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Professional paper

THE EFFECT OF A 12-WEEK EXPERIMENTAL PROGRAM ON THE SEGMENTAL VELOCITY AND EXPLOSIVE STRENGTH OF THE LOWER AND UPPER EXTREMITIES IN ADOLESCENTS

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Abstract

The aim: The aim of this study was to validate the 12-week effect of the experimental program on the performance of segmental velocity and explosive strength of the lower and upper extremities in adolescents. Methods: The research was carried out in a sample of 220 male entities aged 15 years ± 6 months, high school students in the municipalities of Kumanovo and Likova, in the Republic of North Macedonia. The sample of 220 subjects was divided into 2 groups: Group A: Experimental (EG, n=115, height 168.6, weight 60.4, IMT 21.09) and Group B: Control (CG, n=105, height 168.1, weight 56.8, IMT 20.8)). Subjects from the experimental group underwent a 12-week experimental program, while the control group did not follow any adequate program, except for 2 regular hours during the week in the subject of physical education. To evaluate the performance of segmental speed and explosive strength of the lower and upper extremities, we used foot tapping, hand tapping, standing long jump, vertical jump, medicine ball chest throw and seated medicine ball throw tests. The study had a longitudinal character and lasted 12 weeks, with 36 hours of training or 3 hours during the week and 2 hours from the subject of physical education.Results**:** The results of the study after the application of the experimental model, in the final measurements, show that all the variables of the explosive force of the lower and upper extremities have statistically significant differences (p=0.05), between the control and the experimental group, in favor of the experimental group, while the segmental velocity variables have no significant differences. According to data from the univariate analysis of variance (ANOVA), in the initial measurements, no significant differences appeared in any test used in this study. While according to the data from the univariate analysis of covariance (ANCOVA), in the final measurements, we find that the data system in the space of physical fitness has statistically significant differences in the vertical jump (VJ) (p=0.019), medicine ball chest throw (MBCHTH) (p=0.026), seated medicine ball throw (SMBTH) (p=0.038) and standing long jump (SLJ) (P=0.047), while segmental speed parameters have no significant statistical differences. Conclusion: All the tests are in favor of the experimental group, which can prove that this experimental model, with 3 extra hours per week, in a 12-week period, has a positive effect on the development of the explosive strength performance of the lower and upper extremities in adolescent. Practical application: These findings provide further evidence for the improvement and enhancement of physical fitness performance through the implementation of the experimental program model in the adolescents who attended this experiment.

Keywords: experimental model, segmental velocity, explosive strength, adolescents, ANOVA, ANCOVA.

1. Introduction

Experimental training programs are complex and comprehensive processes for the development of functional and motor skills, as well as the maintenance of morphological parameters and body composition of athletes and students. The basic tasks of experimental programs, whether resistance or plyometric, which are carried out for a certain period of time, are dedicated to improving exercises and increasing sports results by raising the general skills and characteristics that are necessary for the successful performance of activities during training and competition (Iseni & Kryeziu, 2021). The experimental program which includes plyometric exercises, exercises with different jumps with resistance, exercises for the development of starting accelerations and stabilization exercises are important parameters for the development of explosive strength performance in the lower extremity in adolescents (Radulovic et al., 2022). While (Ronnestad et al. 2008) showed that the combination of plyometric training and specific strength training are also effective in developing lower limb explosive strength in adolescent athletes. Furthermore, (Blattner & Noble, 2013) in their study showed that isokinetic training can produce similar effects as plyometric training on vertical jump in adolescent athletes. Combined programs that contain plyometric and resistance exercises have positive effects on raising and improving motor skills, especially the development of vertical jump capacities and starting accelerations in the lower limbs in male adolescents aged 12-14 years (Fischetti et al. ., 2019). Training programs containing jumps and plyometric exercises have a positive effect on increasing explosive strength and speed (Chu, 1993), and agility (Potach & Chu, 2000). Various researchers have shown that plyometric training, especially when used with a well-designed program or model and delivered to athletes and students over a longer period of time, can contribute to improving performance in types of long jumps, as well as muscle strength of the lower limbs (Miller et al., 2006). However, plyometric programs are not intended to be the only exercise programs for the development of speed and explosive strength (Bompa, 2000) (Faigenbaum et al., 2007), but significantly greater gains in the development of sports performance can be observed when training plyometric is combined with explosive strength development program and resistance training (Almoslim, 2014). Also, resistance training or the weight method offers an effective way to increase motor performance, especially the development of speed and strength in children and adolescents (Behringer et al., 2011). The effects of resistance and plyometric training on muscle strength are more pronounced in adolescence than in childhood, and in boys they improve more than in girls (Granacher, 2016). Adaptations of experimental training in the development of speed skills are more variable, showing an initial increase during ages 5–9 years, which is followed by a second period of rapid improvement during puberty (Meyers et al., 2017). The study aimed to analyze the effect of the 12-week experimental program on the segmental speed and explosive strength of the lower and upper extremities in adolescents who perform such parts of different exercises in physical education classes with no previous training experience of the experimental program. Very important for physical education pedagogues is to further investigate the effect of the experimental program on the development of the ability of segmental speed and explosive strength of the lower and upper extremities in adolescents. However, taking into account the fact that exercises with an experimental program, such as plyometric programs, programs with resistance, combined, with high training intensity, etc., have had an impact on the development of morpho-functional characteristics, we hope that the results of our study will be able to provide physical education educators as well as sports and sports science specialists with a concrete plan to see the effects of the experimental model in improving segmental speed and explosive

