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EFFECTS OF EXPLOSIVE TYPE STRENGTH TRAINING ON SELECTED PHYSICAL AND TECHNICAL PERFORMANCE CHARACTERISTICS IN MIDDLE DISTANCE RUNNING – A CASE REPORT

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Abstract

Introduction. Distance running performance is a simple function of developing high speeds and maintaining this speed as long as possible. Thus a correct running technique becomes an important component of performance. Technique is effective if the competitor can reach a better performance result with the same or lower energy consumption. The purpose of this investigation was to examine a six weeks application explosive type strength training on lower extremities power and maximum speed performance improvement in order to facilitate running technique in sub-elite male middle-distance runner. ***Material and methods***. A sub-elite runner performed twice a week special exercises and running drills. He completed a pre and post-training jumping (SJ, CMJ, standing long jump, standing five jump) and speed (20 m from standing and flying start) field tests. For kinematical analysis, a video (SIMI Motion System) of a 10 m sprint from a 20 m flying start was collected. ***Results***. Improvement occurred in all measurements but strong changes were evident in the 10 m from 20 flying start and in stride frequency from 3.90 to 4.01 Hz, due to decreasing of ground contact time from 160 to 156 ms. No strong evidence in the participant's running technique changes. ***Conclusion***. This proved that six weeks of dynamic type strength program seems to improve neuromuscular characteristics of running speed and explosive power and no changes in running technique.

Key words: dynamic strength, sports technique, plyometrics, special tempo work, middle distance running

Introduction

The study described in this manuscript relate to one sub-elite middle-distance runner. This forces the reader properly analyzed the information and obtained results, in order to maintain an objective message of this manuscript.

Middle distance and long distance running performance is a simple function of developing high speeds and maintaining this speed as long as possible. Thus a correct running technique becomes an important component of performance. Technique is effective if the competitor can reach a better sports result with the same or lower energy consumption [1] The secret of the running technique lies not only in the correct structure of movements from the point of view of biomechanics but, above all, in the ability of combining the full activation of energy and maximization of muscular efforts. Both of these parameters in distance running affect the efficiency of running economy (RE). This ability may be acquired not only by mastering the form of movements but, above all, by the appropriate training, leading to their full coordination and automation [2]. However, it is difficult to point out which technique is more effective in order to guarantee the best results. From biomechanical point of view the improvement of running regardless of events (sprint, middle and long distance) will result only by increasing the speed, which heavily relay on the utilization of current running technique. It is well observed that distance runners spend more time on the ground and have deeper knee flexion during stance phase compared to sprinters at different speed [3, 4]. It has also been known that horizontal displacement between the landing foot and center of mass (CM) during ground contact time is much longer in distance runners [3]. We also know that sprinters had much longer stride than distance and long-distance runners [3, 5, 6]. Thus the optimization of running technique is dependent on the relationship between stride length and its frequency [6, 7, 8, 9] and specific kinematics of running stride execution [10]. However there is still relatively little know about kinematics during the footstrike that may concerns where your feet land relative to your body rather than that mid-foot runners are faster and perform better than heel-strike runners. We want to know which of theses factors the most determine the running economy, and first of all how these factors directly facilitate faster running.

Strength and power training in its various forms has been used successfully by sprinters, jumpers, throwers, and power-related sporting events to increase performance via changes in the neuro-muscular system [11, 12, 13, 14, 15, 16, 17]. The question is, how much does explosive type strength training improve lower extremities power and speed performance in endurance sports, especially in running? Application of strength training (both explosive-type and high resistance in distance running) is not a new concept and is quite often used in performance improvement [18, 19, 20, 21, 22]. In most cases it is closely related to the running economy (RE), which can be defined as the oxygen consumption (VO2max) and running velocity (10). Research has identified several factors that may be associated with RE. They can be divided into two main groups: physiological and muscle/mechanical [23, 24, 25]. Research indicates that anaerobic power and muscular strength may be important for improvement of running performance through muscular and neurological changes [26, 27, 28]. Neural adaptations may be connected with motor unit recruitment and synchronization, progress, what increase the force development rate via improvement in the stretch-shortening cycle [26, 27, 19]. In contrast to these changes the muscular adaptation may increased force production, intramuscular glycogen or made some changes in anaerobic enzyme activity [28, 26]. Therefore the muscular and neurological changes may really challenges the improvements and should enhance running performance and all are becoming important performance predictors [29, 30, 19].

