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**Original Article**

# Effects of combined explosive, plyometric, and sprint training on the physical fitness of soccer players

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**Abstract**
This study aimed at investigating the efficacy of a 6-week combined plyometric and speed training program focusing on developing the speed-strength abilities of U14 soccer players. The study was conducted under the conditions of a two-group parallel experiment. Experimental groups I. and II. (EG I. and II.) consisted of youth soccer players (n = 20 and 18) in the top German and Slovak leagues, respectively. To obtain data, we performed 6 tests: squat jump (SJ), countermovement jump (CMJ), drop jump (DJ), 10-m sprint test, 20-m sprint test, and 505 agility test. EG I. players completed a 6-week experimental period, including two training sessions per week using plyometrics and short sprints, while EG II. players underwent the same experimental period without plyometrics and short sprints. Both groups completed an identical training program to develop their speed skills. Compared to the results of the EG II. group, the values of all tests were significantly more increased in the EG I. group: the SJ ($p < 0.00001$), CMJ ($p < 0.00001$), DJ ($p < 0.00001$), 10-m sprint test ($p = 0.00122$), 20-m sprint test ($p = 0.00027$), and 505 agility test ($p = 0.00062$). The results of the combined plyometric and speed program demonstrated higher efficacy in developing selected speed and strength parameters compared to the speed program without strength training. In summary, our study showed the necessity of using plyometric and sprint drills alongside game-specific training in soccer.
**Key words**: **soccer training, testing, repeated sprint ability, physical performance**

## Introduction

The intensification of training and competition load has diametrically changed the load of soccer players. Nowadays, many authors (Dolci et al. 2020; Hands & Janse de Jonge 2020; Reynolds et al. 2021; Hulton et al. 2022) consider soccer to be an intermittent activity in which low to high intensity activities alternate, with high intensity activities requiring high level of explosive power and speed skills produced by the neuromuscular system. The match load includes many maximal and high-intensity movement activities such as jumps, changes in running direction and pace, sprints (Benítez-Jiménez et al. 2020; Dolci et al. 2020; Gómez-Álvarez et al. 2020; Hands & Janse de Jonge 2020; Reynolds et al. 2021; Hulton et al. 2022). The ability to repeat these high-intensity activities with as little decrease in intensity as possible during the match becomes a limiting factor in the fitness of players in a match as well (Tvrdý et al. 2022). Players' physical activities require a high level of explosive power of lower extremity, which should be reflected in the training programs of soccer players. Although specific soccer training includes many direction changes, jumps, linear and repetitive sprints, it does not seem to be able to independently improve the above mentioned abilities (Marques et al. 2013; Hermassi et al. 2014; Ramírez-Campillo et al. 2015; Hammami et al. 2016; Zhgal et al. 2019; Drouzas et al. 2020; Karahan 2020; Cherni et al. 2021; Nayiroglu et al. 2022; Ouertatani et al. 2022; Tvrdý et al. 2022; Brini et al. 2023; Daryanoosh et al. 2023).

Several studies (McMaster et al. 2014; Dello Iacono et al. 2016; Asadi et al. 2016; Drouzas et al. 2020; Cherni et al. 2021; Palma-Munoz et al. 2021) have shown that plyometrics has a positive effect on the development of speed skills. However, according to a meta-analysis by Rumpf et al. (2016), the specific development of speed skills (free sprint, resistance sprint, supramaximal sprint) is more efficient when compared to the non-specific development of speed abilities (plyometrics, resistance training). The potential benefits of both training programs (plyometric and speed training) have been researched by many authors (Marques et al. 2013; Asadi et al. 2016; Hammami et al. 2016; Beato et al. 2018; Michailidis et al. 2019; Kargarfard et al. 2020; Brini et al. 2023; Michailidis et al. 2023), noting greater effectiveness in the development of speed skills and explosive power in combined programs compared to the isolated use of these programs, or compared to game-


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based training. Based on these results, we wanted to verify the effect of a combined (plyometric and speed) and isolated speed training program on the development of speed-strength abilities of U14 soccer players.

## Materials and Methods

*Participants*

The experimental group consisted of elite youth soccer players (n = 37) in the U14 category. The experimental group I. (EG I.) consisted of youth soccer players (n = 20; age = 13.87 ±0.34 years; body height = 159.3 ±4.29 cm; body weight = 56.07 ±5.53 kg) of the top German league. The experimental group II. (EG II.) consisted of youth football players (n = 17; age = 13.82 ±0.44 years; body height = 158.41 ±6.24 cm; body weight = 54.20 ±6.18 kg) of the top Slovak league. Goalkeepers were not involved in this experiment.

