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INFLUENCE OF A 6-WEEK MIXED BALLISTIC-PLYOMETRIC TRAINING ON THE LEVEL OF SELECTED STRENGTH AND SPEED INDICES OF THE LOWER LIMBS IN YOUNG FOOTBALL PLAYERS

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Abstract. *The development of muscle power should be taken into account in soccer training. The aim of this study was to evaluate the influence of a 6-week of mixed power training on the level of the motor skills of the lower limbs of young soccer players. The training was conducted during the starting period. The study included twelve 16-18-year-old players who regularly participated in specific soccer trainings and played in regional competitions. Their basic anthropometric features were measured. The assessment of the power of the lower limbs was carried out using two jump tests: CMJ and SJ. The maximum anaerobic power was calculated and was expressed in relation to body weight and lean body mass. In addition, Drop Jump tests were performed from three different heights on the basis of which RSI reactive strength index were calculated. On completion of the training program an increase in the level of the results of all the tests was observed: SJ (cm) (cohen's d: 0.43), CMJ (cm) (cohen's d: 0.33),* SJP_{max} *(W/kg) (cohen's d: 0.43),* $CMJP_{max}$ *(W/kg) (cohen's d: 0.30),* SJP_{max} *(W/LBMkg) (cohen's d): 0,57),* $CMJP_{max}$ *(W/LBMkg) (cohen's d: 0,44), RSI 0,2 (cohen's d: 0,59), RSI 0,3 (cohen's d: 0,45), RSI 0,4 (cohen's d: 0,58). An additional six-week ballistic-plyometric training program, used as a supplement to the basic training plan during the start period, resulted in an increase in the motor skills of the lower limbs of young soccer players. The application of combined ballistic and plyometric training methods helps to improve the strength and speed potential of young soccer players.*
Keywords: *ballistic-plyometric training, maximal anaerobic power, RSI, soccer*

Introduction

Soccer is a dynamic muscular work discipline, dominated by acyclic movement activities. Short-term efforts of maximum intensity and high intensity are intertwined with moderate and low intensity efforts (Bompa, Zając,

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Waśkiewicz, & Chmura, 2013). During a game of soccer, players perform a large number of movement activities such as: hitting the ball, slides, sprints with and without the ball, jumps and changes of running direction (Bangsbo, Mohr, & Krustrup, 2006). Strength and speed capabilities, understood as the anaerobic power and muscle strength, are crucial in the context of the high level of fitness preparation in many disciplines (Stec, Pilis, Witkowski, Pilis, Michalski, & Zych, 2018). In football, muscle strength, agility, speed and special endurance are indicated as the most important motor determinants of sports performance (Bompa & Buzzichelli, 2015).

In terms of strength and speed preparation, the main areas of training interaction in soccer are maximum power and muscle strength (Bompa & Buzzichelli, 2015). In sports practice there are many methods of developing muscle strength and power. In this study a combination of ballistic and plyometric methods was used to increase muscle power levels. Plyometric training based on skip forwards, jumps, and leaps using the phenomenon of stretch shortening cycle (SSC) is conducive to increasing the level of muscle strength and power (Chu & Myer, 2013). Ballistic exercises consist in performing a dynamic motor activity (throw, jump, sprint) with the use of external or self-resistance. The player must generate a level of muscle strength/power to overcome self-resistance or the resistance of the equipment (e.g. medicine balls) with maximum possible acceleration. Ballistic training induces positive adaptation in the following areas: FT fibre recruitment, intramuscular coordination and the frequency of muscle cell stimulation (Bompa & Buzzichelli, 2015).

In the light of specialist literature, it can be asserted that in recent years numerous studies have been carried out on the effectiveness of various types of muscle strength and power training in soccer players. Scientific research pertains to sprint exercises, combinations of strength exercises with and without equipment or plyometric exercises (e.g. Mujika, Santisteban, & Castagna, 2009; Chelly et al., 2010; Wong, Chamari, & Wisløff, 2010; Meylan & Malatesta 2009). However, an analysis of the available literature indicates lack of studies on the influence of mixed ballistic-plyometric training with medicine balls on the level of motor skills of the lower limbs of young soccer players (U-19).

Thus, it seems justified to scientifically verify the rarely used muscle power training methods which can easily (and considerably cheaply) be used in working with young soccer players. The aim of the study was to assess the effect of a 6-week ballistic training combined with plyometric training with the use of medicine balls on the level of the development of selected strength and velocity indices of the lower limbs in young footballers. Experimental training was conducted during the start period, as an addition to specialist (tactical-technical) trainings.