The practical question being addressed is does the efficacy of special type strength training cause middle distance runner to improve its physical and technical abilities? Therefore first it is necessary to examine the direct effect of the application of these type of training in order to improve the lower extremities power. Then how does this increase of power relate to several kinematic parameters of maximum running speed, and which of these variables has a direct impact on the speed improvement. According to these statements we are able to confirm that the practical question of the nature of this study is contained in the description of the purpose of this report. The purpose of this investigation was to examine a six weeks of combine dynamic strength and plyometric intervention program on lower extremities power and maximum speed performance improvement in male middle-distance runner. A secondary purpose was to examine the potential connection between improvement of maximum speed and explosive power in order to facilitate running technique. Based on these assumptions we are able to formulate our hypothesis: is that improvement in kinematical measures of a single running step executed at maximum speed (the utilization of stored elastic energy in muscles after plyometric training) can be demonstrated concomitant with some changes of current athlete running technique.

Material and methods

This single subject study utilised (n=1) a male, sub-elite (masterclass) middle-distance runner (27 years old, 64 kg body mass, 180 cm height) with personal best results of 800 m – 1'47.96 and 1500 m – 3'44.04 . He is medalist of indoor and outdoor Polish Championships in Athletics. This subject volunteered for the six week study during end of special preparation II and pre-competition phase (spring) of yearly training schedule. The six week training duration was chosen because the authors hypothesised that both neural and muscular adaptation toward special dynamic strength exercises may occur within the six week time frame. During the experiment, the runner participated in all scheduled training activities and has not suffered any injury. The participant was informed of the protocol and procedure of the experiment prior to the exercise. Written consent to participate was obtained. The study was approved by the Human Ethics Committee of the University School of Physical Education in Wroclaw.

Dynamic strength and plyometric intervention programme

In addition to the regular training schedule, the runner was assigned a twice a week (Monday and Wednesday) dynamic strength and plyometric programme. Each training session combined: a) lower body dynamic exercises (fig. 1) executed in the following order: split legs jumps on the box, upward jump with slightly straddled legs, step-ups with front leg swing, toe rising from a half-squat, and alternate lunges; and b) special plyometric drills executed in the following order: power skip "A", alternate sprint bounding, and power skip "C" (tab. 1). Plyometric exercises were chosen because they are specific to the running action in terms of both movement structure and the velocity of execution. Exercises 1, 2, 3, and 5 have a nature of eccentric work and build up the speed capabilities of a runner. In this case it might be assumed that the basis of the amount of load is about 1/3 of the competitor's weight. Exercise 4 is to develop muscular power and the nature of work is concentric. The subject performed all exercises in a dynamic manner. In order to adapt to the neural stress and avoid injury, the entire training programme progressed in a periodised manner from period one (weeks one to three) to period two (weeks four to five) and period three (week six). The video recording of proper execution (technique) of these exercises took place in a weight room (fig. 1).

Figure 1. The lower body dynamic strength exercises executed in the following order: (1) split legs jumps on the box, (2) upward jumps with slightly straddled legs, (3) step-ups with front leg swing, (4) toe rising from a half-squat, (5) alternate lunges

