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# Effect of Deep Stabilization System Training on the Shot Velocity in Professional Female Handball Players: Cross-sectional Study

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**Abstract**

The muscles of the deep stabilization system (DSS) affect spinal stabilization, and correct muscular coordination as a prerequisite for a centered position of the joints with optimal biomechanics of movement. Its stimulation by special exercises might lead to better performance in sports. The study verifies the effect of an 8-week intervention to activate DSS on the shot speed in a group of 15 adult elite female handball players. 30 participants were distributed to either the Control group (CG) or the Experimental group (EG). The EG involved special blocks with exercises activating DSS included in regular handball training. The CG involved only casual training. Input and output measurements included shot velocity assessment from various positions with a Stalker Sports Radar Gun. Mann-Whitney U-test was utilized for the statistical analysis with a 0.05 level of significance. The experiment showed a significant speed increase for all three tested throws. Speed increased by 3.82% for a one-handed overhead shot from the ground from a distance of 7m (free throw), 2.23% for a one-handed overhead shot from the ground after a run-up from a distance of 9m, and 2.23% for a one-handed overhead shot from a jump from a distance of 9 m by 2.38%. Specific activation exercises of DSS of the spine led to increased shot speed in handball.

***Keywords:*** *Handball, Shot velocity, Deep stabilization system of the spine, performance, core*



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## Introduction

Handball is very popular sport in the Czech Republic. Professional athletes tend to achieve better results and thus bring the game to a higher level, which is also conditioned by increasing performance. In this context, the new research studies that bring updated training methods lead to an increase in sports performance (Fritz et al., 2020, Jiang et al., 2022, Junker and Stöggl, 2019, Nuhmanni, 2022, Takahashi et al., 2019, Reed et al., 2012).

The one-handed overhead shot is most often used in handball during a gradual attack by players in backcourt positions through the opponent's defense. Shooting with a jump above the

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goal area is usually used when ending counterattacks and quick attacks on the opponent's unformed defense. Shooting with a jump above the goal area is most often used by players in the wings position or players in the backcourt position after penetrations of the defense and has the highest percentage of success of all in a gradual attack against the formed defense (Hammami et al. 2021, Martínez-Rodríguez et al., 2021, Risberg et al., 2018, Russomanno et al., 2021, Zmijewski et al., 2020.) One of the essential prerequisites for a successful shot is its high speed, increasing of which can improve the overall team results. Shot speed can be increased by many factors. Wilk et al. (2000) define it as a complex movement scheme that requires flexibility, coordination, muscle strength, synchronization of muscle units involvement, and neuromuscular adaptation. Garcia et al. (2013) state that the shot speed is affected by the shooting technique, spatiotemporal coordination of individual body segments, and muscle strength of the upper and lower limbs. Choutka et al. (1999) and Lemos et al. (2020) include, among other factors, also inborn dispositions, motor abilities, and movement skills. They summarize them as somatic, tactical, technical, fitness, and psychological determinants of sports performance.

The DSS of the spine, or the center of the body, forms the basis for all body movements, and its activation level affects playing skills. That means if the efficiency and strength of the deep stabilizers are increased, the efficiency and speed of body movements will subsequently increase (Coulombe et al., Frizziero et al., 2021, 2017, Hlaing et al., 2021, Kellis et al., 2020). The muscles of the shoulder girdle, flexors and rotators of the trunk, muscles that allow the arm to be raised above the horizontal axis of the shoulder, muscles that are used when moving the arms backward, and the muscles of the forearm and hand for gripping the ball together with the deep stabilizing muscles form the so-called muscle chain consisting of local and global stabilizers (Ammer et al., 2022, Bernacíková, 2010, Kostadinović et al., 2020, Srhoj et al., 2012). The mentioned muscles are one of the prerequisites for a movement pattern based on a kinetic chain, the components of which must work together to achieve proper movement, preventing muscle imbalance or injury (Lin et al., 2022, Manchado et al., 2017, Thurgood and Paternoster, 2014, Szczygieł et al. 2018). One factor that influences the functioning of this kinetic chain during shooting is the muscles of the DSS of the spine. Besides others, they include, the trunk and pelvic muscles, which are responsible for maintaining the stability of the spine and pelvis while helping to generate and transfer energy from the significant parts of the body to the small ones. Stability of the center of the body (so-called postural stability) is the ability of the human body to ideally distribute and control the forces acting on the skeleton not only during static standing but also during movement activities, with the help of movement and muscle tension of agonists and antagonists of the muscles of the trunk, pelvis, and lower limbs, and thereby ensuring stability even in complex movement activities, such as shooting in handball (Lin et al., 2022, Kibler et al., 2006, Rivera, 2016).

