Original Article

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The Comparison of Unilateral and Bilateral Training Effect to Changes in Speed and Speed-Strength Abilities in Preadolescence Athletes

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Abstract

Introduction: The aim of the study was to compare the effectiveness of unilateral and bilateral training program on changes in the level of speed and speed-strength abilities. *Methods*: Experimental group 1 (EG1) consisted of 8 young athletes (age = 12.76±1.55 years) and experimental group 2 (EG2) consisted of 8 athletes (age = 12.51±1.59 years) who regularly participate in the training process at a frequency of three times a week. All of our athletes had more than 4 years experiences with regular athletic training 3 times per week prior to this study. During a period of 8 weeks in the preparatory period, such exercises were applied which were performed unilaterally in EG1 and bilaterally in EG2. To determine the effectiveness of take-off training on change in the level of speed and speed-strength abilities, the following tests were performed: relative strength index (RSI), squat jump (SJ), countermovement jump (CMJ), standing long jump (SLJ), 20 m run from standing start. *Results*: We found out that in the posttest, the athletes of both groups achieved an improvement in the explosive strength of the lower extremities as well as in the acceleration speed. A significant improvement ($p<0.05$) was recorded in EG1 in SLJ and in EG2 in RSI. The effect size coefficients showed a large effect in RSI in EG2 and in SLJ in EG1. *Conclusion*: The results clearly did not confirm a higher effect of the unilateral program in comparison with the bilateral program, but indicated a higher efficiency, especially in the take-off explosiveness of athletes with a unilateral training program.

Keywords: acceleration speed, athletics, unilateral training, explosive strength of lower extremities, pupils category

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INTRODUCTION

In the past, the perception of muscle work was based on the functions they performed in individual movements (flexion, extension, abduction, adduction...), but in an isolated sense. At present, we know that muscles are constantly working in cooperation through the so-called kinetic chains where their regime changes during movement [1]. In the moment when the lower extremity touches the pad during further activity, all the muscles of the lower extremity cooperate with one simple task - to prevent falling [2]. Most sports in terms of the implementation of their activities take place by alternating muscle work in a unilateral position. It is well known that if we want to improve in an activity, we should train that particular activity, and therefore if the sport takes place in a unilateral position, logically unilateral training should also have a better transfer directly to this sport [3].

But is unilateral training more effective than bilateral? The answer to this question has been examined by many authors, but the results of their research have not provide a clear answer. In examining the submaximal and maximal strength generated by each extremity separately and with both extremities simultaneously, the authors came to the same conclusions, e.g. [4-6]. The sum of the strength generated by each extremity separately exceeds the values of the strength generated by both extremities simultaneously. The authors described this phenomenon as a phenomenon of bilateral deficit, but they could not agree on the reasons for this phenomenon. The only fact where the authors agree is that the bilateral deficit probably has its origin in the activity of the nervous system.

Another positive of unilateral training is its usability after injury, when due to the training of a healthy extremity there are performance gains in the injured extremity. The increase in the untrained lower extremity in maximum strength by 18.9% in bench press and by 6.7% in lower extremity extension was achieved after 10 weeks of intervention [7]. There is a transfer to the contralateral extremity during unilateral training, but insignificant [8].

Unilateral, bilateral maximal strength and isometric strength performance in a group training unilaterally and bilaterally with an effort to point out greater neuromuscular adaptation after unilateral training were researched. Both unilateral and bilateral groups recorded an increase in the performance of unilateral maxima (14.3% vs. 11.9%), bilateral 1RM (6.8% vs. 12.3%) as well as isometric strength (11.3% vs. 12.5%). The unilateral group recorded a higher increase in unilateral strength as well as increased muscle activity [9,10].

There is a clear correlation between unilateral training and its impact on performance in sports games [11]. The authors studied the effect of unilateral and bilateral training on maximum lower extremities performance, muscle imbalance, bilateral deficit, speed with changes of direction, vertical strength production as well as linear sprint. The tests were performed on basketball players aged 16 to 19 years. The training program lasted 6 weeks. Both groups recorded an increase in performance, but the authors point to a higher increase in performance after unilateral training, improved muscle imbalance and higher performance in physical activities directly related to the unilateral nature of work in basketball. We can state that unilateral training has a significant impact on improving unilateral movement, bilateral training has a greater impact on bilateral movement. It is not clear from the research what is the role of factors such as gender, age and level of training in the effectiveness of unilateral training.