strength of the lower and upper extremities in adolescents. The aim of this study was to present a model of experimental exercises that contain many exercises with acceleration sprints, jumps, one-leg jumps, deep jumps, Swedish box jumps, etc., that have an effect based on a well-designed program for adolescents. Hypotheses also derive from the goal, as a first hypothesis we presented the issue of how much the experimental training program affects the development of segmental speed indicators. While, as a second hypothesis, we presented the question of how much effect the experimental program would have on the explosive strength of the lower and upper extremities in adolescents .

2. Methods

2.1.The participants

The sample of participants was drawn from the population of secondary school students of the "Sami Frashëri" gymnasium - Kumanovo and the "Ismet Jashari" gymnasium - Likovë, R. of North Macedonia, aged 15 years ± 6 months. The sample consists of a total of 220 entities. The same is divided into 2 subsamples or groups: group A: Experimental (GE, n=115, height 168.6, weight 60.4, IMT 21.09) who, in addition to 2 hours of physical education in the framework of regular lessons, organized a training system with experimental program with three additional hours per week, and group B: Control (GK, n=105, height 168.1, weight 56.8, IMT 20.8) who were not active in any training process, except for 2 hours per week of regular lessons of physical education. Consent regarding the performance of the tests was obtained from the parents and their caretakers before the start of the study. All students were healthy and active, without any chronic pediatric diseases. Also, none of the participants had performed any training experiment with an adequate or similar program for three months prior to the start of the current study. The study was given institutional ethical approval by the University of Tetova, Faculty of Physical Culture and meets all standards according to the Declaration of Helsinki.

Table 1. Descriptive anthropometric characteristics of the groups (arithmetic mean; standard deviation)

Variables	Control group (n=105)				Experimental group (n=115)			
	Mean		St.dev.		Mean		St.dev.	
	IT	FT	IT	FT	IT	FT	IT	FT
Age	15.5	15.6	2.43	2.36	15.6	15.9	2.76	2.61
Height	168.1	168.8	7.24	7.42	168.6	169.3	6.672	6.864
Weight	56.8	56.8	10.65	10.33	56.7	60.4	8.74	8.53
BMI	20.807	20.877	3.304	3.241	21.096	20.735	3.790	3.639

2.2.Testing procedures

In this study, a total of 6 physical fitness variables were used to assess segmental speed, lower extremity explosive strength, and upper extremity explosive strength. First, anthropometric measurements were taken, such as body height, body mass, body mass index, which were in accordance with international standards for anthropometric assessment (Stewart, 2006). Segmental speed was assessed by foot tapping and hand tapping motor tests. Foot tapping is performed from a sitting position in which the entity performs as many foot movements as possible on the foot tapping tool in time for 20 seconds and is measured using a stopwatch. A point is scored when the foot makes two side kicks. The same procedure also applies to hand tapping, only that the test is performed from a standing position, in which the subject performs as many hand taps as possible on both sides of the hand tapping measure (Eurofit, 1993). Explosive leg strength was measured with the vertical jump test using a specialized apparatus called Vertec®. The test can be performed by jumping squat, starting from the position of bent knees (Sargent, 1921). Each participant jumps three times, with a break of 1 minute. In the standing long jump test, participants stood behind the starting line with their feet slightly apart and jumped forward as far as possible. The length of the jump is measured until the first touch of the heels on the floor (Marta, 2013). Explosive strength of the upper extremities was assessed with the motor tests of throwing the medicine ball from the lying position and throwing the medicine ball from the sitting position. The measuring instruments for these tests are the medicine ball weighing 3 kilograms and the metric tape for measuring the distance covered. The subject performs a total of three attempts, while the best attempt is recorded (Stockbrugger, 2001) (Ikeda et al. 2007). All tests were carried out by people specialized in the field of physical education.

