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Research article

Effects of Strength vs. Ballistic-Power Training on Throwing Performance

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Abstract

The purpose of the present study was to investigate the effects of 6 weeks strength vs. ballistic-power (Power) training on shot put throwing performance in novice throwers. Seventeen novice male shot-put throwers were divided into Strength (N = 9) and Power (n = 8) groups. The following measurements were performed before and after the training period: shot put throws, jumping performance (CMJ), Wingate anaerobic performance, 1RM strength, ballistic throws and evaluation of architectural and morphological characteristics of vastus lateralis. Throwing performance increased significantly but similarly after Strength and Power training (7.0-13.5% vs. 6.0-11.5%, respectively). Muscular strength in leg press increased more after Strength than after Power training (43% vs. 21%, respectively), while Power training induced an 8.5% increase in CMJ performance and 9.0 - 25.8% in ballistic throws. Peak power during the Wingate test increased similarly after Strength and Power training. Muscle thickness increased only after Strength training (10%, $p < 0.05$). Muscle fibre Cross Sectional Area (fCSA) increased in all fibre types after Strength training by 19-26% ($p < 0.05$), while only type IIx fibres hypertrophied significantly after Power training. Type IIx fibres (%) decreased after Strength but not after Power training. These results suggest that shot put throwing performance can be increased similarly after six weeks of either strength or ballistic power training in novice throwers, but with dissimilar muscular adaptations.

Key words: Shot put, muscle fibres, ultrasound, ballistic training, muscle mass.

Introduction

Performance in track and field throwing events depends, to a large part, on muscle power production (Zatsiorsky et al., 1981). Muscle power is the product of force and velocity, thus, either of these components or both of them, needs to be addressed in a training program in order to develop muscular power and therefore throwing performance (Judge, 2007; Kawamori et al., 2004). Both novice and elite throwers spend a large fraction of their preparation using either conventional strength training or various forms of power training in order to increase their muscular strength and their muscular power, and as a consequence to increase their throwing performance. However, the effectiveness of such training programs on shot put throwing performance is poorly investigated. In novice and moderately trained throwers, resistance training induces a significant increase in shot put throwing performance (Stone et al., 2003; Terzis et al., 2008). Anecdotal communications with coaches of novice shot put throwers indicate that a common issue in designing training programs is to focus either on strength or power training during a short training cycle. However, to the best of our knowledge, the effect of power training on shot put throwing performance in novice shot put throwers has not been investigated yet.

Muscular power is mainly determined by the amount of muscle mass, the fibre type composition of the contracting muscles and the number of activated motor units during a specific movement (Moritani, 2002). Strength training of only a few weeks can increase muscle mass significantly with a concomitant decline in the proportion of IIx muscle fibres in favor of type IIa fibres (Adams et al., 1993; Andersen and Aagaard, 2000; Jones et al., 1989). This combination of adaptations, results in significant increases in muscular strength and power production (Aagaard and Andersen, 1998; McBride et al., 2002). Indeed, 14 weeks of resistance training in novice throwers resulted in 12-18% increase in vastus lateralis fibre cross-sectional area (fCSA) and 6-12% increase in shot put throwing performance (Terzis et al., 2008). In contrast, short-term power training results in smaller increases in muscular strength/mass as compared to strength training (Winchester et al., 2008; Vissing et al., 2008; Cormie et al., 2010). However, it remains unknown, in which way the neuromuscular adaptations of such short-term power training may affect shot put performance. Moreover, resistance training with ballistic exercises induces a continued acceleration throughout the range of motion, which is similar to the projection of the shot put in the final thrust (Newton et al., 1996). Previous studies have shown that ballistic training can induce significant increases in force and power (Newton et al., 1996; Cormie et al., 2011), but its effect on throwing performance is not yet investigated.

The purpose of the present study was to investigate the effects of short-term strength training versus ballistic-power training on shot put throwing performance in novice shot put throwers. Performance and biological parameters which might be related to the development of muscle strength and power, such as the fibre type composition, fCSA and muscle architecture were also investigated in order to provide insights into the nature of the results.

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Table 1. Background data mean values (standard deviations) of the Strength group (n = 9), the Power group (n = 8) and the Control group (n = 8). There was no significant difference between the groups.

