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Original Article

Track and field throwing performance prediction: training intervention, muscle architecture adaptations and field tests explosiveness ability

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Abstract
Purpose: The purpose of the present study was to investigate whether a) modification in muscle architecture due to training intervention and b) neuromuscular explosive field tests results may predict competition performance in track and field throwing athletes. Methods: Eleven track and field throwers completed 10 weeks of specific training that was performed prior to the summer official national competition. Before and following the 10 weeks of training programe, track and field throwing trials, vastus lateralis muscle architecture, shot put tests, standing long jump, and 40m sprinting were evaluated. Results: Track and field throwing performance, muscle thickness, fascicle length and power-position shot put throw all increased by 5.78 ± 2.82% (P = 0.000), 6.2 ± 7.4% (P = 0.01), 10.5 ± 13.1% (P = 0.02) and 2.8 ± 3.9% (P = 0.04), respectively. Sprinting time in 40m decreased by -1.2 ± 1.0% (P = 0.004), whilst, work power output during the standing long-jump increased by 1.7 ± 2.5% (P = 0.03) when compared between pre- and post-training intervention. The power-position shot put throwing result was positively correlated with the increase in standing long-jump (r = 0.81, P < 0.01) and with the increase in 40m sprint (r = -0.63, P < 0.05) performances. The increase in muscle thickness was positively correlated with the increase in 40m sprint performance (r = 0.62, P < 0.05). The multiple linear regression analysis, combining the percentage alteration in backward shot put throw and vastus lateralis thickness with the proportional increase in track and field throwing competition performance, explains the 56% increase observed in throwing competition result. Conclusions: These results may suggest that consistent examination of muscle thickness and evaluation of throwing ability using explosive field tests during a training period both may be used to predict the increase in track and field throwing competive performance.
Keywords: athletics throwing performance, strength-power, explosive field tests, muscle thickness

Introduction

Muscle power development was suggested to be a crucial training element for athletics throwing performance (Zaras et al., 2016). Regular monitoring therefore, of power development might be an important training tool for track and field coaches for being able to a) adjust periodically the training stimulus and b) potentially predict modifications in competitive throwing performance. Several explosive-type laboratory tests, (such as the vertical jumping on a force platform or the leg press and chest press rate of force development), are considered as valid tools for assessing both upper and lower body muscle power ability (Kyriazis et al., 2009; Zaras et al., 2016). However, these laboratory tests have several practical limitations including the demand of the participants to visit the laboratory, the cost of the evaluations and the necessity to perform these fitness evaluations without imitating the actual throwing-related movements. On the other hand, field tests are readily applied and able to provide instant feedback about explosive performance. For instance, performance in shot put throws, in the standing long jump and short distance sprints are commonly recognized among coaches as valid tests for explosive performance in track and field throwers (Terzis et al., 2010 or Zaras et al. 2014). However, scarce scientific data exists regarding the interconnection between performance results obtained using these field power tests and the track and field throwing actual performance.

Shot put throwing tests such as the underhand hot put throw and the backward overhead shot put throw (Ekstrand et al., 2013) are used to evaluate whole-body power performance; and explosive exercises are employed for throwing performance improvement by several track and field throwers (Terzis et al., 2010; Zaras et al., 2014). Performance in backward overhead shot put throw was found to be positively correlated with the