Since in athletics the movement patterns have a unilateral character, we have decided to focus on athletes in the pupils age, in order to verify the influence of the unilateral exercise program on selected speed and speed-strength abilities and compare it with the bilateral program in our study. Based on the presented studies, we assume that both bilateral and unilateral training will have a positive effect on the level of speed and speed-strength abilities. In our opinion, unilateral training could have a more significant effect on reflective explosiveness and starting speed. The main intent of this study was to examine the unilateral-bilateral training effect on specific age group of 12-13 years athletes with focus on speed-strength abilities.

MATERIALS AND METHODS

Participants

The research of experimental design was attended by girls and boys with more than 4 years experiences with regular athletic training 3 times per week prior to this study. Experimental group 1 (EG1) consisted of 8 athletes (age = 12.76±1.55 years) and experimental group 2 (EG1) consisted of 8 athletes (age = 12.51±1.59 years). Athletes were evenly divided so that the representation of boys and girls in the groups (3 boys and 5 girls in each group) was the same, approximately the same age structure, performance level and somatic parameters (Table 1). Measurements were carried out in accordance with the ethical standards of the Declaration of Helsinki and the ethical standards in sport and exercise science research [12].

Organization of research

The research period during which we applied the assembled battery of unilateral and bilateral exercises lasted 8 weeks. The experiment began with a pretest, followed by an 8-week intervention period, and after its finishing they underwent a posttest. The 8 week period was chosen since it is generally considered as long enough to initiate the changes in speed and speed-strength qualities. Athletes completed 3 training units per week. In the monitored period, the athletes completed 23 training units lasting 60 - 90 minutes. The specific physical program was a set of exercises that had the same volume in EG1 and EG2 and gradually increased. EG1 performed the exercises unilaterally, ES2 bilaterally (Tables 2,3).

Table 1. Somatic parameters in experimental group 1 and experimental group 2 at the beginning of the monitored period.

Indicator	Experimental group 1 (EG1)			Experimental group (EG2)		
	Body height (cm)	Body weight (kg)	BMI (i)	Body height (cm)	Body weight (kg)	BMI (i)
M *(SD)*	161.38 (13.02)	47.09 (12.06)	17.73 (2.11)	162.0 (12.07)	46.83 (9.6)	17.72 (2.5)

M = Mean; *SD* = standard deviation

Table 2. Volume of exercises of a specific movement program on one training – experimental group 1 (n=8).

No.	Exercise description	At the beginning of experiment		At the end of experiment	
		Number of repetitions	Together	Number of repetitions	Together
1.	Ankle hops unilateral	5 x 10 left leg, 5 x 10 right leg	100	7 x 10 left leg, 7 x 10 right leg	140
2.	Half squats to 120° unilateral	5 x 5 left leg, 5 x 5 right leg	50	7 x 5 left leg, 7 x 5 right leg	70
Number of repetitions together			150		210

Table 3. Volume of exercises of a specific movement program on one training – experimental group 2 (n=8).

No.	Exercise description	At the beginning of experiment		At the end of experiment	
		Number of repetitions	Together	Number of repetitions	Together
1.	Bilateral ankle hops	5 x 20	100	7 x 20	140
2.	Half squats to 120° bilateral	5 x 10	50	7 x 10	70
Number of repetitions together			150		210

Table 4. Completed training load of athletes EG1 and EG2 during the monitored period.

No.	Training indicators	n
1	Days of loading (number)	23
2	Load units (number)	23
3	Duration of the load (hour)	32
4	Gymnastics (hour)	2.5
5	Games (hour)	3.5
6	Swimming (hour)	0.0
7	Hiking, skiing, skating (hour)	0.0
8	Coordination exercises (hour)	1.25
9	Speed exercises (hour)	3.0
10	Endurance exercises (hour)	0.35
11	Ankle hops (number)	2700
12	Half squats (number)	1350
13	Strengthening exercises (hour)	4.0
14	Training of running technique (hour)	3.6
15	Training of hurdle run technique (hour)	1.5
16	Training of jumps technique (hour)	1.0
17	Training of shots and throws (hour)	2.0
18	Warm up, stretchning, cool down (hour)	4.5

The training units included more versatile preparation than special training (Table 4). The volume of the physical program in 23 training units was 2700 ankle hops and 1350 half squats in the whole monitored period. In addition, we present the total volume of training load in the monitored training indicators (Table 4). All monitored athletes completed at least 80% of the planned training load.