	Strength	Power	Control	Difference (95%*CI*)	*P*
Age (years)	22.6 (3)	24.6 (5)	21.1 (2)	2 (-6-1)	.315
Height (m)	1.78 (.05)	1.75 (.06)	1.77 (.05)	3 (2-4)	.589
Body mass (kg)	71.4 (9)	74.1 (12)	68.4 (6)	-2 (-6-1)	.523
Body mass index (kg/m^2)	22.5 (3)	24.1 (3)	21.9 (5)	2 (-3-1)	.392
Shot put throw (m)	10.0 (1)	10.1 (1)	9.7 (1)	1 (-1-1)	.730

CI values refers to the Strength and Power group, *P* value refers to one-way ANOVA test before initiation of the training period

Methods

Subjects

Twenty novice male shot put throwers (6 months of throwing experience) gave their written consent to participate in the study. They were divided into two groups according to their initial underhead shot put throw performance: the Strength training group (n = 10) and the Power training group (n = 10). All subjects participated in all measurements before the initiation of the 6 weeks training period (pre measurements). However, due to reasons unrelated to the training program, one participant from the Strength group and two from the Power group withdrew before the completion of the study. Thus, seventeen participants performed the second measurements after the end of 6 weeks training (post measurements). Descriptive characteristics of the subjects are presented in Table 1. A group of eight male physical education students served as a control group (Control). All procedures were performed in accordance with the principles outlined in the Declaration of Helsinki.

Training protocol

Three major resistance exercises were used for both training groups: leg press, bench press, and half squat. Both groups performed all exercises in every session with this exact order, for 6 weeks, 3 times per week. The acute training variables of the two different training protocols are presented in Table 2. For the Strength group, the load was set to meet 6 Repetion Maximum (RM) and it was increased frequently (once or twice each week) in order to meet the 6RM. The rest between sets was 2-3 min, and between exercises 3-4 min. On the other hand, the Power group performed the same exercises but with a ballistic mode of movement, and a load equal to 30% of 1RM, as described in previous studies (Liu et al., 2003; Kyröläinen et al., 2005). The ballistic training mode was chosen because of its continued acceleration throughout the range of motion, which is similar to the projection of the shot put in the final thrust. Specifically, in the present study, in leg press and bench press the load was thrown as far as possible with two assistants catching it at the end of its projection. The ballistic squat was performed in a smith machine, so that the subjects jumped as high as possible in the air. Special pads were placed between the barbell and the neck in order to avoid injuries. Subjects in the Power group were instructed to perform each repetition with maximum speed. In this training group, the rest between repetitions was approximately 2-3 seconds. The load was increased by 2.5 % every week starting from 30 % in the first week and concluding to 42.5 % in the sixth week of the initial 1RM. During the 6-weeks training period, subjects did not follow any form of throwing technique training. With this design we hypothesized that their throwing skills would not interfere with the results of the throwing performance (Terzis et al., 2008). The Control group refrained from any systematic exercise training during the same period.

One major challenge was to create two comparable exercise protocols, at least in terms of the training volume, expressed as the total amount of work in Joules (Fleck and Kraemer, 2004). According to data from video recordings during the pilot experiments, we calculated the training volumes by multiplying the resistance by the displacement by the total number of repetitions performed in a training session. We found that the training volume of a ballistic training session was 28% lower compared to the training volume of strength training, using the same exercises. Thus, we decided to add 3 sets x 8 drop jumps from 45 cm in the Power training protocol, in order to equalize the two protocols, at least in terms of the training volume (Strength training 4800.0 ± 22.4 J, vs. Power training 4600.0 ± 15.2 J, p = 0.546). Drop jumps were performed from a bench, starting at 35 cm in the first week of training and progressively increased to 45 cm in the 3rd week of training. Ten seconds interval was allowed between each jump and 2 min between sets. It must be noted that although the training volume did not differ between Strength and Power training, these two training protocols were very different in terms of time under tension (17 times higher in Strength vs. Power training) and perceived exertion, after each training session (Borg

Table 2. Acute variables of the two training protocols.