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hammer throwing performance [r = 0.95, (Terzis et al., 2010)]. However, it remains unknown whether performance changes in such tests may predict changes in competitive track and field throwing performance. Empirical data from track and field coaches reveal that training-induced improvement in standing long jump and short distance sprints ability of the throwers are common training strategies to increase lower body muscle power. Indeed, performance in standing long jump, which can be performed either indoors or outdoors year-round with minimal equipment, is strongly associated with lower body muscle power (Ashby et al., 2002; Castro-Pinero et al., 2010; Maulder et al., 2005). Previous results revealed a significant positive correlation between shot put throwing performance and standing long jumping [r = 0.69, (Morrow et al., 1982)]. Sprinting is considered as a complex ballistic movement that involves stretch shortening cycle and explosive force production of the leg extensors (Marcovic et al., 2007; Mero et al., 1992). Morrow et al., (1982), showed a significant positive correlation between shot put throwing and sprinting (r = -0.64) in a group of well-trained shot putters. However, it remains unknown whether changes in jumping and sprinting performance due to specific training intervention may predict positive modifications in competitive track and field throwing performance. Muscle architecture is highly adaptable in response to resistance training (Blazevich et al., 2003; Nimphius et al., 2012; Stasinaki et al., 2015; Zaras et al., 2013). Moreover, it has been suggested that performance in vertical jumping and sprinting are associated with muscle thickness and fascicle length (Abe et al., 2001; Earp et al., 2010; Kumagai et al., 2000). Recently, it was revealed that performance in shot putting tests is related with vastus lateralis muscle thickness and fascicle length, while the increase in vastus lateralis muscle thickness and fascicle length might explain 33% of the training-induced increase in track and field throwing performance in young throwers (Zaras et al., 2016). However, it remains unknown whether training-induced muscle architectural alterations are correlated with training-induced changes in competitive performance in track and field throwers. The purpose therefore, of the present study was to examine the relationship among training intervention-induced changes in competitive track and field throwing performance, in muscle architecture adaptations and in performance in explosive field tests in track and field throwers. It was hypothesized that changes in muscle thickness and fascicle length, and performance in explosive field tests would be associated with changes in competitive track and field throwing actual performance.

Materials And Methods

Experimental Approach to the Problem

Eleven (n = 11) track and field throwers followed 10 weeks of periodized specific athletic training organized in two 5-week mesocycles, aiming to increase muscular strength and strength-power, respectively. The 10-weeks of training preparation was performed prior to the summer official national competition. Before (T1) and after (T2) the training intervention, athletic throws, shot put tests , standing long jumps and 40m sprint were evaluated while vastus lateralis muscle architecture was also measured. Correlations between muscle architecture and performance were calculated both at T1 and T2, while correlations between the training-induced percentage changes in these parameters were also evaluated. Comparisons were made using ANOVA for repeated measures while the relationships between parameters were calculated using the Pearson's product moment correlation coefficient.

Participants

Six male (age 21.3 ± 7.5, range18-26 years, body height: 1.78 ± 0.07 m, body mass: 90.4 ± 20.8 kg) and 5 female (age 18.4 ± 2.9, range 17-22 years, body height: 1.68 ± 0.04 cm, body mass: 77.7 ± 18.9 kg) track and field throwers, gave their written consent to participate in the study after being informed about the experimental risks and procedures. Written parental consent was also obtained in participants under 18 years of age. Five of the participants were discus (3 males, 2 females), 3 hammer (2 males, 1 female), 2 shot put (1 male, 1 female), and 1 (female) javelin throwers. Ten of the participants were officially qualified for the national championship, and their performance was among the top 15 of the nation. All throwers were in good health and received no medication or nutritional supplements during the training period. All procedures were performed in accordance with the principles outlined in the Declaration of Helsinki and were approved by the local ethics committee.

Procedures

Training

Athletes completed 10 weeks of training aiming to enhance track and field throwing performance at the upcoming summer national competition. All athletes were familiar with shot put throws like the backward overhead throw, the shot put throw from the power position, and with the field power tests (see below). Training was separated into two mesocycles according to the principles of periodization, as previously described (De Weese et al., 2015 a; b; Hartmann et al., 2015; Turner, 2011). During the first mesocycle, the main targets of resistance training was to enhance muscle hypertrophy and maximum strength, while during the second mesocycle, the training aim was to increase maximum strength and power. The acute training variables are presented in Table 1. About 5% of all the planned training sessions were not completed due to insignificant injuries. All efforts were performed with maximum possible movement velocity, especially during the second mesocycle when strength-power was developed. Training also included plyometrics with various jumping bounds and standing long jumps, agility exercises and short-distance sprinting with maximum intended velocity.

Table 1. General characteristics for the strength, throwing and plyometric training.