Table 4 represents the volume of the load of participants specified to activities they completed during the program. The load we calculated from monitoring the training sessions individually, summarizing the calculations of all 8-week program training sessions as well as attendance of each participant on trainings. We recorded the time and sets, repetitions of each sessions, the participants provided us their athlete´s sport diaries so we could estimate the total load in the end very precisely.

Measurement

Before implementation of the research, we performed measurements of somatic parameters - body height, body weight and BMI index. Pretest (PRE) and posttest (POST) measurements took place in the gym, without the use of track spike running shoes.

To determine the level of motor performance of speed and speed-strength abilities, we selected tests that were performed in the following order:

1. relative strength index (RSI) jump after jumping from a height of 20 - 30 cm (according to the level of take-off abilities), without arm swing - eccentric-concentric contraction test (fast SSC),
2. squat jump (SJ) - test of concentric contraction, with the involvement of ankle, knee and hip joints in the take-off,
3. countermovement jump (CMJ) - test of eccentric-concentric contraction, with involvement of ankle, knee and hip joints in the take-off,
4. standing long jump (SLJ) - test of explosive strength of lower extremities,
5. 20 m run, measuring performance 5 m, 10 m, 15 m, 20 m - acceleration speed test.

Take-off tests were performed 3 times each test, and each athlete repeated 20 m run 2 times. The choice of tests was based on the intention to determine the effectiveness of the program at the level of reflective explosiveness and acceleration speed. Relative strength index test (RSI = ht-1, h - jump height in mm, t - contact time with the pad in ms), eccentric-concentric contraction test, jump after jump, indicates the ability to quickly stretch and shorten in the minimum time interval (fast SSC).

The squat jump (SJ) test expresses the ability of concentric muscle contraction in a longer time interval and with the involvement of a larger number of motor units. The countermovement jump (CMJ) test expresses the ability of muscular eccentric-concentric contraction in a longer time interval and with the involvement of a larger number of motor units. Standing long jump (SLJ) is a general test of reflective explosiveness of the lower limbs. The level of acceleration speed was determined with 20 m run.

When it comes about validity and reliability of the tests, SJ and CMJ tests were proved to have high relationship with explosive power factor (r = 0.76-0.87) and so great factorial validity [13]. We used the Optojump Jump next instrument (Microgate, Italy) to measure speed-strength abilities. Optojump next is an optical device operating across a transmitting and receiving platform, each of which contains 96 LEDs (1.04416 cm resolution – distance between individual LEDs alongside the platform). OptoJump Next is a device used to measure and objectify the main properties of a jump, such as flight and contact time with the pad [14]. Opto jump Next was proved to be one of the most reliable and valid device for measuring vertical jump height on the field as well as in laboratory conditions. The comparison between Optojump Next device and force plates showed very high intraclass correlation coefficients (ICCs) for validity (0.997-0.998), even if a systematic difference was consistently observed between force plate and Optojump (-1.06 cm; p<0.001). Test-retest reliability of the Optojump system was excellent, with ICCs ranging from 0.982 to 0.989, low coefficients of variation (2.7%), and low random errors (±2.81 cm). The Optojump photocell system demonstrated strong concurrent validity and excellent test-retest reliability for the estimation of vertical jump height [15]. Since there is natural need of horizontal force and speed production in athletics as well, we decided to measure standing long jump and acceleration for 5 m, 10 m, 15 m and 20 m as a supplementary tests for our research. The standing long jump was measured with a tape measure. We used photocells to measure the acceleration speed. To record the results of speed skills, we used a timer - Witty (Microgate) designed for sports and training, which works on the coaxial optical principle.