		Training (3 sessions/wk)
Strength Training	Leg Press (45° Inclination)	4 sets / 6RM
	Bench Press (Smith machine)	4 sets / 6RM
	Half Squat (Smith machine, knees 90°)	4 sets / 6RM
Power Training	Leg Press Throw (45° Inclination)	4 sets / 8 reps (30% of 1RM)
	Bench Press Throw (Smith machine)	4 sets / 8 reps (30% of 1RM)
	Jump Squat (Smith machine, knees 90°)	4 sets / 8 reps (30% of 1RM)
	Drop Jumps (from 45 cm)	3 sets / 8 jumps

Rest between sets: Strength training: 2-3 min, Power Training 1-2 min
Rest between exercises: Strength training 3-4 min, Power Training: 2-3 min

scale 7.8 ± 1.5 in Strength training vs. 4.5 ± 1.5 in Power training, $p < 0.01$).

Throwing performance and CMJ jumps

Throwing performance was measured outdoors on a standard circle during the morning hours at an ambient temperature of 18-23^{0}C. Three different throwing performance tests were used with a 6 kg shot: a) backward overhead throw, b) squat underhead throw, and c) one arm standing throw (legs in parallel), as described in detail before (Judge et al., 2003; Terzis et al., 2008). Briefly, after a short warm up (10 min light running, stretching, 2 squat underhead and 2 backward overhead shot throws), subjects performed three attempts of each one of the throwing tests, with this specific order, with an interval of 2 min between attempts. The best performance was used in further statistical analysis. The *ICC* for throwing performance was examined on two different days in a different group of subjects (n = 25, r = 0.93, CVs = 7.5-6.5%, p = 0.002). The counter movement jump (CMJ) was performed indoors, thirty minutes after the throwing tests, as described before (Beachle et al., 2000). Participants performed three trials with one-minute rest in between. The ICC for the counter movement jump test (n = 25) was r = 0.98, CVs = 5.1-6.5%, p = 0.004.

Peak power performance during the Wingate test

Peak power during the initial 10 sec of the Wingate anaerobic test was measured on a mechanically braked cycle ergometer (Monark ergomedic 834 E, Monark Vansbro, Sweden). All tests were performed at early afternoon hours. The breaking force was set at 0.075 $kg \cdot kg^{-1}$. After reporting to the laboratory, subjects were instructed to pedal at 60 revolutions per minute for 10 minutes with light external resistance. Subsequently, subjects pedaled at maximum voluntary speed, the external testing resistance was applied and the subjects continued to pedal at maximum voluntary speed for 10 sec. The number of revolutions was recorded at real time (1 kHz). Peak power was achieved 3-6 sec after the application of the external resistance. The *ICC* for the peak power during the Wingate test has been described before by Gullstrand and Larsson, (1999) (r = 0.94).

Muscular strength

One repetition maximum (1RM), for the leg press, the bench press and the half squat, was measured on a separate day. Briefly, after a short warm-up on a stationary bicycle, participants performed 2-3 warm up sets of 8-6 repetitions according to their predicted maximum repetition. After that, subjects performed incremental submaximal efforts until they were unable to lift a heavier weight (Beachle et al., 2000). The same protocol was followed for all exercises. Three minutes rest was allowed between the trials. Maximal strength was determined for all of the three exercises in the same day in the order described above, with a rest period of 30 minutes between exercises. The ICC for the 1RM measurement in our laboratory is $R = 0.92$.

Ballistic throws

Ballistic throws in leg press, bench press and the jump squat were performed with 30% of 1RM, one day after the measurement of maximum strength, according to the protocol used before (Terzis et al., 2003). After a short warm-up on a stationary bicycle, participants performed 2 sets of 8 repetitions with moderate speed on the leg press with 30% of 1RM. After that, participants performed three ballistic trials (initial knee and angle of 90^0) with 1 min rest in between. They were instructed to apply force as fast as possible and throw the plate of the leg press machine as high as possible. Two certificated supervisors were catching the weight at the end of its projection and slowly returned it at the initial position. The same protocol was applied for the bench press and the half squat in the same day, with a rest period of 10 minutes between exercises. The *ICC* for the three ballistic throws was determined in two different days (n = 18, r = 0.85, CVs = 4.2-5.2%, p = 0.002).

