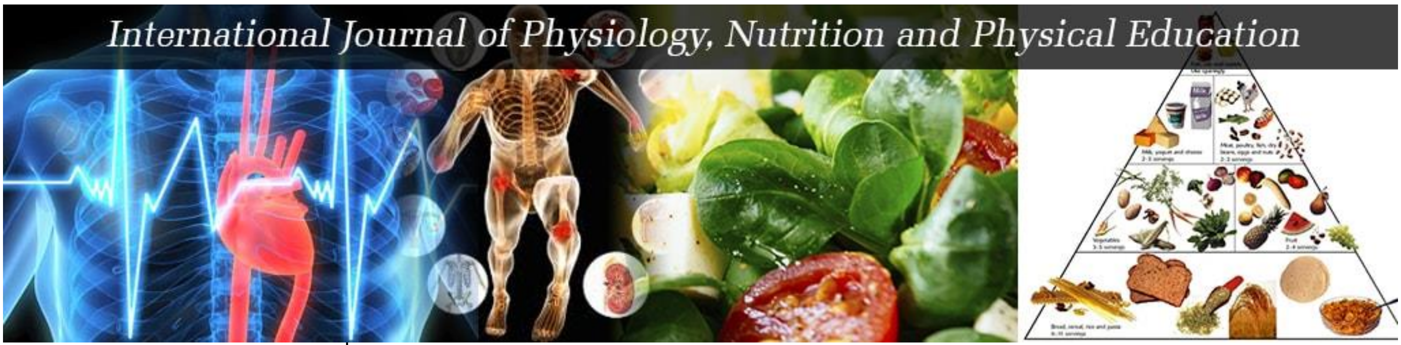

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Influence of strength and plyometric program on accleration speed in 14-15 years old hockey players at 5 m distance on-ice and off-ice

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Abstract
The aim of our study was to find out the effect of strength and plyometric excercises using acceleration speed on-ice and off-ice at a distance of 5 meters in ice hockey players during the regular season. The research set consisted of 33 players (Male; age: 14.7 ± 0.7; height: 166.5cm ± 7.3; weight: 53.4kg ± 6.9) divided into two grup. Experimental group (n=18) and control group (n=15). During 8 weeks, the players in experimental group performed 4-5 training units on-ice, two training units off-ice, one match and +2 extra strength and plyometric units off-ice from 20 to 30 minutes before training units on-ice. Players from control group performed the same training units without +2 extra strength and plyometrical units off-ice from 20 to 30 minutes before training units on ice. Speed diagnostics consisted of the following one tests on-ice and one tests off-ice. We used two-way ANOVA and effect size theory to process the statistical data. The results show that between Pretest1 and Posttest1 in the experimental group, an effect size was demonstrated in tests 5 on-ice (d = 0.53) medium. Between Pretest1 and Posttest2 in the experimental set, the effect size was (d = 0.38) small. Off-ice test in experimental group shows small effect size (d = 0.25) between Pretest1 and Postest1 and deterioration between Pretest1 and Postest2. Results in control group on-ice shows that between Pretest1 and Postest1 effect size is (d = 0) trivial (stagnation) and between Pretest1 and Postest2 deterioration. Off-ice test in control group shows small effect size (d = 0.26) between pretest1 and Postest1 and deterioration between Pretest1 and Postest2. The results of the quasi-experiment showed that the influence of strength and plyometric exercises on the improvement of the level of running and skating speed of the players of the experimental group was proven.

Keywords: plyometric excercise, strength excercise, acceleration speed, ice hockey

Introduction
Ice hockey tests the player's strength, speed and, last but not least, coordination. Authors such as Tóth, *et al.* (2010) [20], Skahan (2016) [19] and others agree that ice hockey is faster from year to year. Tóth, *et al.* (2010) [20] argue that skills, which are closely related to dynamics and strength, are currently considered to be the most important factors in the performance of a modern hockey player. Perič and Dovalil (2010) [16], Boyl (2016) [1], Owen and Della (2016) [15], Jebavý and Hojka (2017) [10] characterize speed skills as the ability to perform activities with maximum intensity to develop the maximum possible speed in the shortest possible time with a movement activity of up to 20 seconds. Training speed, dynamics and strength are essential in the development of a hockey player. Terry and Goodman (2020) argued that the speed of skating depends on the speed and strength of the thigh, lumbar and calf muscle groups, which is confirmed by the fact that skilled skaters are always overdeveloped in these parts. Although ice hockey is most often associated with speed, dynamics and strength, one can easily forget about flexibility and mobility. If a player wants to achieve the highest possible performance for as long as possible, he must train in various ways. Hansen and Kennelly (2017) [5] say that the plyometric method is based on the principle of stretching and shortening. At present, plyometric is widespread and used in almost all sports. Authors such as Lockwood and Brophey (2008) [12], Haukali and Tjelta (2015) [6], Deahlin, *et al.* (2017) [4] examined plyometric in direct relation to the speed of skating. Chu (1998) [9] argues that