*Procedures*

The research was conducted as a two-group parallel experiment. The aim of the research was to study and compare the effectiveness of a 6-week combined (plyometric and speed) training program and an isolated speed training program on the development of speed-strength ability level. The EG I. applied a combined training program and the EG II. employed an isolated speed program. The dynamics of changes in the level of selected strength and speed abilities during the experiment was determined by motor tests, which players performed in the order indicated (SJ, CMJ, DJ, 10-m sprint test, 20-m sprint test, 505 agility test) on an artificial turf field during one day. After the initial testing, the EG I. completed the combined experimental factor (Table 3. and 4.) and game specific trainings (4 times per week). The EG II. completed the same speed training program (Table 3.) and the same amount of game specific training (4 times per week). Each training session was supervised by a qualified fitness coach. We hypothesized that the use of a combined training program (EG I.) would be more effective for the development of speed-strength skills compared to an isolated sprint program (EG II.).

**Table 1.** Special training indicators in the EG I. and EG II.

| Special training indicators | Number [min / %] | | Difference |
|---|---|---|---|
| | Experimental group I. | Experimental period II. | |
| Specific (game) training | 1450 / 73 % | 1585 / 80 % | -135 |
| Non-specific (conditioning training) | 530 / 27 % | 395 / 20 % | 135 |
| Speed | 100 | 90 | 0 |
| Strenght and Power | 300 | 155 | 145 |
| Endurance | 0 | 0 | 0 |
| Coordination | 130 | 150 | -10 |

**Table 2.** Speed and strenght/power training indicators in the EG I. and EG II.

| Condition training indicators | Distance [m] | | Difference |
|---|---|---|---|
| | Experimental group I. | Experimental period II. | |
| Speed | Distance [m] | Distance [m] | |
| Change of direction | 600 | 600 | 0 |
| Acceleration | 1230 | 600 | 630 |
| Strenght a power | Repeats [n] | Repeats [n] | |
| Horizontal jump | 660 | - | 660 |
| Vertical jump | 1030 | - | 1030 |
| Resistence sprint [m] | 240 | - | 240 |
| Own weight excercise | - | 740 | 740 |
| Resistance excercise | - | 140 | 140 |

**Table 3.** Volume characteristics of speed training in both groups

| Speed training program | | | |
|---|---|---|---|
| Excercise/Seasson | 1. | 2. | 3. |
| Sprint from a standing position (20 m) | 1 x 5 | 1 x 5 | 1 x 5 |
| Flying sprint (10 + 20 m) | 1 x 5 | 1 x 5 | 1 x 5 |
| Excercise/Seasson | 4. | 5. | 6. |
| Sprint 2 x 10 m (COD 90°) | 1 x 5 | 1 x 5 | 1 x 5 |
| Sprint 2 x 10 m (COD 180°) | 1 x 5 | 1 x 5 | 1 x 5 |