	Strength Training (3-4 sessions/week)			Track and field throws (2-3 sessions/week)		
	Structural Exercises	Weightlifting	Assistance Exercises			
Training Week	Bench press, Squat, Shoulder Press, Dead Lifts	Snatch, Clean and jerk	Assistance exercises (dumbbells & machines)	Track and field throws (Discus, Hammer, Javelin, Shot put)	Shot put throws	Plyometric Training (2 sessions /week)
Week 0	Pre-Test (T1)					
Week 1	4 x 6 RM	4 x 5-6 (70% RM)	4 x 10-12 RM	40-50	20-30	
Week 2	4 x 6 RM	4 x 5-6 (75% RM)	4 x 10-12 RM	40-50	20-30	
Week 3	4 x 5 RM	4 x 4-5 (80% RM)	4 x 10-12 RM	50-60	30-40	(e.g. standing broad jumps and triple jumps, hurdles, sprints and agility sprints)
Week 4	4 x 5 RM	4 x 4-5 (85% RM)	4 x 10 RM	50-60	30-40	
Week 5	4 x 4 RM	3 x 3-4 (85% RM)	3 x 8-10 RM	50-60	30-40	
Week 6	Transition week (similar to week 2)					
Week 7	4 x 4 RM	3 x 2-3 (90% RM)	3 x 8-10 RM	40-50	30-40	
Week 8	4 x 3-4 RM	3 x 2-3 (90% RM)	3 x 8-10 RM	50-60	20-30	
Week 9	3 x 2-3 RM	2 x 2-3 (90% RM)	3 x 6-8 RM	30-40	20-30	(e.g. standing broad jumps and 45cm drop jumps, hurdles, sprints and agility sprints)
Week 10	3 x 2-3 RM	2 x 2-3 (95% RM)	3 x 6-8 RM	20-30	15-25	
Week 11	3 x 2-3 RM	2 x 1-2 (95% RM)	2 x 6-8 RM	15-20	15-20	
Week 12	Post-Test (T2)					

Track and Field Throws

Shot put, javelin, hammer, and discus throwing performance were measured outdoors (each athlete performed his/her own specialty) during afternoon, following the official rules of the International Amateur Athletics Federation (IAAF). Ambient temperature was approximately 24–28ºC. Briefly, following a short warm-up including jogging, dynamic stretching and 2-4 near to maximum warm up throws, athletes performed 6 throws with maximum effort (Dunn and McGill, 1991). After each attempt, technical feedback was provided by a certified coach while the best throwing performance, out of the six attempts, was used for the statistical analysis.

Shot Put Tests

The next day, all athletes performed two different shot put tests: (a) the backward overhead shot put throw and (b) the shot put throw from the power position (Zaras et al., 2016). The backward overhead shot put throw is considered to be a whole-body power test with minimal technically demands (Ekstrand et al., 2013). However, the shot put throw from the power position is considered to be a highly technically demand throwing test. All athletes were familiar with both shot put tests since they all used them regularly during their training sessions over the years. Athletes performed 4 attempts of each test with maximum effort. The best performance for each throwing test was included into the statistical analysis. The intraclass correlations (ICCs) for the shot put tests were as follows: 0.98 (95% confidence interval [CI]: lower = 0.92, upper = 0.99, n = 13) for the backward overhead shot put throw, and 0.94 (95% CI: lower = 0.83, upper = 0.98, n = 13) for the shot put throw from the power position.

Standing long jump

Fifteen minutes after the shot put tests, athletes performed the standing long jump trials. All athletes were familiar with this test since they frequently performed long jumps during their daily training sessions. Measurement was performed outdoor, in a track and field sand pit with an ambient temperature of 24-28°C. Specifically, all athletes placed their toes at the edge of the running lane in front of the sand pit in an attempt to push with their feet and jump with arm swing as fast and long as possible (Almuzaini et al., 2008). Prior to the main jump trails and for warming-up purposes, three standing long jumps were performed where the participants were advised to progressively increase their jumping velocity to maximum. Then, the three main maximum standing long jump trails were performed with one minute rest between each trial. The distance of the best jump was measured to the nearest centimeter from the take off point to the mark where the heels landed inside the sand. Marks were placed on the sand as goal-reaching feedback. The longest jump was recordered and included into the statistical analysis. Analysis also included the calculation of work production during the long jump with the equation: $W = F \cdot S \cdot g$ (W = work in joules, F = force which is the body mass in Newton's, S = distance of the long jump in meters and g = the gravity 9.81 m•sec-1, [Baker, 1995]). The ICC for the standing long jump was 0.96 (95% CI: Lower = 0.88, Upper = 0.99, n = 11).