puberty is the fastest growing period, and therefore the best time to develop speed-strength skills in ice hockey players. We decide to focus on hockey players aged 14-15 for our research. This was based on the above research and mainly because Slovak players in the U15-U18 categories lag behind advanced hockey countries such as the USA or Canada. Also important in ice hockey, is the rate of speed one can skate as many times the result of the match is decided by hundreds of a second.

Methods

For the research, we chose a field two-group time-parallel model of the quasi-experiment type, in which it was not possible to randomly assign the monitored objects to individual experimental conditions. Two sets of ice hockey players already existed before the experiment was set up, so they are a type of experiment of so-called unequal groups requiring a pretest and a posttest of the experimental and control groups. The experimental grup (n=18) performed plyometric excercices for 8 weeks in addition to a regular training program including special and general training units. The control group (n=15) performed a regular training program without an experimental factor of plyometric excercices followed in the experimental group, which we wanted to monitor the long-term effect of strength and plyometric excercises. The experimental and control groups were tested 3 times. Testing consisted of input measurements, output measurements and post-experimental measurements in both groups. The whole experiment was performed during the competition period from September 2019 to January 2020.

Participants

A total of 33 ice hockey players aged 14-15 years players (Male; age: 14.7 ± 0.7; height: 166.5cm ± 7.3; weight: 53.4kg ± 6.9) were involved in the research, divided into two groups, the control group (KO) consisted of players of the Martin team (n=15) and the experimental group (EXP) were formed by the players of the Banská Bystrica team (n=18). Both teams play the highest cadet competition in Slovakia.

Table 1: Basic statistical characteristics of the experimental and control set

Variables/Groups	Experimental (*n* = 18)				Control (*n* = 15)				*d*	ES
	M	SD	Min.	Max.	M	SD	Min.	Max.		
Age (years)	14.8	0.6	14.2	15.4	14.6	0.8	14.1	15.4	0.28	small
Height (cm)	165.0	8.0	156	173	168.0	6.5	158	175	0.41	small
Weight (kg)	52.6	7.2	45	65	54	6.6	48	69	0.20	small
BMI	19.5	2.1	17.4	21.6	19.1	3.5	15.6	22.6	0.14	trivial

Explanation: *n* = number of subjects; M = mean; SD = standard deviation; *d* = effect size index; ES = effect size

Regular training program

During the experimental period, the players of both groups completed training units on dry land and ice. The players in the experimental set completed 5 training units on ice per week for 60 minutes and one match. The players in the control group completed 4 training units on ice per week in range of 75 minutes and one match. The training units of the general training were completed by the players in the experimental and control group 3 times a week in the range of 60 minutes. Training methods on ice were a similar nature in expermiental and control files according to the methodological guideline of SZLH.

Testing protocols

All tests (Pre, Post1 and Post2) were performed in both groups equally. Both test on-ice and off-ice test (5 m sprint) were performed in the morning at the gym. Ice testing (5 m sprint) was performed on the same day in the afternoon at the ice rink. A 15 minute warm-up was performed before each test. The 5 sprint tests were performed in one run/skate. Photocells were used for measurement. In each test, the players had two attempts, the better of the two results being including in the results.

Experimental factor

An experimental factor of plyometric excercises was added to the experimental set, which the players performed twice a week in the range of 30-40 min before the training units on-ice. Experimental stimuls in the form of strength and plyometric excercises in the form of circular training, where subjects completed excercises at 9 stations, each station had 1-2 subjects, performed excercises in three round with a total of 360 different reflections on one training unit on Tuesday and 366 different reflections on the other training on Thursday with a load and rest interval of 1:3. After thorough warming up, the players were deployed in pairs to individual positions. Load and rest interval at the station 1:1. At the trainer's sound signal, the first of the pair performed a given number of repetitions at their stand, then performed the second of the pair's excercises. After completing the practice at each station, the players moved to the next station in a clockwise direction and resumed the excercise at the coach's beep. After completing all nine stations, players had a longer break to regenerate and replenish fluids. This was followed by the second and third rounds with the same load interval at the site and the same rest period between rounds.