Ultrasonography

B-mode ultrasound images were recorded from the right vastus lateralis in order to determine its architectural characteristics (MicroMaxx Ultrasound System, Sonosite, Bothel, USA). Participants were lying at a supine position with both knees extended at a resting position (Kumagai et al., 2000). Images were taken at the 50% of the distance between the greater trochanter and the lateral condoyle of the femur and analyzed for vastus lateralis thickness, pennation angles and fascicle lengths (Motic Images Plus, 2.0). The *ICC* for muscle thickness was determined in two consecutive days (n = 15, r = 0.95, CVs = 2.0-2.1%, p = 0.001).

Muscle biopsies and histochemistry

Immediately after ultrasonography, a muscle sample was obtained from the middle portion of the right vastus lateralis, 20 cm from mid patella, under local anesthesia. The biopsy sample after the training period was obtained at 5 cm distal to the first one. All samples were aligned, placed in embedding compound, frozen in pre-cooled isopentane and kept in liquid nitrogen. Serial cross sections (10 μm) were cut at -20°C and stained for myofibrillar ATPase after pre-incubation at pH 4.3, 4.6, and 10.3 (Brooke and Kaiser, 1970a; 1970b). A mean of 486 ± 87 muscle fibres from each biopsy were classified as type I, IIa, or IIx. The cross sectional area (CSA) of all the classified fibres from each sample was measured with an image analysis system (Image Pro: Media Cybemetics Ins, Silver Spring, MD, USA).

Statistical analysis

Mean ± SE was used to describe variables. One-way analysis of variance was used to evaluate differences between the experimental groups before the beginning of the training period. Two-Way analysis of variance for repeated measures was used to test differences before and after the training period with LSD post hoc analysis to test specific differences among these time points. $P < 0.05$ was used as a two-tailed level of significance.

Results

Throwing performance in backward overhead throw, squat underhead throw, and standing throw increased in the Strength group by 13.4 ± 3.6%, 11.6 ± 3.2%, and 7.3 ± 2.7%, respectively ($p < 0.05$). In the Power group, performance increased in backward overhead throw by 11.6 ± 2.9% ($p < 0.05$), in the squat underhead throw by 8.3 ± 3.2% ($p = 0.265$, ns) and in the standing throw by 6.2 ± 2.7% ($p < 0.05$, Figure 1A,B,C). Performance was not altered in the Control group.

Countermovement jumping performance increased after Power training by 8.5 ± 2.4% ($p < 0.01$), but not after Strength training. Peak power at the Wingate test increased similarly in the Strength and the Power group by 7.9 ± 2.8% and 6.5 ± 2.5%, respectively ($p < 0.05$). No significant differences were found between the initial strength levels of the two training groups. Maximum strength in leg press, bench press and half squat increased after Strength training by 43.1 ± 3.9%, 16.9 ± 2.6%, and 23.9 ± 3.9%, respectively, ($p < 0.01$), and after Power training by 20.9 ± 3.2%, 11.8 ± 2.7%, and 19.1 ± 2.8%, respectively ($p < 0.05$). The increase in leg press 1RM was significantly higher after Strength compared to Power training ($p < 0.05$, Table 3).

Performance in ballistic throws increased significantly in the Power group by 25.8 ± 4.2%, 9.0 ± 2.5%, and 10.4 ± 3.2%, in leg press, bench press and the jump squat, respectively, ($p < 0.05$), while no statistical difference was found in the Strength group (Table 3). Vastus lateralis thickness increased by 9.9 ± 2.6% in the Strength group ($p < 0.05$) but pennation angles as well as fascicle lengths were not altered significantly. Ultrasonographic data did not reveal any significant alteration for the Power group.

