by -3.1±1.4% (Table 4).

Seated medicine ball throws increased for the one kilogram ball by 6.9±5.9% (P = 0.003, η^2 = 0.685), the two kilogram ball by 6.4±6.3% (P = 0.032, η^2 = 0.455) and the three kilogram ball by 6.2±4.3% (P = 0.005, η^2 = 0.656, Figure 1), with no significant increases observed for the four kg ball (3.2±7.6%, P = 0.410, η^2 = 0.086) and five kilogram ball (1.4±6.0%, P = 0.796, η^2 = 0,009). When all medicine ball throws were calculated as one variable, the combined seated ball throw increased significantly by 5.2±5.1% (Table 4).

CMJ height increased for both the unloaded and the 20kg conditions by 7.5±5.5% and 10.7±10.5%, respectively, but no significant change was observed for the 30% of 1-RM condition. For the unloaded condition power production increased by 3.4±3.9% with no changes occurring for both the 20kg and 30% of 1-RM conditions. Power production expressed per body mass increased significantly for the unloaded and 20kg by 3.5±3.1% and 3.7±3.9%, respectively, but remained unaltered for the 30% of 1-RM condition (Figure 2). Force remained unaltered after all conditions while velocity increased by 7.5±5.5% and 10.7±10.6% during unloaded and 20kg conditions, respectively (Table 5).

Lean mass remained unaltered after the training period (before 55.9±13.15kg vs. 56.4±12.8kg after, P = 0.235, η^2 = 0.153) but lean mass for the legs increased significantly (before 19.3±4.3kg vs. 20.6±3.9kg after, P = 0.001, η^2 = 0.744).

Table 4: Performance changes in shot put tests and power field tests after 20 weeks of periodised training

Field Tests	Pre	Post	% Change	P	η^2	Power
Backward (m)	12.5±1.1	13.1±1.2	4.9±4.6	0.005	0.596	0.899
Underhand (m)	11.2±1.4	11.7±1.2	4.5±5.3	0.024	0.451	0.678
Front throw (m)	8.6±1.2	8.9±1.0	3.4±6.4	0.184	0.187	0.252
Power position (m)	8.6±1.2	9.2±1.3	6.8±4.9	0.002	0.679	0.972
Standing long jump (m)	2.3±0.3	2.5±0.4	5.9±4.0	0.001	0.722	0.990
Standing long jump (J)	1866.5 ±461.9	1970.9 ±482.1	5.8±4.9	0.007	0.578	0.876
30m Sprint (sec)	4.6±0.4	4.4±0.3	-2.6±1.9	0.000	0.807	0.999
Combined seated ball throw (m)	5.6±1.4	5.9±1.4	4.7±5.1	0.026	0.440	0.660

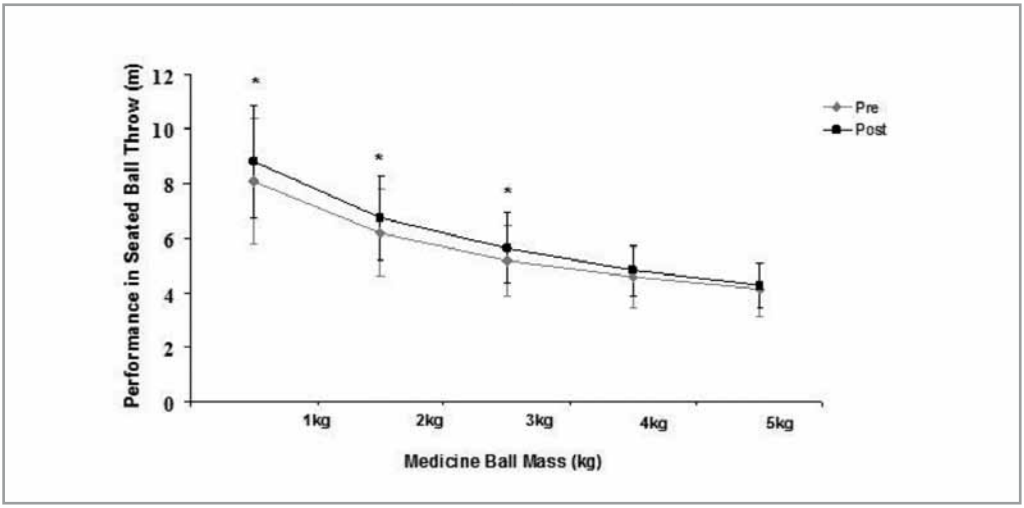

*Figure 1: Performance in seated medicine ball throws before (gray line) and after (black line) the 20-week training programme (Significant increases for the 1, 2 and 3kg medicine balls (*P < 0.05))*