**Table 4.** Volume characteristics of the experimental agent I. (EG I.)

| Plyometric training program | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Excercise/Seasson** | **1.** | **2.** | | **3.** | **4.** | | **5.** | **6.** |
| Squad jump | 4 x 8 | 4 x 10 | Horizontal jump | 4 x 10 | 4 x 12 | Countermovement jump | 4 x 10 | - |
| | | | 2-leg jump (20 cm hurdle) | 4 x 10 | 4 x 12 | Ankle jump | 4 x 10 | - |
| | | | Horizontal one leg jump | 4 x 10 | - | Horizontal one leg jump | | - |
| Countermovement jump | 4 x 8 | 4 x 10 | 2- leg lateral jump | - | 4 x 12 | 2- leg lateral jump | 4 x 10 | - |
| | | | One leg jumg (10 cm hurdle) | 4 x 10 | - | 2-leg jump (20 cm hurdle with between jump) | 4 x 10 | 4 x 10 |
| Horizontal jump | 4 x 8 | 4 x 10 | | | | 2-leg plyometic jump (20 cm hurdle) | - | 4 x 10 |
| Horizontal one leg jump | 4 x 8 | 4 x 10 | Lateral one leg jump | | 4 x 12 | One leg lateral plyometric jump | - | 4 x 10 |
| | | | | | | Power skips | - | 4 x 10 |
| **Excercise/Seasson** | **7.** | **8.** | | **9.** | **10.** | | **11.** | **12.** |
| Split jumps | 4 x 10 | - | Ankle jump + 10 m sprint | 5 x 6 | 6 x 6 | 3 m acceleration + Bounding | 6 x 10 | 6 x 12 |
| ankle jump | 4 x 10 | - | | | | | | |
| 2-leg plyometic jump (20 cm hurdle) | 4 x 10 | 4 x 10 | 2-leg plyometic jump (20 cm hurdle) + 10 m sprint | 5 x 6 | 6 x 6 | Resistance band run (10 m) + 10 m sprint | 6 | 6 |
| 2-leg plyometic lateral jump (20 cm hurdle) | 4 x 10 | 4 x 10 | | | | | | |
| One leg lateral plyometric jump | - | 4 x 10 | | | | | | |
| One leg jumg (10 cm hurdle) | | 4 x 10 | 2-leg plyometic lateral jump (20 cm hurdle] + 10 m sprint | 5 x 6 | 6 x 6 | Sled push (10 m, 10 % weith) + 10 m sprint | 6 | 6 |
| One leg lateral plyometric jump | 4 x 10 | - | | | | | | |
| Power skips | - | 4 x 10 | | | | | | |

*Statistical analysis*

We used the Shapiro-Wilk test to determine the normality of the data distribution. The t-test for two dependent means was used to compare input and output measurements within each experimental group. The t-test for two independent means and Mann-Whitney U-test were used to compare increases in values between experimental groups. The statistical significance level was set at $p < 0.05$.

**Results**

In the initial measurement, we did not observe any significant differences between the performance of the EG I. and EG II. The EG I. was able to significantly improve in all measured tests after the 6-week intervention: SJ ($p < 0.00001$), CMJ ($p < 0.00001$), DJ ($p < 0.00001$), 10-m sprint test ($p < 0.00001$), 20-m sprint test ($p < 0.00001$), 505 agility test ($p < 0.00001$) (Table 5.). In contrast, although the EG II. was able to improve in 4 tests (SJ, CMJ, 10-m sprint, 505 agility), significant differences were observed only in the 505 agility test. When comparing the performance improvement in individual tests between the groups, the EG I. achieved significantly higher performance values´ increases in all tests compared to the EG II.: SJ ($p < 0.00001$), CMJ ($p < 0.00001$), DJ ($p < 0.00001$), 10-m sprint test ($p = 0.00122$), 20-m sprint test ($p = 0.00027$), 505 agility test ($p = 0.00062$) (Table 5.), demonstrating the higher effectiveness of the training intervention in the EG I. compared to the intervention in the EG II.

**Table 5.** Results of individual measurements in the EG I. and EG II. and their comparison

| Test | Experimental group I. | | | | *p* |
|---|---|---|---|---|---|
| | test ($t_0$) | | re-test ($t_1$) | | |
| | *M* | *SD* | *M* | *SD* | |
| **SJ [cm]** | 32.36 | 4.28 | 34.52 | 4.04 | < 0.00001** |
| **CMJ [cm]** | 32.99 | 5.48 | 35.79 | 4.70 | < 0.00001** |
| **DJ [cm]** | 29.74 | 3.87 | 32.15 | 4.04 | < 0.00001** |
| **10-m sprint [s]** | 1.86 | 0.09 | 1.83 | 0.09 | < 0.00001** |
| **20-m sprint [s]** | 3.30 | 0.17 | 3.26 | 0.16 | < 0.00001** |
| **505 agility [s]** | 2.48 | 0.11 | 2.44 | 0.11 | < 0.00001** |
| **Test** | **Experimental group II.** | | | | ***p*** |
| | test ($t_0$) | | re-test ($t_1$) | | |
| | *M* | *SD* | *M* | *SD* | |
| **SJ [cm]** | 33.52 | 4.48 | 33.63 | 4.53 | 0.19 |
| **CMJ [cm]** | 32.36 | 4.50 | 32.38 | 4.43 | 0.50 |
| **DJ [cm]** | 30.14 | 4.63 | 30.11 | 4.49 | 0.012* |
| **10-m sprint [s]** | 1.94 | 0.06 | 1.93 | 0.06 | 0.11 |
| **20-m sprint [s]** | 3.40 | 0.14 | 3.40 | 0.14 | 0.45 |
| **505 agility [s]** | 2.50 | 0.07 | 2.48 | 0.08 | 0.41 |
| **Test** | **EG I.** | | **EG II.** | | ***p*** |
| | $t_1$-$t_0$ | | $t_1$-$t_0$ | | |
| | *M* | *SD* | *M* | *SD* | |
| **SJ [cm]** | 2.17 | 1.64 | 0.11 | 0.35 | 0.00122** |
| **CMJ [cm]** | 2.81 | 1.67 | 0.01 | 0.36 | 0.00027** |
| **DJ [cm]** | 2.41 | 1.35 | -0.02 | 0.41 | 0.00062** |
| **10-m sprint [s]** | -0.03 | 0.02 | -0.01 | 0.03 | < 0.00001** |
| **20-m sprint [s]** | -0.04 | 0.02 | 0.00 | 0.04 | < 0.00001** |
| **505 agility [s]** | -0.05 | 0.03 | -0.01 | 0.02 | < 0.00001** |