Table 1. Summary of special dynamic strength exercises training programme

Dynamic strength and plyometric exercises programme				
Weeks	**Exercise**	**Sets**	**Reps**	**Load (kg/m)**
1-3	Split legs jumps on the box	3	20	20 kg
	Upward jumps with slightly straddled legs	3	20	20 kg
	Step-ups with front leg swing	3	12	20 kg
	Toe climbing from a half-squat	4	10	60 kg
	Alternate lunges	3	30	20 kg
	....	......	......	....
	Power skipping (skip A)	2	-	20 m
	Alternate sprint bounding	2	-	30 m
	Power skipping (skip C)	2	-	20 m
4-5	Split legs jumps on the box	4	20	25 kg
	Upward jumps with slightly straddled legs	3	20	25 kg
	Step-ups with front leg swing	3	12	25 kg
	Toe climbing from a half-squat	5	10	60 kg
	Alternate lunges	3	30	25 kg
	....	......	......	....
	Power skipping (skip A)	3	-	20 m
	Alternate sprint bounding	3	-	30 m
	Power skipping (skip C)	3	-	20 m
6	Split legs jumps on the box	2	20	30 kg
	Upward jumps with slightly straddled legs	2	20	30 kg
	Step-ups with front leg swing	2	15	30 kg
	Toe climbing from a half-squat	3	10	65 kg
	Alternate lunges	2	30	30 kg
	....	......	......	....
	Power skipping (skip A)	2	-	20 m
	Alternate sprint bounding	2	-	30 m

Lower extremity explosive jumping ability measurement

The runner completed a battery of four pre- and post-tests at the beginning and end of the study (week 6). The explosive power of the lower extremities was assessed by means of two vertical jumps: squat jump (SJ) and countermovement jump (CMJ). The participant must jump as high as possible snapping the horizontal vanes (each 0.5 cm) using the Vertical Jump Measuring Device (Polsport, Poland). The measured distance was between the standing reach height and the maximum jump height. In addition, two horizontal jumps – standing long jump (SLJ) and standing five jumps (SFJ) – were applied where the participant attempts to jump as far as possible, landing on both feet without falling backward using landing mats (Polsport, Poland). The measurement is taken from the take-off line to the nearest point of contact on the landing (back of the heels) after one jump (SLJ) and after five jumps (SFJ). The average of three attempts was used for data analysis.

Kinematics of maximum speed measurement

To determine maximum velocity, two sprint runs were performed. After a standardised warm up, the athlete ran 20 m and 50 m from a standing start. Two (customised) photocells were used for timing. The first was placed directly in front of the front foot at the ground level. The second photocell was at the finish line. The time starts as the sprinter passes the first photocell and stops when he passes the finish line photocell. For data analysis the average of three attempts of 20 m and two attempts of 50 m were used. A video recording of a 10 m sprint from a 20 m flying start during 200 m tempo repetition was taken using the SIMI Motion System (SIMI Reality Motion Systems GmbH, Germany) from one digital video camera (Panasonic VC 210/Full HD) set at 50 Hz, then analysed frame-by-frame. The camera was placed perpendicular to the running direction in the 10 m interval, then between 150 and 160 m along the track. The 20 m flying mark was used to force the runner to change speed in order to reach the highest possible value during the 10 m sprint. The pre-training measurement took place during the first of ten 200 m repetitions (26.05 s). The target time for this tempo was 27.0 s (13.5 per 100 m). In turn, the post-training measurement was also taken during the first of four 200 m repetitions (24.69 s). This time the target was 26.0 s (13.0 s per 100 m). The average time of four 200 m repetitions was 24.90 s. The frame-by-frame analysis of the 10 m recording allowed to distinguish the following kinematics parameters: 10 m flying time, 10 m speed (m/s), 10 m – stride number, 10 m – stride frequency (Hz), 10 m – stride length (m), and 5 m contact time (ms).

Special tempo running programme

After completing two sessions of dynamic strength workouts and special plyometric drills (Monday and Wednesday), the runner performed a separate periodised session (Friday) of special endurance tempo workout. The participant performed two series of 5 repetitions of 200 m at 13.5 s per 100 m in weeks one to three, then 4 to 6 reps at 13.0-13.5 s in weeks four to five, and 3 to 4 reps at 12.8 s in week six. The main principle of application of this type of training was to perform work in the mixed (aerobic-anaerobic) energy zone at the beginning of the six week programme, and then move to a predominantly anaerobic zone in the last two to three weeks. In addition, after each 200 m repetition the heart rate was recorded using a heart rate monitor – Polar RS300X GPS (Finland).

Statistical analysis

Statistics included the calculation of mean and standard deviation (SD). All data were analysed using the statistics package for Windows Statistical Package for Social Science (version 11.0, Chicago Il.).