Table 5: Changes in countermovement jump performance with different loads after 20 weeks of periodised training

Variable	Pre	Post	% Change	P	η^2	Power
Unloaded						
CMJ height (cm)	27.4±6.3	29.6±7.9	7.5±5.5	0.009	0.553	0.843
CMJ force (kg)	105.5±25.1	103.4±18.1	0.96±19.74	0.762	0.011	0.059
CMJ power (W)	3399.7 ±756.5	3512.9 ±778.2	3.4±3.8	0.017	0.484	0.735
CMJ Power/kg (W/kg)	41.5±4.3	43.1±5.3	3.5±3.2	0.009	0.550	0.838
CMJ velocity (m·sec^{-1})	2.3±0.5	2.5±0.7	7.5±5.5	0.004	0.612	0.916
20kg load						
CMJ height (cm)	19.9±5.6	21.9±6.1	10.7±10.5	0.012	0.523	0.798
CMJ force (kg)	93.8±21.8	94.6±20.2	3.2±11.9	0.831	0.005	0.054
CMJ power (W)	3009.9±814.8	3112.2±833.9	3.6±5.3	0.072	0.317	0.446
CMJ Power/kg (W/kg)	36.4±4.8	37.7±4.9	3.7±3.9	0.016	0.494	0.752
CMJ velocity (m·sec^{-1})	1.7±0.5	1.8±0.5	10.68±10.5	0.009	0.551	0.840
30% of 1-RM						
CMJ height c(m)	16.3±3.9	17.1±3.9	5.7±9.1	0.110	0.259	0.354
CMJ force (kg)	87.3±19.6	88.6±19.1	2.6±13.0	0.738	0.013	0.061
CMJ power (W)	2825.8±722.2	2865.1±731.5	1.4±4.1	0.323	0.108	0.155
CMJ Power/kg (W/kg)	34.2±3.7	34.8±3.8	1.5±2.9	0.138	0.227	0.307
CMJ velocity (m·sec^{-1})	1.3±0.3	1.4±0.3	5.7±9.1	0.103	0.267	0.367

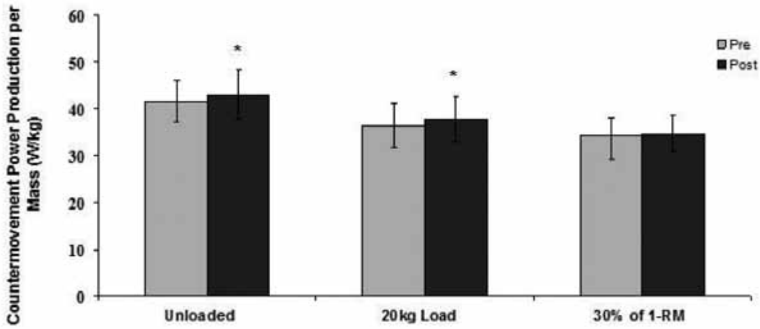

*Figure 2: Changes in CMJ power production per body mass (Significant increases for the unloaded and the 20kg conditions (*P < 0.05))*

Percentage change correlations and multiple linear regression

Significant percentage change correlations were found between throwing performance and shot put tests. In addition, a significant percentage change correlation was found between throwing performance and the combined seated medicine ball throws (Table 6). The percentage increase in these throws was significantly correlated with the percentage change in CMJ's with 30% of 1-RM muscle power (r = 0.756, P = 0.011) and power per mass (r = 0.729, P = 0.017).

The percentage change in total lean mass was significantly correlated with the percentage increase in unloaded CMJ power (r = 0.64, P = 0.046) and with 20kg load CMJ power/kg (r = 0.673, P = 0.033).

Multiple linear regression revealed that the linear combination of the percentage increase in work production during the long jump with the percentage increase in 30m-sprint accounted for the 63% of variance the percentage increase for throwing performance (P = 0.021, Long jump Beta = 0.656, P = 0.022, Sprint Beta = -0.559, P = 0.040).