**Discussion**

The results showed that EG I. players recorded significant improvement ($p < 0.00001$) in all the observed speed and speed-strength abilities (SJ, CMJ, DJ, 10-m sprint test, 20-m sprint test, 505 agility test). On the other hand, the EG II. players showed significant improvements due to the influence of the isolated speed program only in the 505 agility test ($p = 0.012$). In all the tests observed, we recorded significant differences in performance increases between the groups, with the EG I. achieving significantly higher increases in all the tests studied compared to the EG II. Vertical jump height (SJ) increased in the EG I. (+6.26%), while we found no significant changes in the EG II. (+0.33%).

The height of CMJ increased in the EG I. (+7.85%), while no significant changes were found in the EG II. (+0.15%). These results are in accordance with those of several studies (Marques et al. 2013; Beato et al. 2018; Makhlouf et al. 2018; Hammami et al. 2019; Michailidis et al. 2019; Aloui et al. 2021), where significant improvements in jump tests (SJ, CMJ) were observed after the application of a combined plyometric and speed training program. An exception is the study by Michailidis et al. (2019) who observed significant improvement in prepubertal soccer players (12 ±0.8 years) after combined training ($p < 0.05$) in the SJ and long jump test compared to the control group, but not in the CMJ and five-jump test (5JT), which may be due to the different methodology (training frequency and volume) as well as the training level of the probands.

To date, there is no known study that has evaluated the change in performance on the DJ test following the application of a combined training program. According to Pedley et al. (2017), the DJ is used to assess and develop reactive strength using the stretch-shortening cycle (SSC). In our study, the height of the DJ increased significantly in the EG I. (+6.75%). However, we found no significant changes in the EG II. (+0.10%). Research by Michailidis et al. (2013) and Ramírez-Campillo et al. (2019) also reached the same results. Billot et al. (2010), Markovic & Mikulic (2010), Michailidis et al. (2013) or Marques et al. (2013) state that these increases occurred on the basis of improvement in neural factors (improved intra- and intermuscular coordination, higher recruitment of motor units, maximization of the ability to exploit the muscle stretching and shortening cycle), which dominate in the initial phases of strength and plyometric training. The results obtained in the jump tests in the EG II. demonstrate that speed training did not provide sufficient stimulus to develop jump performance in any of the tests (SJ, CMJ, DJ), which is in conformity with the findings of Buchheit et al. (2010) and Rey et al. (2017).

Rey et al. (2017 explain this by the lack of speed training specificity, which stimulates predominantly horizontal force, which is not sufficient to improve force production in the vertical direction. In contrast, Markovic et al. (2007) and Chaouachi et al. (2014) reported significant improvement in the CMJ test after 6- and 10-week speed training with direction change - SJ ($p < 0.01$). The difference in results may be due to the training frequency, since in our study the experimental group had speed training only 1 time per week and in the above mentioned studies it was 2-3 times per week. Thus, speed training may lead to improvements in jump performance, according to the training duration, volume and frequency, while further research will be needed to deeply clarify these relationships. In general, the results of our research, as well as most of the results of other research, show that combined training programs lead to more significant improvements in jump parameters compared to the game-based, isolated, training of one movement skill.