The proportion of type I and type IIa muscle fibres of vastus lateralis was not altered significantly in either group. However, the percentage of type IIx fibres was significantly decreased in the Strength group (14.7 ± 2.4% before vs. 8.0 ± 2.3% after, $p < 0.001$, Figure 2A). In contrast, the percentage of type IIx fibres was not altered in the Power group (Figure 2B). Muscle fCSA increased significantly after Strength training by 19.0 ± 3.9% for the type I fibres, 22.3 ± 4.1 % for the type IIa fibres, and 25.9 ± 5.2% for the type IIx fibres, ($p < 0.05$, Table 4). In contrast, in the Power group a significant increase was found only in the CSA of type IIx muscle fibres (36.3 ± 6.9%, $p < 0.05$). None of the anthropometrical parameters were altered significantly after the training period in any group.

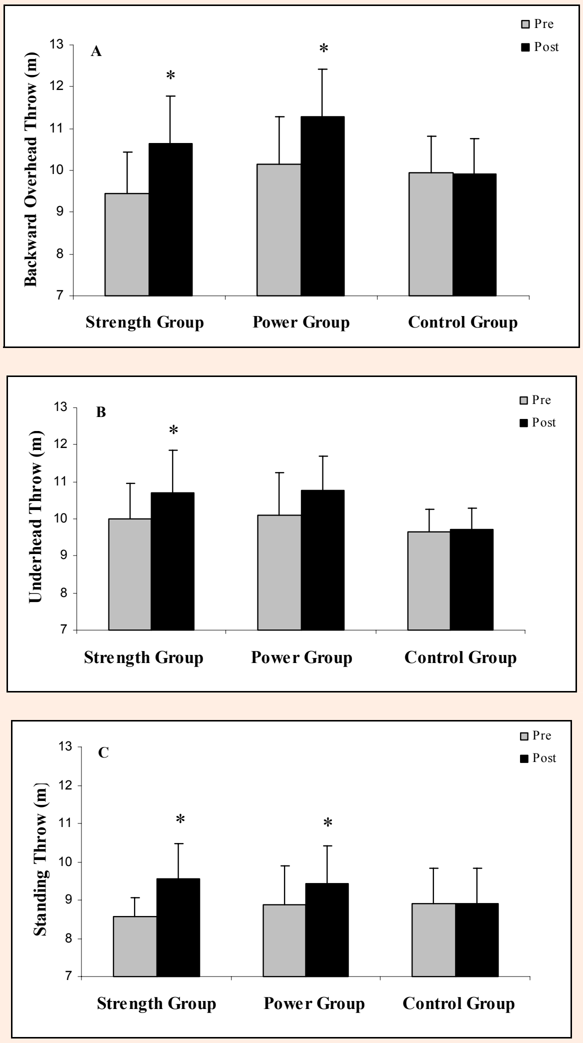

Figure 1. Changes in 6 kg shot put throwing performance after 6 weeks of Strength or Power training: A) Backward overhead throw, B) Underhead throw, and C) Standing throw. * p < 0.05 before and after the training period.

Discussion

The purpose of the study was to investigate the effects of six weeks of strength versus ballistic-power training on shot put throwing performance in novice throwers. The main finding was that shot put performance increased similarly after either strength or power training but with different muscle adaptations. Strength training induced an increase in shot put throw distance, muscular strength and Wingate peak power, which were accompanied by an

Table 3. Changes in 1RM muscular strength and ballistic throws performance (external load 30% 1RM), after 6 weeks of Strength or Power training. Data are means (SE).

	Strength Group (*N* = 9)		Power Group (*N* = 8)	
	Pre	**Post**	**Pre**	**Post**
Leg Press (kg)	208 (5)	297 (7) *†	252 (7)	303 (7) *
Bench Press (kg)	85 (4)	99 (4) *	105 (5)	118 (5) *
Half Squat (kg)	159 (6)	208 (5) *	167 (5)	199 (5) *
Leg Press Throw (cm)	62 (2)	62 (3)	59 (2)	65 (3) *
Bench Press Throw (cm)	60 (2)	58 (4)	56 (2)	70 (3) #
Jump Squat (cm)	59 (3)	52 (2)	59 (2)	65 (2) *†

*p < 0.01, # p < 0.05, significant difference between pre and post. † p < 0.05, significant difference between groups

Table 4. Changes in muscle fibre type composition of vastus lateralis, after 6 weeks of Strength or Power training. Data are means (SE).