Data analysis

A Paired Samples t-test was used to determine the significance of the differences between the pretest (PRE) and posttest (POST) measurements in the examined parameters in EG1 and EG2. The effect size within the Paired Samples t-test procedure was evaluated by the Cohen coefficient d, which was interpreted using the cut-off values as follows: d = 0.20 - small effect, d = 0.50 - medium effect, d = 0.80 - large effect [16]. The normality of the data distribution was verified by the Shapiro-Wilk test. In case of violation of normality of data distribution, a nonparametric paired Wilcoxon test was used. The coefficient r [17] was used to evaluate the effect size within the paired Wilcoxon test procedure, which was interpreted using the cut-off values as follows: r = 0.10 - small effect, r = 0.30 - medium effect, r = 0.50 - large effect [16]. The probability of error type I. was set to the conventional value α = 0.05 in all analyzes. Statistical analysis was performed using computer programs IBM® SPSS® Statistics V25 and Microsoft® Office Excel 2016.

RESULTS

In the relative strength index (RSI) we recorded i = 1.49±0.3 (Table 5) in pretest measurement (PRE). In posttest measurement (POST), experimental group 1 (EG1) achieved the average performance 1.72±0.26, an average improvement by 0.23 (15.4%). The difference was not significant (p>0.05) but effect size (ES) showed a medium effect (d = 0.65).

In the SJ test, ES1 reached a value of 32.34±3.71 cm in PRE. In POST, the average performance was 33.3±5.44 cm, the average improvement by 0.96 cm (2.97%). The difference was not significant (p>0.05), but the ES coefficient showed a medium effect (r = 0.37). In the CMJ test, ES1 achieved an average performance 33.1±4.49 cm in PRE. In POST, the average performance was 34.09±5.76 cm, the average improvement by 0.99 cm (2.99%). The difference was not significant (p>0.05), but the ES coefficient showed a medium effect (r = 0.36).

In the reflective explosiveness test, the standing long jump (SLJ) achieved an average performance 212.13±22.58 cm in PRE. In POST there was an improvement by 219.62 cm, on average by 7.49 cm (3.53%). A significant difference (p<0.05) with a large effect (*d* = 1.16) was observed in the test. In acceleration speed at 5 m, EG1 achieved an average performance 1.16±0.06 s in PRE. In POST, the average performance was 1.14±0.08 s, the average improvement by 0.02 s (1.72%). The difference was not significant (p>0.05) with small effect (*d* = 0.47). In acceleration speed at 10 m, EG1 achieved an average performance 1.96±0.12 s in PRE. In POST, the average power was 1.93±0.11 s, the average improvement by 0.03 s (1.53%). The difference was not significant (p>0.05) with small effect (*d* = 0.41). EG1 reached an average performance 2.67±0.15 s in 15 Dem run in PRE. In POST, the average performance was 2.65±0.15 s, the average improvement by 0.02 s (0.75%). The difference was not significant (p>0.05) with small effect (*d* = 0.29). In acceleration speed in 20 m run, the EG1 achieved an average performance 3.37±0.20 s in PRE. In POST, the average performance was 3.34±0.17 s, the average improvement by 0.03 s (0.89%). The difference was not significant (p>0.05) with small effect (*d* = 0.41). In the relative strength index (RSI) we recorded i = 1.29±0.4 in PRE (Table 6). In POST, experimental group 2 (EG2) achieved an average performance 1.51±0.36, an average improvement by 0.22 (17.05%). A significant difference (p<0.05) with a large effect (*r* = 0.63) was observed in the test.

In the SJ test, EG2 reached a value of 29.76±5.33 cm in the PRE. In POST, the average performance was 30.84±5.79 cm, the average improvement by 1.08 cm (3.63%). The difference was not significant (p>0.05) with small effect (*d* = 0.41). In the CMJ test, EG2 achieved an average performance 30.28±5.38 cm in PRE. In POST, the average performance was 30.35±4.67 cm, with a minimum average improvement by 0.07 cm (0.23%). The difference was not significant (p>0.05) with no effect (*d* = 0.03).

Table 5. Values of speed-strength and speed indicators and statistical analysis in EG1 (n=8).