The results of the effect of training programs on speed ability showed that the 10m running time decreased significantly in the EG I. (- 1.46%). In the EG II., the running time also decreased (-0.55%), but this was not significant. The 20m running time decreased in the EG I. (-1.25%), while in EG II. the running time remained unchanged compared to the initial measurement. Similar results have been reached by several authors (Marques et al. 2013; Beato et al. 2018; Makhlouf et al. 2018; Hammami et al. 2019; Michailidis et al. 2019; Kargarfard et al. 2020; Aloui et al. 2021), who reported significant improvements in speed performance after the application of a combined training program. Marques et al. (2013) observed an improvement ($p < 0.05$) in the 30-m sprint test and the 15m to 30m fly distance in an age-similar sample after a 6-week combined training program; on the other hand, a non-significant improvement was observed in the 15m sprint distance, which the authors explained by the predominance of vertical jumps in the training program. They refer to the findings of Mann & Murphy (2022), who claims that the vertical force is crucial in sprints from a distance of 10m.

On the other hand, it has been found in the past that the horizontal force is important in the first metres of sprinting (Zatsiorsky et al. 2020). As another reason, the authors stated the low volume of sprints, which was not sufficient to improve acceleration speed to 15 m. Beato et al. (2018) compared combined training with isolated speed training, noting significant improvement in all jump and straight-line speed tests by the combined training group. By speed training, the authors observed improvements only in the long jump and 10-m sprint test. When comparing groups, significant changes were observed only in the long jump test, once again in favor of combined training. Despite the non-significant differences (except for the long jump), the results of this test indicate a higher effectiveness of the combined approach compared to an isolated training.

Another important manifestation of speed in soccer is speed with direction change, which we assessed using the 505 agility test. Running time decreased significantly in the EG I. (-1.65%), as well as in the EG II. (-0.41%). In this test we found higher effectiveness of combined training compared to an isolated speed training too, which is confirmed by the results of other studies (Makhlouf et al. 2018; Michailidis et al. 2019; Hammami et al. 2019; Kargarfard et al. 2020; Aloui et al. 2021). Only Beato et al. (2018) did not observe significant changes measured by the 505 agility test after a 6-week intervention of either the combined or speed protocol. The authors attribute this to the insufficient training volume and the high level of training of probands. In our experiment, the low training frequency adds to the above stated reasons, as in the EG II. probands completed only one speed stimulus per week, while the EG I. has completed two speed stimuli per week for the past 2 weeks, what represents a total of 630 m more speed training. According to a meta-analysis by Rumpf et al. (2016), free sprints together with resistance sprints are the most effective means of developing speed skills, which supports our assumption of insufficient volume or frequency of speed training in our research. Meta-analyses by de Villarreal et al. (2012) and Rumpf et al. (2016) also examined the effect of isolated plyometric training on speed ability levels, with plyometric training having a small to moderate effect across all distances. It had the greatest effect at distances from 0 to 10 m. Another meta-analysis by Asadi et al. (2016) studied the effect of plyometric training on speed with direction change and showed an improvement in speed level with direction change with a medium effect. Thus, our results clearly confirm the higher efficiency of speed skills development using combined plyometric and speed training (EG I.) in comparison with the identical isolated speed training (EG II.).

**Conclusions**

The level of speed and speed-strength abilities are one of the limiting factors for soccer and therefore coaches should be concerned with the effective development of these abilities. Our research has shown that even short-term combined protocols (6-week plyometric and speed training) are effective and offer significant improvement in speed and jump parameters. On the other hand, isolated speed training or game training did not create sufficient stimulus for the development of speed and speed-strength abilities. Not only the significant improvements in speed and jump performance that we found in our research, but also the results of other studies contribute in favor of the use of combined protocols.

Based on our results, we recommend to include 1 plyometric training and 1 speed training per week for at least 6 weeks in the training schedule of U14 soccer players. In terms of plyometric training volume, we recommend using a combination of vertical and horizontal jumps with a total of 128 to 200 jumps in 1 training session. We recommend 200 m of speed training in 1 training session.

For training protocols, we recommend using a system of progressive overload with increasing complexity, volume, or intensity of exercises. As a recommendation for further research, we propose a study design that allows for the same amount of training load in both the combined and isolated speed program to further elucidate the benefits of a combined approach to the development of speed-strength displays (for example adding one more speed stimulus per week). We further recommend to confirm the research results on older top-level probands or on a female sample.

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