40 meters maximum sprint

Fifteen minutes after the standing long jump, athletes performed the 40m maximum sprinting test with a standing start. Briefly, following two short distance sprints with sub maximum velocity and some dynamic stretching exercises applied on the major muscle groups of lower limbs, athletes performed 2 maximum sprints with 5 minutes interval between the attempts. Time measurement was collected with a stopwatch, starting from the initial movement of the rear leg to the cross of the finish line (Ashby et al., 2002; Moore et al., 2007). Athletes were instructed to accelerate as quickly as possible and maintain maximum speed until the finish line. The fastest time in sprinting performance was reordered and used for the statistical analysis. The ICC for the 40m sprint was 0.94 (95% CI: Lower = 0.76, Upper = 0.98, n = 11).

Ultrasonography

Forty eight hours following the above described field tests, B-mode ultrasound images were obtained from the vastus lateralis (VL) of the dominant leg of the participants using a 38-mm linear probe (Product model Z5, Shenzhen Mindray Bio-Medical Electronics Co., Ltd, Shenzhen, China). Extended-Field-Of-View mode was used to obtain panoramic images along the fascicle length as previously described (Noorkoiv et al., 2010). For the assessment of VL architecture, participants laid supine with their knees fully extended and their muscles relaxed. A mark was drawn at 50% of the distance from the central palpable point of the greater trochanter to the lateral condyle of the femur (Blazevich et al., 2007). A water-soluble gel was applied to the transducer to aid acoustic coupling and reduce the needed pressure from the probe against the muscle. The transducer was placed longitudinal at femur or tibia, parallel to the muscle fascicles and perpendicular to the skin. Due to inter-individual variability, the transducer was occasionally aligned slightly diagonally to the longitudinal line of the muscle, so as several fascicles could be easily delineated without interruption across the image. Based on this orientation, a dashed line (approximately 10 cm in length) was drawn forwards and backwards to the aforementioned mark, identifying and capturing the largest, continuous fascicle visualization. For obtaining the muscle image, a continuous single view was taken by moving the probe along the marked, dashed line.

Ultrasonography images were analyzed for muscle thickness, fascicle angle and fascicle length with the relevant image analysis software (Motic Images Plus, 2.0). Muscle thickness was defined as the mean of the distances between the superficial and deep aponeurosis measured at the ends of each panoramic image (Blazevich et al., 2005), fascicle angle as the angle of insertion of muscle fascicles into the deep aponeurosis, and fascicle length as the fascicular path between the insertion of the fascicle into the upper and deeper aponeurosis. The ICC for the ultrasound image analysis was for muscle thickness 0.97 (95% CI: Lower = 0.87, Upper = 0.99), for fascicle angle 0.88 (95% CI: Lower = 0.60, Upper = 0.98) and for fascicle length 0.85 (95% CI: Lower = 0.47, Upper = 0.98, n = 11).

Statistical Analyses

All data are represented as mean ± SD. Analysis of variance for repeated measures was used to test differences between T1 and T2. Bonferroni confidence interval adjustment was used to compare the main effects between time measurements. Effect sizes and statistical power were also calculated. Pearson's r product moment correlation coefficient was used to explore the relationship between T1 and T2, and between the percentage (%) changed for the variables measured. Standard multiple regression analysis was performed between the % changes and adjusted R2 was used for the interpretation of the multiple regression analysis results (Tabachnick and Fidell, 2007). Significance was declared at P ≤ 0.05. All statistical analyses were performed using SPSS version 17.0 software (SPSS inc. Chicago, IL, USA).