Inticator	Pretest (PRE)	Posttest (POST)	t-test, Wilcoxon test	Effect size (ES)	
	M (*SD*)	*M* (*SD*)		ES value	ES level
RSI [i]	1.49 (0.30)	1.72 (0.26)	t = -1.827	*d* = 0.65	medium effect
SJ [cm]	32.34 (3.71)	33.30 (5.44)	Z = -1.472	*r* = 0.37	medium effect
CMJ [cm]	33.10 (4.49)	34.09 (5.76)	Z = -1.439	*r* = 0.36	medium effect
SLJ [cm]	212.1 (22.6)	219.6 (22.0)	t = -3.284*	*d* = 1.16	large effect
5 m run [s]	1.16 (0.06)	1.14 (0.08)	t = 1.316	*d* = 0.47	small effect
10 m run [s]	1.96 (0.12)	1.93 (0.11)	t = 1.16	*d* = 0.41	small effect
15 m run [s]	2.67 (0.15)	2.65 (0.15)	t = 0.823	*d* = 0.29	small effect
20 m run [s]	3.37 (0.20)	3.34 (0.17)	t = 1.169	*d* = 0.41	small effect

RSI = relative strength index; SJ = squat jump; CMJ = countermovement jump; SLJ = standing long jump; *M* = Mean; *SD* = standard deviation; * = significance $\alpha = 0.05$ (p<0.05).

Table 6. Values of speed-strength and speed indicators and statistical analysis in EG2 (n=8).

Indicator	Pretest (PRE)	Posttest (POST)	t-test, Wilcoxon test	Effect size (ES)	
	M (*SD*)	*M* (*SD*)		ES value	ES value
RSI [i]	1.29 (0.4)	1.51 (0.36)	Z = -2.521*	*r* = 0.63	large effect
SJ [cm]	29.76 (5.33)	30.84 (5.79)	t = -1.15	*d* = 0.41	small effect
CMJ [cm]	30.28 (5.38)	30.35 (4.67)	t = -0.089	*d* = 0.03	no effect
SLJ [cm]	204.4 (18.1)	206.9 (19.7)	t = 0.947	*d* = 0.33	small effect
5 m run [s]	1.22 (0.09)	1.20 (0.1)	t = 0.743	*d* = 0.26	small effect
10 m run [s]	2.03 (0.1)	2.01 (0.11)	Z = -1.156	*r* = 0.29	small effect
15 m run [s]	2.77 (0.13)	2.76 (0.15)	t = 0.267	*d* = 0.09	no effect
20 m run [s]	3.48 (0.19)	3.46 (0.18)	t = 0.439	*d* = 0.16	no effect

RSI = relative strength index; SJ = squat jump; CMJ = countermovement jump; SLJ = standing long jump; *M* = Mean; *SD* = standard deviation; * = significance $\alpha = 0.05$ (p<0.05).

In the reflective explosiveness test, standing long jump, EG2 achieved an average performance 204.38±18.13 cm in PRE. In POST there was an improvement by 206.88 cm, on average by 2.5 cm (1.22%). In the test, no significant difference (p>0.05) was noted, with little effect (*d* = 0.33). In acceleration speed at 5 m, the EG2 achieved an average performance 1.22±0.09 s in PRE. In POST, the average performance was 1.20±0.10 s, the average improvement by 0.02 s (1.64%). The difference was not significant (p>0.05) with little effect (*d* = 0.26). In acceleration speed at 10 m, the EG2 achieved an average performance 2.03±0.1 s in PRE. In POST, the average power was 2.01±0.11 s, the average improvement by 0.02 s (0.99%). The difference was not significant (p>0.05) with little effect (*d* = 0.41). EG2 reached an average performance 2.77±0.13 s in PRE when running at 15 m. In POST, the average power was 2.76±0.15 s, the minimum average improvement by 0.01 s (0.36%). The difference was not significant (p>0.05) with no effect (*d* = 0.09).

In acceleration speed at 20 m, the EG2 achieved an average performance 3.48±0.19 s in PRE. In POST, the average performance was 3.46±0.18 s, the average improvement by 0.02 s (0.57%). The difference was not significant (p>0.05) with no effect (*d* = 0.16).