Scientific discussion on the effectiveness of activation exercises, i.e., exercises to strengthen the body center, for individual and group performance is still open (Belli et al., 2022, Esteban-García et al., 2021, Ozmen et al., 2016, Jiang et al. 2022, Kabadayı et al., 2022, Reed et al., 2012). In handball sport, Saeterbakken et al. (2011) discovered the positive effect of a six-week intervention, a targeted activation exercise, introduced twice a week to the training units of junior handball players. Further, for example, Manchado et al. (2017) observed the effect of a 10-week intervention on shot speed in handball among adult amateur players. The measurement was performed from three different positions, while the greatest improvement was recorded in the penalty throw. Other researchers verified the effect of muscle-strengthening exercises in the lumbopelvic area in adult soccer players (Stray-Pedersen, 2002) and the effect of specific strength training on the speed of the tee shot in junior golf players. (Seiler et al., 2006).

The aim of the research was to determine the effect of activation of the DSS of the spine on the shot speed in professional female handball players. In addition, we tried to verify the assumption that the experimental group will have a higher average velocity measured of all three shots in the output measurement than the control group.

## Materials and Methods

*Participants*

The research study included 30 professional female handball players who regularly participated in the top Czech-Slovak competitions with an average age of 18.7 ± 2 years and an average time of active handball playing of 12 ± 3 years. The group's average weight was 64.2 kg ± 6 kg, and the average height 166.9 cm ± 9 cm. Before participating in the research, we obtained written informed consent from each tested person. Information about each player's medical history, age, BMI, training characteristics, injury history, experience with handball team, and performance level was recorded by personal interviews. Data on height and weight were recorded by calibrated instruments. The participants were included based on the following criteria: DSS insufficiency confirmed by clinical assessment of postural stability based on Kolar (2009). Injury-free status and experience in a handball team at a professional level for at least eight years. Participants were randomly distributed into two groups - 15 female players in the control group and 15 in the experimental group. Table 1 reports baseline comparisons (Mean±Standard deviation) of both groups.

**Table 1.** Baseline Characteristics

| Characteristic | Experimental Group | Control Group | Sig. (p-Value) |
|---|---|---|---|
| N | 15 | 15 | - |
| Height [cm] | 170±4.94 | 163.93±4.35 | 0.11 |
| Weight [kg] | 65.40±5.82 | 63.48±4.83 | 0.33 |
| BMI | 22.65±1.56 | 23.64±1.80 | 0.12 |

The teams were in the phase of the competition. The players regularly practiced 10 hours a week and played 1 championship match on the weekend. Apart from handball, all players do not intensively participate in any other physical activity. Therefore, the research was conducted during the competition period, when the training units are not dominantly focused on developing movement skills.