	Strength Group (n = 9)		Power Group (n = 8)	
	Pre	Post	Pre	Post
Type I CSA (μm^2)	4485 (26)	5267 (24) *	4869 (35)	5418 (27)
Type IIa CSA (μm^2)	5560 (37)	6645 (33) *	5115 (37)	5907 (30)
Type IIx CSA (μm^2)	4382 (34)	5371 (35) #	3861 (37)	4858 (30) #
Type I CSA (%)	44.5 (3)	46.0 (3)	49.6 (3)	49.8 (2)
Type IIa CSA (%)	42.5 (3)	47.0 (3)	40.3 (2)	41.4 (2)
Type IIx CSA (%)	13.0 (2)	7.0 (2)†	10.1 (3)	8.8 (2)

* $p < 0.005$, # $p < 0.05$, significant difference between pre and post. † $p < 0.01$, significant difference between pre and post

increase in muscular thickness, fCSA and a reduction in the proportion of type IIx fibres. Ballistic-power training induced an increase in shot put throw distance, a smaller increase in muscular strength compared with strength training, a similar increase in Wingate peak power and an increase in jumping performance. These performance alterations were accompanied by a conservation of the proportion of type IIx muscle fibres and an increase in their CSA. These results suggest that strength training induced an increase in throwing performance mainly by increasing the strength component of muscular power. On the other hand, power training resulted in an increase in throwing performance mainly through a smaller increase in the strength component which was counterbalanced by adaptations in type IIx muscle fibres. Thus, it seems that in novice throwers, both strength and ballistic-power short-term training regimes can be used to increase shot put performance but the expected muscular adaptations would be different.

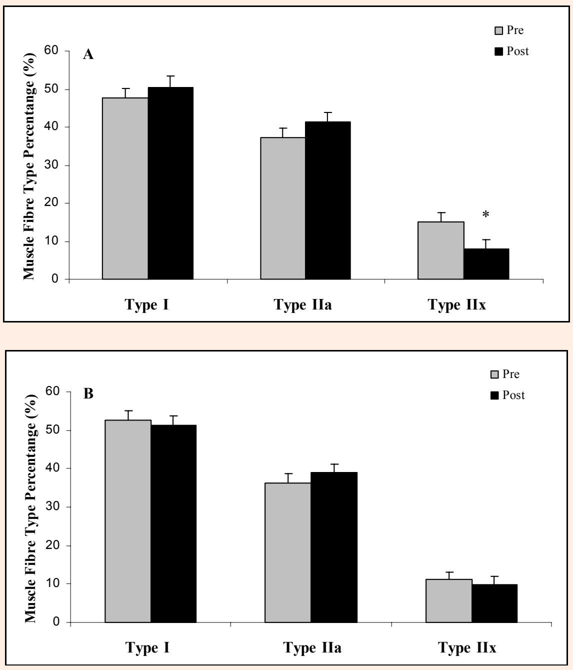

Figure 2. Fibre type composition of vastus lateralis before and after 6 weeks of A) Strength and B) Power training.
* $p < 0.05$, before and after the training period.

It is well established that strength training induces significant increases in muscle mass and strength as well as a decrease in type IIx fibres in favor of the type IIa fibres (Adams et al., 1993; Andersen et al., 1994; Andersen and Aagaard, 2000). Analogous adaptations were revealed in the present study after 6 weeks of strength training. On the other hand, the proportion of muscle fibre types remained unaltered after 6 weeks of ballistic-power training but there was an increase in the CSA of the IIx muscle fibres by 36%. These adaptations might have contributed to an increase in muscle power and finally in throwing performance. Peak power of type IIx fibres is considerably higher than peak power of type IIa fibres (Bottinelli et al., 1996). Thus, a small change in their proportion and CSA might have a large impact on whole muscle power production. It should be noted that recent studies also have shown that the proportion of type IIx muscle fibres remains unaltered after short-term power training (Liu et al., 2003; Malisoux et al., 2006; Vissing et al., 2008). In these studies, the power training protocol contained mostly jumping exercises, i.e. high intensity muscle actions with short duration, which is comparable to the nature of the training parameters used in the present study.