Material and methods

Twelve players of calendar age between 16 and 18 took part in the research, attending classes at the soccer academy. The research was carried out during the start period in September-October 2018. The players surveyed participated in 90-minute trainings, 4-5 times a week and played one championship match every week. The respondents had at least 4 years of training experience.

Experimental ballistic-plyometric training was conducted twice a week (on Mondays and Thursdays) for a period of six weeks (Table 1). The players participating in the classes were divided into 3 groups of 4 players each. 30 cm high athletic fences, spaced every 0.90 m, and 5 kg medicine balls were used in the training. The experimental training consisted in a series of exercises in which the player would first perform a series of jumps from the squat combined with an upward throw of the ball from a previously prepared starting position, and would next perform a series of back throws of the medicine ball, in which the starting position was the squat. The interval between each successive exercise was about 25 seconds, and between each series – 60 seconds. As the third task, the player performed a series of sprints with a medicine ball in his hands. During the running exercises, the participants performed 15-metre-long runs (lasting about 3 seconds), after which they rested for about 60 seconds (work-rest ratio being 1:20). The fourth task to be performed by the player consisted in a series of 5 jumps, holding the medicine ball in the hands, keeping contact time with the ground as short as possible. The duration of the exercise was about 5 seconds, and the interval between successive series was 60 seconds (work-rest ratio being 1:15). Between successive series there were breaks of about 60 seconds, in accordance with the recommendations of Lentz and Dawes (2015).

Table 1 ***Experimental training program (series x repetitions)***

week	medicine ball back throw	a jump from a squat position with a medicine ball throw	a 15m sprint with a medicine ball (sum of repetitions)	jumps with a medicine ball over 30 cm high fences
1	2x6 & 3x6	2x6 & 3x6	x2 & x3	2x5 & 3x5
2	3x6	3x6	x3	3x5
3	3x6	3x6	x3	3x5
4	4x6	4x6	x4	4x5
5	4x6	4x6	x4	4x5
6	5x6	5x6	x5	5x5

In the first week of the experiment, during the first training classes 2 series of exercises were carried out, during the second training 3 series of exercises were carried out, and in the following weeks the series progression presented in Table

1 was applied. During the implementation of individual exercises, the players were all the time verbally encouraged to do their best at working out.

Before and after the beginning of the training program, measurements of somatic features and motor skills of the lower limbs were taken. Somatic measurements of body height (BH), body weight (BW), lean body mass (LBM), percentage of adipose tissue (FM) in the body weight were included in the scope of the study. Somatic measurements were performed with the use of an anthropometric, in accordance with ISAK standards (Marfell-Jones, Olds, Stewart, & Carter, 2006). The measurements of body tissue components were carried out with the use of TANITA model BC-730 scales. Measurements of motor efficiency of the lower limbs included: measurement of the height of the SQUAT JUMP after a 3-second stop (90 degrees of knee joint flexure) (SJ), measurement of the COUNTERMOVEMENT JUMP height with upper limb swing (CMJ), a series of DROP JUMP tests (jumps from a height of 20, 30 and 40 cm), on the basis of which reactive strength index (RSI) based on the McClymont formula were calculated: RSI=h/t, where h stands for jump height (m), t stands for depreciation and rebound time (s) (Bober et al., 2007). On the basis of SJ and CMJ tests the maximum anaerobic power of jumps was calculated using Sayers et al. equation (1999): P_{max} = 60.7 x height of jumps (cm) + 45.3 x body weight (kg) – 2055. Power results were expressed in W/kg and W/LBMkg. Measurements were carried out using the Optojump system (Microgate, Italy).

In the statistical analysis of the collected data, after the evaluation of the normality of the distribution of variables with the Kolmogorow-Smirnov test, the following were calculated: basic descriptive statistics in order to describe the study group; the Student's T-test for dependent samples in order to assess the diversity of the level of development of the examined somatic and functional features of the players before and after the implementation of the experiment. Standard thresholds for arithmetic mean differences proposed by Cohen (d) (Hopkins, Marshall, Batterham, & Hanin, 2009) were used in the evaluation of the effect size (ES).