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*Assessment*

All the tested players had an organized warm-up exercises 15 minutes before the start of shot speed measurements. The warm-up included running with inserted activities, dynamic stretching, and throws with the shooting arm at sub-maximal intensity. Shot velocity was subsequently measured from three different positions and distances: a one-handed overhead shot from the ground from a distance of 7 m (7 m throw or penalty throw), a one-handed overhead shot from the ground after a run-up from a distance of 9 m, a one-handed overhead shot from a jump from a distance of 9 m. Finally, the shooting was carried out into an empty handball goal without the goalkeeper. The Stalker Sports Radar Gun Pro II radar gun with an accuracy of ± 0.1 km/h to measure the speed of the shot was utilized. The radar gun, operated manually, was placed behind the handball gate in its center at a height of 170 cm. The participants were instructed to shoot the ball with the maximum possible force and speed from the given position and aim the ball directly at the radar gun. Each player had 3 attempts with 1 minute of passive rest in between attempts. The one with the highest measured speed was recorded. Shot velocity testing was initiated one week prior to the indication for intervention and a week after its completion. The players were always informed about the measured values after each attempt. An official IHF ball was used for all shots, and the use of handball glue was allowed. The output measurement was carried out under the same conditions and with the same rules. All the obtained output data were recorded in the recording sheets during the measurement.

*Training plan - intervention*

The special training plan was aimed at the DSS of the spine activation under the experienced physiotherapist's supervision. Its creation was primarily based on Thurgood and Paternoster (2014) and our own experience. We created several blocks of exercises, which were implemented in the experimental group during handball training, always after the initial warm-up, for a period of 8 weeks, always twice a week. Each of these individual blocks contained 7 exercises that focused on improving the function of the kinetic chain of movement involved in throwing, so we assumed that in the center of the body, the most important for handball is an isometric and rotational movement, followed by flexion, extension, and complex movements, in a closed kinematic chain.

The training plan designed for the experimental group was divided into 3 levels. It was characterized by progressive loading, where with each level of exercise, there was an increase in the volume and intensity of the load, as well as an overall transition from simple exercises to more complex and demanding ones. The first level of exercise took place for 2 weeks and contained 4 exercise blocks. This level consisted of basic exercises that should have been mastered before moving on to the intermediate or advanced level. Each of these exercise blocks lasted for 15 minutes. The second level of exercises lasted for 3 weeks and included 6 blocks of exercises, and intermediate-level exercises were included. These exercises followed the basic exercises, but instability, movement, weight, and strength were added to engage the DSS more and increase effectiveness. The individual blocks of the second level lasted 20 minutes each. Finally, the third level of exercise took place, like the previous level, for 3 weeks, and it contained 6 blocks of exercises. Advanced-level exercises, which included complex and challenging movements, were included. Proper execution of the exercises required strength, stability, and mobility of the deep stabilization muscles. Special training blocks lasted 25 minutes.

*Statistical analysis*

The Shapiro-Whilk normality test was performed to identify data distributions, and in only one case, the input data did not correspond to a normal distribution. Due to this fact, we further used the non-parametric Mann-Whitney U-test. The level of statistical significance was chosen for the tests at 5%, and we also determined a substantive significance.

## Results

The input and output measurement results from three shooting positions are recorded in Tables 2-4. The differences between the input and output measurements can be observed in both groups. The most significant improvement in shot velocity on average was recorded in the experimental group in the one-handed overhead shot from the ground from a 7 m distance (7 meters or penalty throw) of 3.82%, the second most significant improvement of 2.38% on average was measured in the one-handed overhead shot from a jump from a 9 m distance, the smallest average improvement was measured in the one-handed overhead shot from the ground after a run-up from a distance of 9 m, i.e., 55 by 2.23%. No improvement was observed in the control group. The complete results of both measurements for individual players are displayed in the Table 2, Table 3, and Table 4.

**Table 2.** One-handed overhead shooting from the ground from a 7 m distance (penalty throw)

| | Experimental group | | | Control group | | |
|---|---|---|---|---|---|---|
| Measurement | Input [km/h] | Output [km/h] | Difference [%] | Input [km/h] | Output [km/h] | Difference [%] |
| M | 69.77 | 72.43 | 3.82 | 65.51 | 65.29 | -0.34 |
| SD | 3.67 | 3.48 | 1.11 | 3.45 | 3.56 | 0.66 |
| Variance | 13.47 | 14.76 | 1.23 | 11.92 | 12.64 | 0.44 |