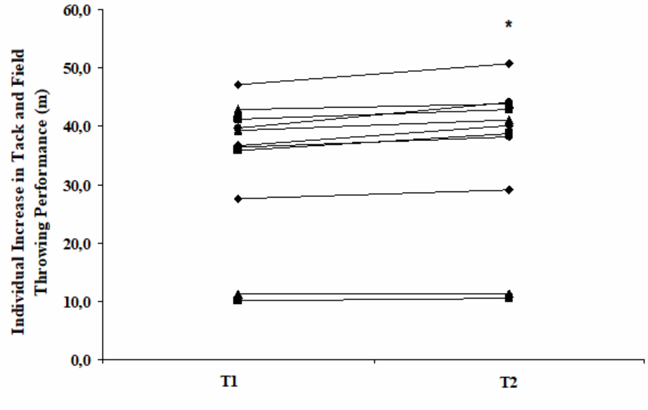

Figure 1. Individual increase in track and field throwing performance after 10 weeks strength and power training in 11 well trained throwers (*P < 0.05).

Results

There were no significant differences between male and female participants in exercise performance measured variables and in muscular morphological changes (e.g. for shot put throwing performance: P = 0.647, and for muscle thickness: P = 0.352). Consequently, the participants are presented as one group.

Table 2. Changes in body mass, throwing, standing long jump, sprinting and vastus lateralis muscle architecture characteristics before and after 10 weeks of specific track and field throwing training, in 11 throwers (mean ± SD).

Variable	T1	T2	% T1-T2	p	Eta^2	Power
Body mass (kg)	84.2±19.8	85.0±20.7	0.75±1.4	0.072	0.289	0.445
Backward throw (m)	13.92±1.5	13.91±1.6	-0.10±2.6	0.984	0.000	0.050
Shot put throw-Power Position (m)	9.9±1.23	10.1±1.3	2.8±4.0	0.040	0.356	0.565
Long Jump (m)	2.3±0.3	2.4±0.3	1.0±3.2	0.304	0.105	0.165
Long Jump (J)	19398.1± 5269.2	19690.1± 5194.5	1.7±2.5	0.029	0.393	0.631
40m Sprint (sec)	6.1±0.4	6.0±0.4	-1.9±0.9	0.005	0.603	0.907
Thickness (cm)	2.5±0.3	2.7±0.3	6.2±7.4	0.016	0.453	0.737
Pennation (dgr)	18.7±2.7	18.6±1.8	1.35±16.4	0.943	0.001	0.051
Fascicle length (cm)	7.9±0.9	8.7±1.2	10.5±13.1	0.030	0.390	0.626

Track and field throwing performance was increased by 5.78±2.82%, (P = 0.000, η2 = 0.724, Power = 0.996) following 10 weeks of periodized training. Individual data are presented in Figure 1. Shot put throw from the power position increased by 2.8±4.0% (P = 0.040), while backward overhead shot put throw remained unaltered (-0.10±2.6%, P = 0.984). Standing long jump remained unchanged after training (1.0±3.2%, P = 0.304), but work production during standing long jump increased significantly by 1.7±2.5% (P = 0.029). Performance in 40m sprint was significantly improved when compared between T1 and T2 trails (-1.9±0.9, P = 0.005). Vastus lateralis muscle thickness and fascicle length were significantly increased following the training intervention by 6.2±7.4% (P = 0.01) and by 10.5±13.1% (P = 0.02), respectively. No significant difference was found in vastus lateralis fascicle angle. All data are presented in Table 2 (1.35±16.4, P = 0.943).

Table 3. Correlation coefficients for all variables during T1 and T2 periods.