Results

Table 2 shows the pre-test and post-test mean values for the selected speed and explosive ability measurement, including 20 m and 50 m from a standing start, SJ, CMJ, SLJ, and SFJ. Improvement occurred in almost all measurements of physical fitness (SJ, CMJ, 20 m, and 50 m from a standing start, respectively 7.1%, 11.7%, 6.7%, and 4.5%). The 10 m running speed improvements of 0.4 s (3.5%) were derived from an increase of stride frequency from 3.90 to 4.01 Hz (about 2.8%), and due to decreased ground contact time from 160 to 156 ms (approximately 2.4%). No changes particularly affect stride length – increase of 2 cm (0.9%).

Table 2. Characteristics of selected speed, explosive ability and kinematic parameters of 10 m from 20 m flying start measurement

Variables	Pre-training		Post-training		Difference
	x	SD	x	SD	%
20 m standing start (s)	3.12	0.05	2.91	0.04	6.7
50 m standing start (s)	6.28	0.01	6.00	0.12	4.5
Squat jump (SJ) (cm)	31.10	1.63	33.71	1.04	7.1
Vertical jump (CMJ) (cm)	41.33	1.26	46.16	2.47	11.7
Standing long jump (SLJ) (m)	2.31	0.06	2.47	0.06	6.9
Standing five jumps (SFJ) (m)	12.06	0.12	12.34	0.14	2.3
10 m time (s)	1.19	-	1.15	-	3.5
10 m velocity (m/s)	8.40	-	8.69	-	3.4
10 m - stride number	4.65	-	4.61	-	0.8
10 m - stride frequency (Hz)	3.90	-	4.01	-	2.8
5 m contact time (ms)	160	-	156	-	2.5
10 m - stride length (m)	2.15	0.008	2.17	0.007	0.9

Analysis of the post-training data (tab. 3) showed a trend suggesting strong improvement in special endurance tempo work. Taking into account the large number of repetitions (6 to 8), the short breaks between repetitions (4 min.), and the intensity of training (85–90% of maximum taken from his 200 m best performance), the athlete ran all 200 m repetitions faster than the target

Table 3. Characteristics of intensive tempo running programme

Weeks	Distance	Sets	Reps	Break between (min.)		200 m target time (s)	200 m time (s)		Target heart rate	Heart rate	
				reps	sets		x	SD		x	SD
1	200 m	2	5	3	6	27.0	26.95	0.34	160	163.60	2.12
2	200 m	2	5	3	6	27.0	27.06	0.19	160	161.90	2.92
3	200 m	2	5	3	6	27.0-26.5	26.91	0.17	160	162.70	2.63
4	200 m?	2	4	3	6-8	26.5-26.0	25.84	0.29	165-170	167.25	3.06
5	200 m	2	4	3-4	6-8	26.5-26.0	25.35	0.21	165-170	168.28	2.05
6	200 m	2	3	3-4	8	26.0-25.5	24.90	0.16	175-180	172.83	2.64

time with an average of 0.6 to 0.7 s (2.5%).

Figure 2 shows the mean values of selected kinematic variables of the subject's running stride of a 10 m flying sprint – the moment between 150 m and 160m of 200 m repetition. The first picture (a) represents the early stance of the support phase. The distance between the first contact point (hill) and projection of center of gravity CG is about 93 cm. The distance of 35 cm and angle of 81ş at a footstrike are similar to the other corresponding values. However, the runner is landing more on the heel than mid-foot. The angle between thigh and shank is 96°. The main amortisation phase (picture b) shows a significant lowering of the hip, which moves the centre of gravity towards an undesirable lower position. The angle between the trunk and the thigh of the support leg is reflected in a narrow angle of approximately 112ş, and the angle between trunk and thigh is about 126°, which indicates a lower position of the hip. Picture (c) underlines a dynamic take-off with a highlighted knee drive forward and upward. The take-off angle of 64ş (the angle between shank and the ground) corresponds with other athletes' measurements. The distance between take-off place and the pro-jection of CG is about 48 cm. The angle between trunk and thigh of the driving leg is about 99°, which indicates the dynamic ac-tion of knee driving. The arms too show a large degree of move-ment, which can result in an increase in energy expenditure and disturbances in the economy of running (picture c). The angle between arms and forearms is about 83ş and corresponds to the value of current running technique.