Statistical analysis

For each ANOVA calculation, we examined the quality of the model that underlies the analysis of variance. We diagnosed the model in order to make sure that the necessary assumptions of the model are met. We therefore checked the normality of the differences using the Kolmogorov-Smirnov test and the Levene test of homogenity of variance. We used a post hoc test to compare individual groups and test each other. We used multiple comparsions of the Tukey HSD test to confirm that the differences between groups and individual tests are different. We interpreted the effect size according to Cohen (ES; Cohen, 1988; Hopkins, 2002) [3, 7]. When summarizing the data, we used Microsoft Excel software, we processed the statistical data in the statistical program Statistica (version 13.2), or with the use of the statistical calculator Social Science Statistics (https://www.socscistatistics.com/). To assess the differences in mean values, we used the effect size (ES) index d, which can be interpreted according to Cohen (1988) [3] as small (d = 0.20), medium (d = 0.50) or large (d =0.80), Hopkins (2002) [7] uses for values d <0.2 interpretation "trivial". For visualization, we used a box diagram of pairwise comparison of differences in mean values. When using parametric statistical tests, we worked with basic characteristics such as mean, median, standard deviation. We assessed the level of significance of the tests according to the value $p<0.05$. When summarizing the data, we used a Microsoft Excel spreadsheet and processed the statistical data in the statistical program R (Chráska).

Results

Table 2 shows the results of the acceleration velocity tests at 5 on the ice of the experimental and control set and their statistical assessment. Assessment of the significance of differences in mean values (M) between input testing (EXP1), output testing (EXP2) and post-experimental testing (EXP3) of the experimental set, as well as between input testing (KO1), output testing (KO2) and post-experimental testing (KO3) of the control file was performed using the effect size (ES) index *d*.

Table 2: Acceleration speed tests on-ice at 5 m (s)

	Test 5 m on-ice					
EXP (*n*= 18)	M	SD	Min	Max	EXP 2 (*d*)	EXP 3 (*d*)
EXP 1	1.29	0.08	1.14	1.42	0.53*	0.38
EXP 2	1.25	0.07	1.13	1.35		0.13
EXP 3	1.26	0.08	1.12	1.42		
KO (*n* = 15)	M	SD	Min	Max	KO 2 (*d*)	KO 3 (*d*)
KO 1	1.31	0.10	1.15	1.55	0	1.09
KO 2	1.31	0.08	1.18	1.45		0.82
KO 3	1.38	0.09	1.23	1.56		

Notes: EXP = experimental file; KO = control file; n - number of probands; M = mean; SD = standard deviation; Min = minimum value; Max = maximum value; *d* = effect size index (* = medium), (red = deterioration)

Between the results of the input tests between EXP and KO in the 5 m on-ice test (EXP1 x KO1, d = 0.22, small). In the output results between EXP and KO in the 5 m on-ice test (EXP2 x KO2, d = 0.80, large). The results of the output tests between EXP2 and KO2 show that strength and plyometric exercises had a large effect size on the acceleration speed in the 5 m on-ice test, where the EXP player achieved 0.06 s better time than the players in the KO.

In post-experimental testing between EXP and KO in a 5 m on-ice test (EXP3 x KO3, d =1.41, large). From the results of post-experimental testing between EXP3 and KO3, the 5 m on-ice test showed a large foreign effect in favor of EXP, where players achieved 0.12 s better time than players in KO. The positive effect of strength and plyometric exercises on the acceleration speed at a distance of 5 m is also indicated by the fact that the effect size was not only manifested between EXP and KO but also in comparing the test results between EXP1 and EXP2 in test at 5 m medium effect size. In a 5 m on-ice test (EXP1 x EXP2, d = 0.53, medium). However, no effect size was observed in the KO tests at 5 m. In the test 5 m on-ice (KO1 x KO2, d = 0.00, trivial).

Table 3 shows the results of the acceleration velocity tests at 5 m outside the ice of the experimental and control group and their statistical assessment. Assessment of the significance of differences in mean values (M) between input testing (EXP1), output testing (EXP2) and post-experimental testing (EXP3) of the experimental set, as well as between input testing (KO1), output testing (KO2) and post-experimental testing (KO3) of the control file was performed using the effect size (ES) index *d*.