		Backward Throw	Shot Put Throw	Long Jump	Long Jump (J)	40 m Sprint	Thickness	Pennation Angle
Backward Throw	T1							
	T2	1						
Shot Put Throw	T1	.769**						
	T2	.707*	1					
Long Jump	T1	.519	.319					
	T2	.500	.241	1				
Long Jump (J)	T1	.662*	.785**	.493				
	T2	.656*	.783**	.362	1			
40 m Sprint	T1	-.401	-.169	-.894**	-.178			
	T2	-.535	-.228	-.889**	-.157	1		
Thickness	T1	.600	.678*	.499	.575	-.335		
	T2	.470	.667*	.426	.611*	-.299	1	
Pennation Angle	T1	.210	.269	.081	.249	.049	.707*	
	T2	-.563	-.082	-.433	-.237	-.367	.296	1
Fascicle Length	T1	.417	.543	.534	.463	-.470	.264	-.470
	T2	.895**	.672*	.725*	.749**	-.602	.674*	-.487

For the correlation analysis results see in Tables 3. The % increase in shot put throw from the power position was significantly positively correlated with the % change in standing long jump (r = 0.81, P = 0.003) and with the % increase in standing long jump work production (r = 0.83, P = 0.002). Negative correlation was found between the % increase in shot put throw from the power position and the % increase in 40m sprint (r = -0.63, P = 0.038). The % increase in muscle thickness was borderline correlated with the % increase in shot put throw from the power position (r = -0.59, P = 0.056), but significantly correlated with the % increase in 40m sprint (r = 0.62, P = 0.045).

Standard multiple regression analysis revealed a significant regression model between the % increase in track and field throwing performance and the linear combination of the % change in backward overhead shot put throw and the % increase in vastus lateralis muscle thickness (adjusted R2 = 0.558, P = 0.016, Backward Beta = 0.644, P = 0.018, Thickness Beta = 0.681, P = 0.014). Furthermore, the linear combination of the % increase of work production in long jump and the % increase in vastus lateralis muscle thickness explained approximately the 80% of the % increase in shot put throw from the power position (adjusted R2 = 0.799, P = 0.001, work production long jump Beta = 0.726, P = 0.001, Thickness Beta = -0.400, P = 0.026).

Discussion

The main finding of the present study was that changes in explosive field tests performance, such as the backward shot put throw and the standing long jump, combined with changes in vastus lateralis muscle thickness, were significantly associated with changes in track and field throwing actual performance and shot put throw from the power position. These percentage relationships were observed following 10 weeks of periodized training intervention in well-trained throwers. Moreover, significant association were observed between standing long jump and 40m sprint with shot put throw from power position and muscle architecture modifications due to training intervention. Data from previous studies showed that performance in backward shot put throw, in standing long jump and in small distance sprints were significantly correlated with shot put throw and hammer throw (Morrow et al., 1982; Terzis et al,. 2010). Additionally, the linear combination of changes in vastus lateralis muscle thickness and fascicle length has been shown to explain 33% of the percent increase of track and field throwing performance in young track and field throwers (Zaras et al., 2016). The current study suggests that an efficient and practically applicable method to potentially predict modifications in track and field throwing actual performance and in shot put throwing performance from the power position is to make use the results taken up from power field tests in combination with training-intervention induced alterations in muscle architecture. Throwing coaches therefore, may apply these explosive field tests for monitoring increases in power capacity of their athletes in an attempt to predict changes in track and field throwing performance. Based on the current results, it might be predicted that a 5% increase in muscle thickness, combined with a 2% increase in backward shot put throw performance, may induce approximately 6.9% increase in track and field throwing actual performance.

The current study also suggested that training-induced significant increases in track and field throwing performance (5.9%) and in shot put throw from the power position (2.8%). Following the training intervention period, all athletes managed to increase their individual track and field throwing actual performance which underpins the effectiveness of this periodized training program. Previous studies revealed similar increases (6.8%) in track and field throwing performance after 12 weeks of training (Zaras et al., 2016), and by 5.5% and 4.8%, after 10 and 8 weeks of training in shot put, respectively (Kyriazis et al., 2009; Stone et al., 2003). Furthermore, the current results suggest that standing long jump, expressed as work production, and 40m sprinting performance both increased following the 10 weeks of training. However, these increases were not associated with the increase in track and field throwing actual performance of the current participants. A potential explanation of this result is the interindividual variability of the current participants, since they are practicing in all four throwing athletic events. Ten weeks of either sprinting or plyometric training induced significant increases in standing long jump by 3.2% and 2.8%, respectively in physical education students (Marcovic et al., 2007), while performance in standing long jump was positively correlated with 100m sprinting performance ($r = -0.81$, $p < 0.01$), in a group of well-trained sprinters (Loturco et al., 2015). Taken together, the current and previous results, may suggest that regular monitoring of performance in standing long jump and 40m sprinting might be useful indicators for the athlete’s power development during a training period.