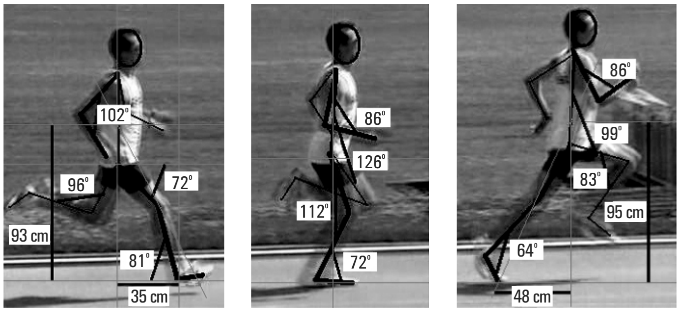

Figure 2. Means value of selected working angels (pre-training and post-training) of stride sequence when running with maximal speed over a 10 m flying sprint

Discussion

The purpose of this investigation was to examine a six weeks application of explosive type strength training on lower extremities power and maximum speed performance improvement in order to facilitate running technique in sub-elite male middle-distance runner. The utilisation of stored elastic energy in muscles after plyometric training should relate to changes of kinematics of running strides – stride length and stride frequency. The reduction of ground contact time will improve the efficiency of running technique (RT) and indirectly increase maximum running speed.

The main focus in middle distance training should be given to accounting for intra-individual variability in changing the current pattern of running technique (RT) via application of explosive type of strength. The literature has well documented that explosive strength and speed training supplemented by special support running exercises of a dynamic character has a positive impact on the neuromuscular system. It can increase the runner's ability for explosive force production (rate of force development), rate of motor unit activation, and an improvement of an athlete's anaerobic energy production. Supporting evidence of these changes can be seen in extensive research done by Paavolainen et al. [19], who studied the effect of explosive strength training on running performance. In this study the runners were able to significantly improve their 5 km performance. In another investigation, Sinnett et al. [31] concluded that a strong relationship exists between explosive strength and 10 km performance. Similar to these two groups of researchers, Turner et al. [21] investigated the influence of a six week plyometric programme on RE improvement. They found that this type of training modalities improved RE by 2–3%. According to Spurrs et al. [20] six weeks of explosive type strength training have a strong impact on improvement in CMJ height and five-bound test in conjunction with a 2.7% improvement in 3 km running performance. Saunders et al. [22] found that plyometric training (nine weeks of application) resulted in RE improvement, with the likely mechanisms residing in the muscle, or alternatively by improving running mechanism in highly-trained distance runners.

The results of measuring post-training physical abilities show an improvement in most of the dynamic parameters – SJ, CMJ, SLJ, SFJ. In our study the maximal CMJ height showed a much bigger improvement than SJ by about 4.6%. This confirms the assumption that stretch-shorten cycle (SSC) potentiation of concentric contraction is much stronger in CMJ than in SJ. However, some earlier studies reported an inverse relationship [32, 33]. The improvement can be explained by noting that dynamic strength training combined with a plyometric programme was extremely intense (twice a week as independent training section) and aimed at both vertical and horizontal jumps. This improvement provides a higher level of power generated by the lower limbs. However, this did not translate into a significant increase in stride length, which only improved by 0.9%. Therefore, the strong increased frequency of stride (2.8%), which is a specific expression of ground contact time reduction during support phase, resulted in an increase of speed. This suggests that explosive power exercises and plyometrics, via movement that involves the SSC, can substantialy improve the ability of muscles to store and return elastic energy.

According to Cornu et al. [34], there are many structures that can be positively changed as a result of plyometric training application, such as contractile components and the series of elastic components (SEC). However, it is the musculotendinous system (MTS) that may determine the runner's ability to store and utilise the elastic energy [34, 20, 24, 25, 35]. Following Spurrs's et al [20] thoughts, we can suppose that stiffer musculotendinous units will cause greater lengthening of the contractile component, which in turn facilitate the production of force through improved length tension and force velocity conditions. This is an extraordinary requirement for speed improvement by shortening ground contact time and facilitating quicker execution of a single stride. If we multiply it by multiples of a single-step execution on the specified distance (example intensive tempo), we get significant improvements in time by the economisation of the running structure [36].