2.3. Experimental program procedures

The investigation of the 12-week training effect of the experimental program on the efficiency of the results in the performance of speed and explosive strength of the lower and upper extremities in boys aged 15 years, was carried out in two groups of participants, the control group (CG) and the experimental group (EG). The 12-week training program for the development of explosive speed and strength was carried out only in the experimental group, who, in addition to the regular 2-hour weekly exercises in the subject of physical education (Tuesday, Thursday), organized a training system with 3 additional hours per week (Monday, Wednesday, Friday), a total of 36 hours of training over a period of 12 weeks. The participants of the control group did not attend any special training, apart from regular physical education classes. In both groups of participants in the same period of time, the initial measurements (before the beginning of the experimental program) and the final measurements (after the end of the experimental program) were performed, in the researched segments: anthropometric measurements and physical fitness tests. We have divided each hour of the experimental program into 4 parts, as well: the introductory part (5-10 min.) in order to prepare the organism for further work, the preparatory part (10-15 min.) in order to warm up the locomotor system, mostly the muscles, tendons and ligaments of the lower and upper extremities, the main part (25-30 min.) the realization of the experimental program plan which contains various exercises, such as: sprinting runs, jumps with one leg, jumps with two legs, deep jumps, Swedish box jumps, etc., and the final part (8-15 min.) calming the body and emotions with forms of relaxing dances and muscle stretching. The number of sets of each exercise was a minimum of 3 sets, with a maximum of 10 repetitions, with a pause between exercises of 45-90 seconds, and with a load intensity of 60-75%. Each participant in all

testing and training of the experimental program was closely monitored by physical education teachers and experts in the implementation of this scientific research.

Table 2. Description of the experimental program

Exercise	Week 1-3	Week 4-6	Week 7-9	Week 10-12
10m sprint – 10m two-legged jumps	X3			
10m Sprint – 10m single leg jumps	X3			
30m progressive sprint	X3			
40m progressive sprint	X3			
30m two-legged depth jump	X3			
30m single leg zig-zag jump	X3			
20inch (50cm) double leg plyo box jumps		3x10 rep.		
25inch (63cm) double leg plyo box jumps		3x10 rep.		
30inch (76cm) double leg plyo box jumps		3x10 rep.		
20 inch (50cm) single leg plyo box jumps		4x10 rep.		
60 cm Swedish box depth jump			4x10 rep.	
80 cm Swedish box depth jump			4x10 rep.	
100 cm Swedish box depth jump			4x10 rep.	
10m jumps with the right leg- 10m jumps with the left leg - 10m sprint				X4
Two-legged jumps on the left– 30m zig-zag on the right				X4
30m two-legged jumps between hurdles				X4

2.4. Statistical analysis

The results were processed using the SPSS statistical package (IBM SPSS statistics, version 26.0, IBM corporation, Armonk, New York, NY, USA). In this context, the basic statistical parameters were calculated, such as the arithmetic mean and the standard deviation in both researched groups in the initial and final measurements. To evaluate the differences between the control group (CG) and the experimental group (EG) in the initial measurements, univariate analysis of variance (ANOVA) was used, while after the 12-week period, the differences between the control and experimental groups in the final measurements were evaluated again using the univariate analysis of covariance (ANCOVA). All p values less than 0.05 are considered significant results.

3. Results

Table 3. Basic statistical parameters of segmental velocity variables and explosive strength of the lower and upper extremities – control and experimental group at initial and final measurements