Discussion

The main finding of the study was that training-induced changes in the results obtained from easy-to-use power field tests may significantly predict percentage increases in competition discipline throwing performance for the shot put, discus, javelin, and hammer. Power field tests are low cost performance tests that can be performed during any training period and used effectively when access to performance laboratories is limited. They provide useful insights into the progression of the athlete's muscular power and may even predict performance in the throwing events. Many coaches and athletes have used these tests to evaluate muscle power during training. The current results reveal for the first time a significant link between these tests and throwing performance.

Previous reports suggest that after eight and 12 weeks of strength-power training shot put performance increased significantly by 5.5% in collegiate throwers and by 4.7% in well-trained rotational shot putters, respectively[4, 5]. In our study we observed a 13.5% increase in performance after 20 weeks of training.

Table 6: Percentage change correlation coefficients between competition discipline throwing performance and shot put test and power field tests

	Competitive Throw	Backward Shot Put Throw	Underhand Shot Put Throw	Front Shot Put Throw	Shot Put Throw From Power Position	Long Jump (m)	Long Jump (Joule)	30m-Sprint	Combined Seated Ball Throw
Competitive Throw	1.000								
Backward Throw	0.732*	1.000							
Underhand Shot Put Throw	0.766*	.0749*	1.000						
Front Shot Put Throw	0.696*	0.510	0.617	1,000					
Shot Put Throw From Power Position	0.152	0.288	0.090	0.590	1.000				
Long Jump (m)	0.466	0.573	0.439	0.621	0.462	1.000			
Long Jump (Joule)	0.576	0.566	0.562	0.785*	0.559	0.928**	1.000		
30m Sprint	-0.543	-0.369	-0.617	-0.402	0.371	0.029	0.025	1.000	
Combined Seated Ball Throw	0.819**	0.466	0.655*	0.555	0.188	0.096	0.266	-0.474	1.000

(*$P < 0.05$, **$P < 0.001$)

Shot put throw tests are easy-to-use power tests as, normally, throwers use them regularly during all training periods. These throws recruit a large percentage of the body's musculature suggesting their use for evaluating whole body power performance capacity. In a previous study, performance in the backward overhead throw was significantly linked with hammer throwing performance in well-trained hammer throwers[19]. In line with this finding, our results showed that training-induced changes in shot put throw tests were linked with competition discipline performance. Coaches and athletes should regularly perform these tests to evaluate full-body power capacity and to help predict maximum performance for competition.

The standing long jump and short sprints are also used by to evaluate lower-body power and are perhaps the most popular power tests used by throwers. MORROW ***et al***. observed a significant correlation between shot put performance and standing long jump (r = 0.69) and 20-yard sprint (r = -0.64)[6], respectively. In the present study, the change in performance in these was not linked with an increase in competition discipline throwing performance. However, multiple linear regression analysis revealed that the linear combination of the increases in long jump and in 30m-sprint could significantly predict 63% of the increase in competition discipline throwing performance. The results of the current study suggest that coaches and athletes should include standing long jump and short distance sprints in their training programmes to enhance muscle power production and for predicting throwing performance in competition.

Although lean body mass remained unaltered after training, the lean mass of the legs increased significantly. Lean mass has been significantly linked with competition performance in the hammer[19] and with performance in the shot put using the glide technique[20]. The subjects in the current study exhibited a smaller proportion of lean mass (55.9±13.15kg) compared to other studies investigating throwers[4,19]. Changes in lean mass were significantly correlated with increases in CMJ power both unloaded and with 20kg barbell. Although no significant link was found between lean mass or CMJs and throwing performance, significant correlations were observed between training-induced changes in lean mass and CMJ power production suggesting that lean mass contributes to power production.

Conclusion

Twenty weeks of training significantly increased competition discipline throwing performance, as well as whole- and lower-body power production. These findings support the use of periodised training regimes for effective programme design. In addition, the percentage increase in throwing performance was significantly linked with simple field power tests (i.e., shot-put tests, standing long jump, and 30m-sprint). Tests like the standing long jump and the 30m-sprint may predict a large part (63%) of throwing performance. Therefore, when access to laboratories is limited, we recommend the use of these easy-to-use tests to evaluate power capacity.

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