Similar to previous reports, after six weeks of training, muscular strength increased after strength training almost twice as much it was increased in the power group (24-43% vs. 12-21%) (Andersen et al., 1994; Terzis et al., 2008; Lamas et al., 2010). Countermovement jumping performance increased by 8.5% with ballistic-power training while it remained unaltered after strength training which is also in concert with previous studies (Kyröläinen et al., 2005; Vissing et al., 2008). Ballistic throwing performance (30% of 1RM) increased significantly after power training but not after strength training. Both ballistic throws and unloaded countermovement jumps are power demanding activities which require a certain level of skill and/or neuromuscular coordination (Cormie et al., 2010). Indeed, peak power during jumping is greatest at bodyweight-only load (e.g. McBride et al., 2002; Cormie et al., 2010). The ballistic-power training protocol included both ballistic and jumping actions. Thus, it would be reasonable to expect specific neural adaptations in these actions in the Power training group compared to the Strength training group, which might explain the different performance enhancement between these two training regimes, as shown before with similar protocols (e.g. Cormie et al., 2010). Moreover, in concert to our results, Liu et al., (2003), showed that after six weeks of power training, the velocity of bench press throw increased after power training by 10 cm·sec^{-1}. Also, Vissing et al., (2008), reported that 12 weeks of power training resulted in 17% improvement in leg press ballistic throws, while strength training increased leg press ballistic performance only by 4%.

Ultrasonography revealed that strength training induced an increase in muscle thickness of vastus lateralis by 10%, whereas no significant changes were found for the pennation angles or the fascicle lengths. Ballistic-power training did not have any significant effect on either of these two architectural parameters. Similarly to the present results, previews studies revealed that vastus lateralis thickness increased significantly after 10 weeks of strength training but not after the same period of power training (Andersen and Aagaard, 2000; Cormie et al., 2010). However, a recent study revealed that both strength and power training induced an increase in muscle pennation angles (Cormie et al., 2010). The lack of alterations in vastus lateralis pennation angles in the present study might be related to the shorter training duration compared to this previous investigation.

The external resistance used during training of the ballistic-power group was 30% of 1RM. The same training load has been used in various previous studies (Cormie et al., 2010; Lamas et al., 2010). The participants in those studies had similar training background to the participants of the present study and the muscular adaptations were analogous to ours. However, it should be emphasized that muscular power can be increased with different training loads as well (i.e. 60-90% 1RM) (McBride et al., 2002). Different power training protocols might have induced different muscular adaptations and different alterations in throwing performance and this is an interesting issue which needs further clarification.

Resistance exercise results in significant neural adaptations (i.e. motor-unit recruitment rate coding and synchronization) which precede the muscular adaptations (Sale, 2002). In the present study, although the shot put throwing skills were not addressed during the training period, the improvement in throwing performance might be related to neural adaptations induced by either strength or ballistic-power training. However, we were not able to estimate the contribution of neural factors (i.e. EMG recording), which was a major limitation of the present study. Interestingly, although muscle power increased after both training protocols, the jumping performance was improved only in the power group. This indirectly reveals the specificity of the training adaptations and might be partly related to neural adaptations.

Conclusion

In summary, the results of the present study suggest that shot put throwing performance can be increased similarly after 6 weeks of strength or ballistic-power training, in moderately trained subjects. The improvement in throwing performance after strength training could be attributed mainly to muscle hypertrophy and subsequent increases in muscle power. The improvement in throwing performance after ballistic-power training could be attributed to the increase in muscular strength and the retention of the proportion of type IIx muscle fibres, which presumably led to increases in muscle power. However, the role of the neural adaptations after such interventions as well as the potential effect of a different power training protocol remains to be elucidated.

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Key points

- Ballistic-power training with 30% of 1RM is equally effective in increasing shot put performance as strength training, in novice throwers, during a short training cycle of six weeks.
- In novice shot putters with relatively low initial muscle strength/mass, short-term strength training might be more important since it can increase both muscle strength and shot put performance.
- The ballistic type of power training resulted in a significant increase of the mass of type IIx muscle fibres and no change in their proportion. Thus, this type of training might be used effectively during the last weeks before competition, when the strength training load is usually reduced, in order to increase muscle power and shot put performance in novice shot putters.

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