Results

Table 2 presents basic descriptive statistics characterizing the somatic structure of the players under examination. The results of the measurements of body height, body weight, body fat percentage and lean body mass are presented. Table 3 shows descriptive statistics characterizing the motor efficiency of the lower limbs of the players under observation in both research periods and the significance of differences that were recorded between the level of the development of this skill before and after implementation of the training experiment. On the basis of the presented results, it can be concluded that statistically significant differences in average SJ parameters occurred (p=0.008, ES: 0.43), SJP_{max} [W/kg] (p=0.011, ES: 0.43), SJPmax [W/LBMkg] (p=0.003, ES: 0.57), RSI 0.2 (p=0.003, ES:0.59), RSI 0.3 (p=0.032, ES:0.45), RSI 0.4 (p=0.004, ES: 0.58). In the case of other motor variables, an increase in the level of efficiency development was also observed; however, the changes were not statistically significant.

Table 1 ***Statistical characteristics of somatic variables of the players under examination***

Period/variables	1		2	
	x	sd	x	SD
BH [cm]	177.07	6.74	177.20	6.83
BW [kg]	67.28	5.44	68.30	5.45
FM %	10.66	2.69	11.48	2.40
LBM [kg]	60.08	4.72	60.43	4.60

Table 2 ***Statistical characteristics of the motor efficiency indicators of the lower limbs of the players under observation***

Period/variable	1		2		p-value	ES (Cohen's d)
	x	sd	x	sd		
SJ [cm]	**35.17**	**4.38**	**37.11**	**4.56**	**0.008**	**0.43**
CMJ [cm]	42.25	5.09	44.11	6.07	0.105	0.33
SJ_{Pmax} [W/kg]	**46.60**	**3.93**	**48.33**	**4.05**	**0.011**	**0.43**
CMJ_{Pmax} [W/kg]	53.08	4.81	54.66	5.64	0.114	0.3
SJ_{Pmax} [W/LBMkg]	**52.16**	**3.97**	**54.63**	**4.64**	**0.003**	**0.57**
CMJ_{Pmax} [W/LBMkg]	59.38	4.59	61.75	6.16	0.057	0.44
RSI 0.2	**1.50**	**0.34**	**1.74**	**0.43**	**0.003**	**0.59**
RSI 0.3	**1.57**	**0.34**	**1.74**	**0.42**	**0.032**	**0.45**
RSI 0.4	**1.59**	**0.37**	**1.81**	**0.41**	**0.004**	**0.58**

Discussion

The basis for effective actions of a player during a game of soccer is highly developed special movement skills, which in turn are conditioned by a high level of the development of motor skills: strength, speed, endurance, coordination. Traditional motor training of a soccer player used to be mainly focused on the development of their aerobic endurance, marginalizing their anaerobic preparation in the aspect of short-term strength and speed efforts. Today's soccer requires that endurance training be subordinated to strength and speed training and that attention be paid to the quality of exercise rather than quantity. Currently, a priority can be observed in the implementation of speed training, strength training with high performance dynamics, neuromuscular training, which are primarily based on anaerobic muscle effort. Such training activities enable the player, during a direct sports competition, to achieve greater efficiency in such activities as acceleration, shooting, jumping or sliding (Chmura, Chmura, & Ciastoń, 2008).

Bompa & Buzzichelli (2015) assert that the most important goals of strength training for soccer players should be to increase the level of maximum strength and muscle power. Recently, soccer players with different levels of training, age and performance, among many methods of power trainings often used and scientifically verified, have been using the plyometric method (e.g. Kobal et al., 2017; Michailidis et al., 2018, Negra et al., 2018; Beato, Bianchi, Coratella, Merlini, & Drust, 2018). As mentioned in the introduction, in the light of analysis of the literature available, no newer studies were found concerning ballistic training or a combined ballistic training with plyometric training in soccer players (with medicine balls). Plyometric training has long been recognised as effective in developing muscle power (Newton & Kraemer, 1994). However, its safe use is subject to certain requirements in terms of health, calendar age, strength or stabilization of the trunk. According to Bompa et al. (2013) or Davies et al. (2015), a player should have such a level of strength of the lower limbs that they can lift a weight equal to 1.5 of their body weight from the squat. Therefore, if the above requirements are not met, other methods of power training should be sought. It can be stated that the ballistic-plyometric method (i.e. a combination) with the use of medicine balls, based on easy, spatially and temporally structured motion, can be successfully used as a substitute for the plyometric method.