A key finding of the present study was that strength and power training induced significant increase in vastus lateralis muscle thickness and fascicle length. Muscle architecture adaptations have been well documented in previous studies, both in untrained and well-trained participants (Aagaard et al., 2001; Blazevich et al., 2003; Cormie et al., 2010; Zaras et al., 2013). Recent results suggest that the percent change in backward overhead shot put throw is correlated with the percent change in vastus lateralis muscle thickness ($r = 0.52$, $p < 0.05$), following 6 weeks of complex and compound resistance training in moderately-trained participants (Stasinaki et al., 2015). Similarly, vastus lateralis muscle thickness partly explained the percent increase in track and field throwing performance, in young competitive throwers (Zaras et al., 2016). Muscle thickness as measured with ultrasound, is an indication of muscle mass, which is one of the major components determining muscle power (Blazevich et al., 2003; Zaras et al., 2016). It seems that ultrasound measurements of muscle thickness may provide useful indication about the muscular adaptations induced with resistance training. The current results reveal that monitoring changes in muscle thickness after a period of training are essential for the estimation of the performance enhancement in track and field athletes.

In the current study, muscle thickness was negatively correlated with 40m sprinting performance , suggesting that participants with the larger muscle thickness performed better in short sprints. Although sprinting performance at T1 was not correlated with fascicle length, interestingly, the correlation coefficients at T2 revealed significant correlations between fascicle length and shot put tests ($r = 0.895 - 0.672$), standing long jump ($r = 0.726$) and 40m sprinting ($r = -0.602$). Correlations between fascicle length, with sprinting (Abe et al., 2001; Kumagai et al., 2001), vertical jumping (Earp et al., 2010) and throwing performance (Zaras et al., 2016) have been previously described, although we are not aware of any previous report about the relationship between fascicle length and standing long jump. Both standing long jump and shot put throw are neuromuscular explosive activities with increased activation of the lower limb muscles (Maulder et al., 2005; Terzis et al., 2007). Training

induced-increased in vastus lateralis fascicle length was found to be associated with faster muscle fiber shortening velocity (Blazevich et al., 2007). Although the current data might suggest that increased fascicle length induced increases in standing long jump, the correlation between the percent changes in these parameters were not significant. The interconnection therefore, between fascicle length with standing long jump needs further investigation. Unfortunately, we were not able to evaluate possible neural or intramuscular training adaptations which would have provided a better insight into the present results. Moreover, the number of athletes, and their performance level might limit the generalization of the present data in elite track and field throwers. Year-round data in elite athletes are needed in order to reach certain conclusions regarding the relationship between long jump and sprinting with track and field throwing performance.
Briefly, ten weeks of strength and power training induced significant increases in shot put throw, standing long jump work production and sprinting performance. These changes were accompanied by adaptations in muscle thickness and fascicle length. The current data suggest that examination of muscle thickness and performance in explosive field tests may partly predict the training-induced increase in track and field throwing actual performance.

Conclussions

Coaches and athletes may apply strength/power training during the final weeks of training before competition in an attempt to increase muscle power and throwing performance. Evaluation of the throwers' power capacity with explosive field tests, such as the standing long jump and short distance sprints are cost-effective, require limited time devotion and potentially correlated with throwing performance. Track and field throwing performance may be influenced by several factors besides muscle power, such as individual technical characteristics and psychological variables. Consequently, it is difficult to identify a single performance test which might accurately reveal performance changes over time. It seems that vastus lateralis muscle thickness as assessed with ultrasound and backward shot put throw which is a common explosive test used regularly by throwers, may partially predict training induced changes in track and field throwing actual performance. It might be predicted that a 5% increase in muscle thickness combined with a 2% increase in backward shot put throw performance may induce a 6.9% increase in track and field throwing performance.

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