There has been no too much differences in the values of selected kinematic variables recorded in pre-training and post-training measurements. Therefore it was difficult to explicitly state that there was an improvement in the subject's running technique (RT) after six weeks of dynamic strength and special plyometric programme application. Figure 2 presents the mean values of selected angles between the segments of the body. An important factor of any efficient RT is a support phase which should generate as little speed decrease as possible. It can be achieved by a fast execution of this movement through landing on the middle-foot. According to Noakes [37] and Cavanagh [38], the runner with poorer economy may be connected with muscles that are less able to utilise the impact energy produced as they eccentrically absorb the force of landing. When viewing the sequence of pictures (1), the runner is landing on the typical middle-foot strike, rather than the heel. This probably contributed to reduction of the support phase (ground contact time decrease about 2.4%). Such improvement depends largely on how the runner plants his/her foot on the ground, and therefore how he/she is distributing the support phase time. In turn, this affects the running speed. This design was to force the runner to change from landing on the heel to landing on the middle-foot as required. Practice has shown that this is very difficult to implement technically. Apparently, a lack of such a motion structure can provide information that a 10 m sprint is not enough to change the way of a foot plant. The explanation might be that the 20 m flying start took place during the 200 m repetition, not as a single 10 m sprint test. From a practical and mechanical point of view the improvement in middle and long distance running can only be possible by keeping an optimal stride length (individual value) leading to maintaining an external structure of running movement and an increase in frequency by reducing the time of the support phase. This assumption is fully proven in our study.

In our study we did not measure a single performance improvement – e.g. 1 km, 3 km, 5 km – as other authors [19, 20, 25, 21]. In spate of that, after the end of the experiment in the second week of pre-competition period, the athlete ran a 600 m test and reached 1:18.92 s. This is a good time, which can predict the results in the range of 1:48.00 in the 800 meters performance. However during six weeks of the dynamic type strength application we control the runner's intensive tempo (IT) workout. The term intensive tempo training refers to exercise at 80-90% (HR 160-180) intensity, a smooth and controlled repetition runs. Its progressively increasing intensity is prerequisite work into special and speed endurance sessions. The single 200 m unit measurement gives a measurable and visible result. Taking into account the periodised number of repetitions (10-8, 8-6, 6-4), the short breaks between repetitions (4 min.), and the intensity of training (85–90% of maximum taken from the subject's 200 m best performance), the runner ran all 200 m repetitions faster than the target time with an average of 0.6 to 0.7 s (2.5%).

The results of this investigation have shown that a six week programme of dynamic strength and support plyometrics led to improvements in all measurements of physical fitness with significant changes in running speed. This proved that a dynamic strength and plyometric programme seems to improve neuromuscular characteristics of running speed by increasing the ability to utilise the energy stored in muscle structures. We can also assume that there has been some optimisation of running technique (RT) by reducing the time of single stride execution. From a practical standpoint, this study provides support for the application of six weeks (twice per week) of special type strength training in order to improve explosive power and speed abilities. Additionally, the final thoughts should not be generalized because of study limitation. This case report has illustrated some trends in middle distance training, however needs to be restricted to the conditions related to this particular runner. The study should be repeated or continued among bigger group where runners demonstrate a varying performance level.

Conclusions

The study only partially proved our hypothesis, that the six weeks of utilization of stored elastic energy in muscles after dynamic type strength and plyometric training can influenced in changes of current athlete running technique. Kinematic analysis (mean angle values) of running technique (RT) in the different phases of a single running step performed during the 10 m sprint in pre-training and post-training measurements showed no significant changes. However the running speed improvements were derived from an increase of stride frequency from 3.90 to 4.01 Hz, due to a decreased ground contact time from 160 to 156 ms, which is one of the parameters that have a direct impact on running technique.

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