The results of our own research demonstrate efficiency of the use of ballistic-plyometric training in order to shape the strength and speed of the lower limbs of footballers. The SJ test is known to allow for determining of the possibility of generating the so-called general power of the lower limbs and to provide information on the concentric efficiency of muscle work, while the CMJ test is known to inform about the efficiency of muscle performance in the slow stretching system (slow SSC) (Martinez, 2017). Maćkała et al. (2015) claim that at the beginning of a sprint, the ability to generate high values of strength/power in the concentric work of the lower limb muscles is conducive to achieving high speeds during acceleration. As a result of the experiment, significant changes in the efficiency of SJ jumps and in the level of the power generated by the muscles involved in these jumps were observed in the players under examination. Power and its changes over time were characterized with indicators expressing its size in relation to body weight and lean body mass. These indicators show that the power of muscles (straightening the hip and knee joints) in concentric work was significantly improved during the experiment. The results of CMJ tests also improved, but the range of the changes was smaller and statistically insignificant. The lack of significant changes was probably due to the fact that the training program did not include exercises that would be similar in terms of movement structure to a shoulder swing jump (in which the SSC cycle occurs). Two experiment exercises consisted in throwing the ball in a jump from the squat and throwing the ball back; thus the main emphasis of the lower limbs performance during the exercise was focused on the concentric phase – straightening of the knee, hip and ankle joints (preparation of the position and then explosive straightening of the lower limbs combined with throwing the ball). Since the results of various jumping attempts are positively correlated with the kinematic parametres of sprint running (Maćkała et al., 2015) and since jumps are typical manifestations of speed abilities (Szopa, Mleczko, & Żak, 1996), it can be asserted that as a result of the training applied, the speed capabilities of the players under examination improved (in the scope of short-term sprint efforts). Moreover, in the Maćkała et al. study (2015) there was a positive correlation between the distance of the medicine ball back throw (one of the exercises used in this study) and the time and speed of running at a distance of 10 meters. Therefore, it seems that medicine ball exercises (throws, jump throws) can be successfully used to shape the speed efficiency (increasing muscle power levels) of young soccer players.

Newton and Kraemer (1994) affirm that the majority of explosive movements make use of the phenomenon of stretching and then shortening muscles in order to accelerate the body or a limb. Martinez (2017) states that jump-down tests with a rapid upward bounce make it possible to assess the specific strength of a jump (the so-called fast SSC). Reactive strength indexes (RSI) can be used to assess the level of explosive force in the lower extremities. McClymont's formula (Bober, Rutkowska-Kucharska, Pietraszewski, & Ćwiczenia, 2007) has been used in this study. The value of RSI depends to a large extent on the time of contact with the ground (the values of the index increase significantly, with shorter contact time) (Bober et al., 2007). In the experimental training only one exercise was used, which was characteristic of the plyometric method: jumping over 30 cm fences with a medicine ball in hands. According to Bober et al. (2007), the efficiency of plyomteric training, which consists in performing a series of jumps, depends on maintaining the shortest possible time of contact with the ground. During the exercises, the players were encouraged to perform jumps with possibly the shortest contact time between the feet and the ground. The results indicate a significant improvement of all analyzed RSI indicators. In the light of the studies cited by Bober et al. (2007), the observed mean values of RSI indices can initially (before the training cycle) be classified as weak or average (index value 1.5). On the other hand, after the end of the training cycle, the mean values of the indicators increased significantly (Table 2) and approached the upper limit of the range defined as the mean level (indicator 2). Based on the results of their research Michailidis Yiannis et al. (2018) suggest that the introduction of plyometric exercises of the lower limbs into the soccer players' training plan leads to an increase in their motor skills. The results of our own research confirm the reports of these authors. The use of plyometric exercise (the only one in which a fast SSC cycle was used) in our own study most probably had a direct effect on the improved RSI indices of the players observed. On this basis, it should be concluded that mixed training methods could be used with positive results in training aimed at shaping the strength and speed of the lower limbs in young players. Such tasks and training methods will enable players to achieve an increase in speed and strength potential and a comprehensive adaptation of the body to anaerobic efforts based on explosive muscle work.

Based on the results of our own research, the following conclusions can be drawn:

1. The use of mixed training methods aimed at shaping the strength and speed of lower limb muscles in young soccer players leads to an increase in their efficiency of movements related to the generation of maximum anaerobic power.
2. Compilation of ballistic and plyometric training with the use of medicine balls significantly increases the level of development of the speed potential of young soccer players.
3. The use of a mixed ballistic-plyometric method in training significantly increases the adaptation of the body to efforts based on explosive muscle work.

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