DISCUSSION

The most important discovery of our study is the fact that the influence of bilateral as well as unilateral training program focused on take-off exercises, significantly improved the ability of athletes to use the elastic energy of tendons expressed through the RSI index. As a result, they are able to use SSC more efficiently, absorb energy in impacts and use stored energy in the subsequent generation of force, which ultimately led to increasing performance in all take-off and speed tests we monitored and in global terms it leads to lowering the risk of injury and transfer to specific physical activities in athletics. Since our program consisted of 8 weeks we did not consider this period long enough for biological age factor to play a major role in affecting our results.

Lower efficiency was observed in other take-off tests, although the nature of the muscle work was similar to that performed in the physical program (vertical strength production). The lowest efficiency of take-off exercises in the level of acceleration speed is explained by the lower volume of running exercises of technical focus during the observed period and the nature of muscle work (horizontal strength production), resp. the duration of the experiment. The acceleration speed was part of session only once a week, therefore it was insufficient stimuli to initiate any long-term changes in acceleration, which our results confirmed. Minimum 2 sessions per week are needed in order to achieve adaptation over the time when it comes about acceleration. The training block for speed followed after our 8-week program but it is not part of this article. That is the reason why there was no significant transformation of the explosive strength into a running technique.

Several authors focused on comparing the impact of bilateral and unilateral training on young athletes [18-22]. The impact of a 6-week bilateral and unilateral strength and plyometric training on footballers aged 15-17 was investigated. Both groups experienced significant performance gains. The bilateral group recorded significantly better results in the back squat test (p<0.05; *d* = 1.27; % Δ = 26.01), the unilateral group in the unilateral tests of the rear foot elevated single leg squat (RFESS 33.29%), the one-legged long jump (9.84%) as well as speeds with changes of direction to 5-0-5m (2.80%) [23]. Comparison, where the impact of unilateral, bilateral and combined training for 6 weeks in 9-12- year old footballers with an emphasis on the performance of explosive strength and endurance was done. Although the results in all groups brought significant performance gains, the most effective was the method of combined training, in which they achieved significantly more significant differences in performance gains in 13 of the 21 monitored parameters [24]. Another study studied the impact of a 6-week plyometric training program divided into unilateral and bilateral groups. Both bilateral and unilateral tests (CMJ, DJ and maximum isometric force on legpresse with one leg were recorded. Both groups recorded significant increases in performance with an insignificant difference between the groups, but only in the unilateral group there was a significant increase in strength in the summation of left and right lower extremity performance compared to pretest, in the bilateral group there was no change. The authors agree that both unilateral and bilateral training leads to an increase in explosive strength performance, unilateral training has a greater transfer to unilateral movement patterns than bilateral, and in terms of effectiveness, neither training method appears to be more effective than the other. Therefore, the authors recommend combining unilateral and bilateral training in order to achieve the best results [25].

CONCLUSION

Medium to large effect in explosive strength was achieved in unilateral group (RSI d = 0.65; SJ; r = 0.37; CMJ r = 0.36; SLJ d = 1.16). However when it comes about acceleration speed small effect size was achieved. There was zero to small effect recorded in all parameters excluding RSI (r = 0.63) in bilateral group. The main contribution of our study is, that unilateral training seems to be better strategy for explosive strength development in specific age group of 12-13 years old athletes with previous experiences with athletic training. The bilateral training is important to use as well, but the idea to explore how 12-13 years old athletes respond to both types of training might be beneficial for scientific as well as sport community.

We consider it important to comment on the limits of implemented study. The biggest limit is the low number of probands in EG1 and EG2, which is a disadvantage in connection with the statistical analysis. At low numbers, error II. (β) rises, resulting in insufficient strength of the statistical test. Therefore, we also used evaluation using coefficients effect size to interpret the results.

Other limitations of the study include the absence of a control group, the short duration of the experiment, the low volume of exercises to practice the running technique as well as the absence of unilateral take-off tests to determine the effectiveness of the unilateral training program, which could bring more interesting results in terms of transfer to performance. Nevertheless, we consider the set of exercises to be appropriate with regard to the age, level of physical development and level of training of young athletes. We would have found a more convincing findings if the overall training was more focused on the development of speed and speed-strength abilities. For future research, we recommend expanding the number of both groups as well as creating a control file, extending the duration of the experiment, including unilateral tests for successful comparison of results.

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