Table 3: Acceleration speed tests off-ice at 5 m (s)

	Test 5 m off-ice					
EXP (*n*= 18)	M	SD	Min	Max	EXP 2 (*d*)	EXP 3 (*d*)
EXP 1	1.23	0.09	1.02	1.42	0.25	1.70
EXP 2	1.21	0.07	1.04	1.34		1.99
EXP 3	1.43	0.14	1.10	1.58		
KO (*n* = 15)	M	SD	Min	Max	KO 2 (*d*)	KO 3 (*d*)
KO 1	1.33	0.11	1.14	1.58	0.10	0.10
KO 2	1.34	0.08	1.18	1.49		0
KO 3	1.34	0.08	1.23	1.50		

Notes: EXP = experimental file; KO = control file; n - number of probands; M = mean; SD = standard deviation; Min = minimum value; Max = maximum value; d = effect size index (* = medium), (red = deterioration)

Between the results of the input tests between EXP and KO in the 5 m off-ice test (EXP 1 x KO1, d = 1.00, large). It is clear from the input tests that it is not appropriate to compare other test results at 5 m off-ice between EXP and KO due to the large difference of input tests, so we will compare test results only between EXP1 - EXP2, EXP2 - EXP3 and EXP1 - EXP3 and also KO1 - KO2, KO2 - KO3 and KO1 - KO3.

In the 5 m off-ice tests, there are between (EXP1 x EXP2, d = 0.25, small), which means a small effect of plyometric exercises on the acceleration speed on the 5 m off-ice. In the post- experimental measurement of Posttest2, the players in EXP deteriorated compared to both Pretest1 and Posttest1, where they gradually reached the following times at the 1st, 2nd and 3rd period (1.23; 1.21; 1.43 s). Players in KO in 5 m off-ice tests deteriorated by 0.01 s between KO1 and KO2 and in the post-experimental measurement of KO3 they reached the same time as in KO2 (1.33; 1.34; 1.34 s).

Discussion

Few authors have addressed the direct effect of plyometric exercises on the acceleration speed of skating. Similar research has been conducted by authors such as Brcko-George (2001) [2], Deahlin, *et al*. (2017) [4] and Novák, *et al*. (2019) [14].

Our 5 m on-ice test results agree with the results of Novák, *et al*. (2019) [14], who worked on research with 14 ice hockey players aged 14.8 during the competition period. He divided the players into two experimental groups. In both groups, in addition to the classic training program, players completed 3 training units for 20-30 minutes focused on agility. In the first group, players performed agility training on the ice twice a week for 4 weeks, followed by a 2-week rest period, followed by a 4-week off-ice agility training. In the second group, the program was performed in reverse, 4 weeks of agility training off -ice, two weeks of rest and 4 weeks of agility training on the ice. The tests consisted of an accelerating skating speed of 6.10 meters, a skating speed of 35 meters, a S corner test, a braking test, a weave agility test and a reaction test. His result of the skating test at 6.10 m coincide with our result of the skating test at 5 m, where in the positive effects of plyometric exercises were proven.

Our test results for 5 off-ice do not match the results of similar research by Singh, *et al*. (2018) [18] who investigated the effect of a 6-week program of vertical plyometric exercises on acceleration running speed and running speed with changes of direction in 17 elite ice hockey players. The players completed plyometric training with a small volume twice a week. In the first group (n = 8) the players completed various types of jumps and jumps from lower to higher box (low to high drop) and in the second group (n = 9) the players completed various types of jumps and jumps from higher to lower box (high to low drop). In both groups, the players completed 5 series of 4 repetitions. The sprint was tested at a distance of 10 and 20 meters and the 505 agility test. The exercises were performed in a small volume because it was a complementary exercise to their individual plans. The results show that the respondents in the high to low group achieved more favorable effects, where there was an improvement in all three tests, but a statistically significant difference was confirmed only in the 10-meter sprint test. In the low to high group, there was an improvement in the 10 meter sprint tests and the 505 agility test.

Conclusion

Based on the results of our quasi-experiment, it was proven that the training protocol of strength and plyometric exercises lasting 8 weeks and performing twice a week for 30-40 min in EXP, always before the training unit on ice, had a positive effect on acceleration speed. EXP players achieved better results on the ice in final and post-experimental tests compared to KO players. In off-ice tests, only a small effect of plyometric exercises on the acceleration speed was shown in the output tests at 5 m in EXP. In post-experimental measurements, there has even been a deterioration. The results indicated a positive effect of the experiment on the acceleration speed on-ice in a longer duration, during the experiment and in the post-experimental period. The acceleration speed off the ice improved only during the experiment, whereas during the post-experimental period its level decreased.

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