Variables	group	Mean		St.dev.		Skewnees		Kurtosis	
		IT	FT	IT	FT	IT	FT	IT	FT
FT	Control	23.0	26.9	3.04	2.74	.71	-.24	1.45	2.10
	Experimental	23.1	26.9	3.04	2.69	.00	-.23	1.36	1.28
HT	Control	34.3	39.8	6.25	5.78	-.28	-.47	2.00	-2.09
	Experimental	34.3	39.9	6.38	5.94	-.28	-.45	-1.15	-2.81
SLJ	Control	194.8	225.3	28.14	27.41	.78	.53	1.95	1.99
	Experimental	196.4	266.5	27.47	26.74	.62	.43	1.83	1.65
VJ	Control	32.0	37.0	5.76	4.94	.29	.12	-2.22	-2.40
	Experimental	32.0	49.9	5.59	4.84	.22	.11	-2.15	-1.36
MBCHTH	Control	384.2	426.4	60.92	61.14	-.97	-.08	-1.54	-1.57
	Experimental	387.2	530.0	61.22	61.68	-.16	-.08	-2.44	-2.55
SMBTH	Control	425.1	467.4	51.08	52.26	-.47	-.20	-2.00	-2.20
	Experimental	425.6	548.5	50.54	51.54	-.34	-.22	-2.01	-2.20

Table 3 gives us a summary of the average values of the control and experimental group on the basic statistical parameters of the variables of segmental speed and explosive strength of the lower and upper extremities in the initial and final measurements. It is seen that there are significant differences between groups in different measurement situations for all these variables. There are also differences between the mean values of the same group compared to the initial and final measurements. According to the values of the standard deviation as the main dispersive indicator, it can be concluded that the variables foot tapping (FT), hand tapping (HT) and vertical jump (VJ) in the initial and final measurements are normally and symmetrically distributed and it is a question of homogeneous results, while the variables standing long jump (SLJ), medicine ball chest throw (MBChTh) and seated medicine ball throw (SMBTh) in the initial and final measurements are at a higher level, which shows that the discriminability is great and it is about results which are heterogeneous, respectively results far from the arithmetic mean. The asymmetry of the curve (skewnees) is small for almost all variables, and for some even with negative values. The value of the roundness of the curve (Kurtosis) for most variables is below 2.75, so that all these values are platykurtic, which means that the results are distributed from the arithmetic mean, except for the manual tapping variable where we have a value above 2.75 and that only in the final measurements of the experimental group, which means that this value is of a mesokurtic character, results concentrated around the average values.

Table 4. Univariate analysis of variance (ANOVA) on the variables of segmental velocity and explosive strength of the lower and upper extremities between the control and experimental groups at initial measurements

Variables	Group	Mean IT	F	Q (Sig.)
FT	Control	23.0	.0534	.8172
	Experimental	23.1		
HT	Control	34.3	.0003	.9841
	Experimental	34.3		
SLJ	Control	194.8	.1654	.6845
	Experimental	196.4		
VJ	Control	32.0	.0000	.9935
	Experimental	32.0		
MBCHTH	Control	384.2	.1398	.7088
	Experimental	387.2		
SMBTH	Control	425.1	.0064	.3615
	Experimental	425.6		

By inspection of Table 4, we have shown the results of the univariate analysis of variance (ANOVA) on the variables of segmental velocity and explosive strength of the lower and upper extremities, between the experimental and control group, at the initial measurements. From the overview of the average arithmetic values, for each indicator individually, it can be observed that there are no significant statistical differences between the experimental and control groups in the variables of segmental speed and explosive strength of the lower and upper extremities, in the initial measurements.

Table 5. Univariate analysis of covariance (ANCOVA) on the variables of segmental speed and explosive strength of the lower and upper extremities between the control and experimental groups in the final measurements with neutralization of the differences with the initial measurements

Variables	Group	Mean		F	Q (Sig.)
		IT	FT		
FT	Control	23.0	26.9	.002	.623
	Experimental	23.1	26.9		
HT	Control	34.3	39.8	.002	.642
	Experimental	34.3	39.9		
SLJ	Control	194.8	225.3	.004	.047*
	Experimental	196.4	266.5		
VJ	Control	32.0	37.0	.005	.019*
	Experimental	32.0	49.9		
MBCHTH	Control	384.2	426.4	.085	.026*
	Experimental	387.2	530.0		
SMBTH	Control	425.1	467.4	.026	.0.38*
	Eksperimental	425.6	548.5		

From the description of table 5, we have shown the results of the univariate analysis of covariance (ANCOVA), between the experimental group and the control in the final measurements with partialization and neutralization of the differences of the average values from the initial measurements, it can be observed that significant statistical differences ($Q < .05$) we have only in the variables of the explosive strength of the lower and upper extremities, also in all the tests in favor of the experimental group, while there are no significant statistical differences in the segmental speed variables. The differences are in the variables: vertical jump (VJ) (.019), medicine ball chest throw (MBCHTH) (.026), seated medicine ball throw (SMBTH) (.038) and standing long jump (SLJ) (.047). From this we can conclude that the 12-week experimental program causes a quantitative improvement with statistical significance in the development of the explosive strength performance of the lower and upper extremities in the subjects of the experimental group in the final measurements.

4. Discussion

In this study, the main goal is to validate the influence of the experimental training model on the segmental speed and explosive strength of the lower and upper extremities in adolescents. From the examination of the results in the initial measurements, in both research subjects, the control and the experimental, it was proven that in the tests which represent the abilities of segmental speed and explosive strength, there are no significant statistical differences in any motor test. After the implementation of the experimental training model, which model lasted for 12 weeks and underwent only the experimental group, from the examination of the final measurements, it was proved that there are no statistically significant differences in the segmental speed skills, while in the explosive strength skills of the extremities of bottom and top there are significant statistical differences in all researched variables, where the obtained results were in favor of the experimental group compared to the control group. It should be noted that the vertical jump (VJ) had a significant improvement between the initial measurement and after the final measurement in the experimental group (EG), it was evident that the result in favor of the experimental group (EG) came as a result of following the program of experimental training, while it is noted that the control group (CG) in the final measurements have shown poorer results, some authors have also found the same improvements in their published studies (Qaili & Iseni, 2020), (Shaikh & Mondal, 2012), (Asadi, 2012). Likewise, even in the medicine ball chest throw (MBCHTH), differences between the initial measurements and after the implementation of the experiment between the groups have been proven at the $p < 0.05$ level. The results were in favor of the experimental group (EG), which means that following the experimental program has a positive impact on improving the explosive strength of the upper extremities in adolescents. Our results agree with the most important results identified by previous studies that highlighted the influence of experimental training on the development of explosive strength parameters in the upper extremity (Jakoljevic, 2013), (Chelly et al., 2010, 2014), (Vossen et al., 2000). Low but significant differences between the initial measurements and after the final measurements between the control group (CG) and the experimental group (EG) with a reliability level of $p>0.05$ were also expressed in the variable seated medicine ball throw (SMBTH). Emphasizing that seated medicine ball throw (SMBTH) had a significant improvement between the initial measurements and the final measurements in favor of the experimental group (EG), a difference which came as a result of the 12-week follow-up of the experimental training program. Also, many authors have found the same improvements in their published research (Salameh, 2020), (Savithiri & Kumaresun, 2016), (Marques et al., 2012). Also in the standing long jump test (SLJ), differences between the initial measurements and after the implementation of the experimental program between the groups have been proven at the $p<0.05$ level of reliability. The results were in favor of the experimental group (EG), which means that following the experimental program has a positive impact on the improvement of the explosive strength of the lower extremity in adolescents. These results are consistent with many other results identified in previous research that highlighted the impact of the experimental program on the development of explosive strength parameters of the lower extremities (Kryeziu et al., 2023), (Laurent et al., 2020), (Ramirez -delaCruz et al., 2022). Since this model of the experimental training program did not affect the improvement of the segmental speed tests, in future research we plan to incorporate other specific exercises into the program that will also develop these motor skills in adolescents, which does not prove the first hypothesis. whereas this experimental program significantly developed the explosive strength of the lower and upper extremities, which fully proves the

second hypothesis. Also, the inclusion of some biomechanical analysis on the segmental velocity and explosive strength of the lower and upper limbs would be beneficial to the impact of the experimental program on adolescents and athletes.

5. Conclusion

The 12-week experimental training program to improve the performance of segmental speed and explosive strength of the lower and upper extremities has positively influenced the improvement of almost all the tests presented in this study, more specifically it has improved the results of the experimental group in the final measurements . If we look at our achievements or findings in this study, we can conclude that like the control group as well as the experimental group showed a small increase in the segmental speed results, while the explosive strength results showed a significant increase in relation to the initial and final measurements. Tests of explosive strength of the lower and upper extremities between the control and experimental groups have shown distinct values between them. The significant differences were in both groups at the reliability level ($p<0.05$), in favor of the experimental group. The most pronounced difference was observed in the spot jump test with a reliability of 0.019, then in the medicine ball chest throw test with a reliability of 0.026, also a significant difference in the seated medicine ball throw test with a reliability of 0.038 and in the standing long jump test we have a value difference of 0.047. These findings show that the 12-week experimental training model improves lower and upper extremity explosive strength indices in adolescents. Sports coaches and educators can safely use appropriate experimental programs to improve lower and upper extremity explosive strength skills to develop general levels of athleticism in 15-16 year olds.

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