M – mean average , SD – Standard deviation

**Table 3.** One-handed overhead shooting from the ground after a run-up from a distance of 9 m

| | Experimental group | | | Control group | | |
|---|---|---|---|---|---|---|
| Measurement | Input [km/h] | Output [km/h] | Difference [%] | Input [km/h] | Output [km/h] | Difference [%] |
| M | 71.77 | 73.34 | 2.23 | 67.83 | 67.77 | -0.1 |
| SD | 3.87 | 3.47 | 1.43 | 2.74 | 2.96 | 0.94 |
| Variance | 14.97 | 12.07 | 2.04 | 7.5 | 8.77 | 0.88 |

M – mean average , SD – Standard deviation

**Table 4.** One-handed overhead shooting from a jump from a distance of 9 m

| | Experimental group | | | Control group | | |
|---|---|---|---|---|---|---|
| Measurement | Input [km/h] | Output [km/h] | Difference [%] | Input [km/h] | Output [km/h] | Difference [%] |
| M | 72.55 | 74.29 | 2.38 | 67.29 | 67.31 | 0.03 |
| SD | 3.27 | 3.55 | 0.99 | 2.85 | 2.89 | 0.57 |
| Variance | 10.7 | 12.59 | 0.98 | 8.11 | 8.38 | 0.33 |

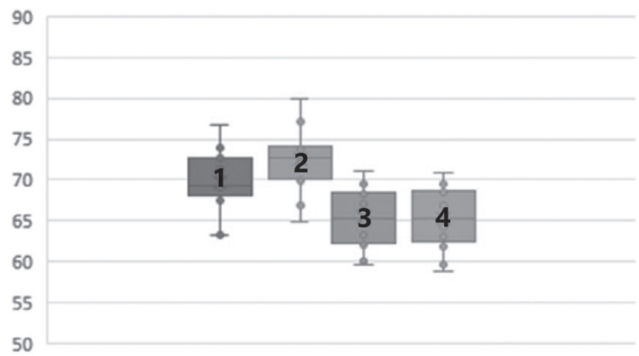
M – mean average , SD – Standard deviation

Based on the initial survey of the data, it can be concluded that the training was successful in all three tested cases. As a measure of improvement, we took the difference between the input and output measurements relative to the output according to the formula: the improvement measure is equal to the output measurement minus the input measurement minus the output measurement. Overall, according to the measured data, there was an average increase in the velocity of the shots by 2.81% in the experimental group and a slight deterioration by -0.14% in the control group, as reported in Table 5.

**Table 5.** Overall results

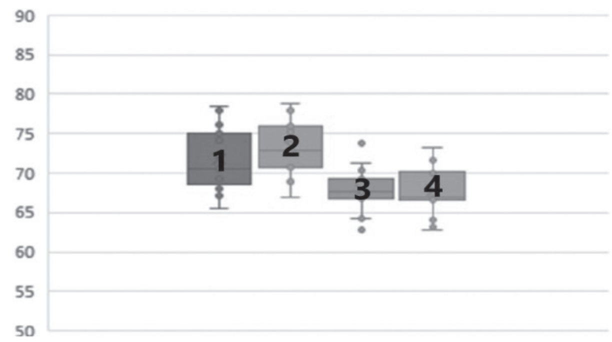
| | Experimental group | Control group |
|---|---|---|
| Difference [%] | 2.81 | -0.14 |

The measured values are shown graphically in Graphs 1–3. In all three cases, an obvious increase in the average of the values of the speeds measured during the output measurement in the experimental group can be observed, compared to an almost zero shift in the values measured during the output measurement in the control group.




1. Experimental group – input measurement [km/h]
2. Experimental groups - output measurement [km/h]
3. Control group - input measurement [km/h]
4. Control group - output measurement [km/h]

**Graph 1.** The difference between the input and output measurement shots velocity during a one-handed overhead shooting from the ground from a 7 m distance (penalty throw)




1. Experimental group – input measurement [km/h]
2. Experimental groups - output measurement [km/h]
3. Control group - input measurement [km/h]
4. Control group - output measurement [km/h]

**Graph 2.** The difference between the input and output measurement of shot velocity during overhead one-handed shooting from a position after a run-up from a 9m distance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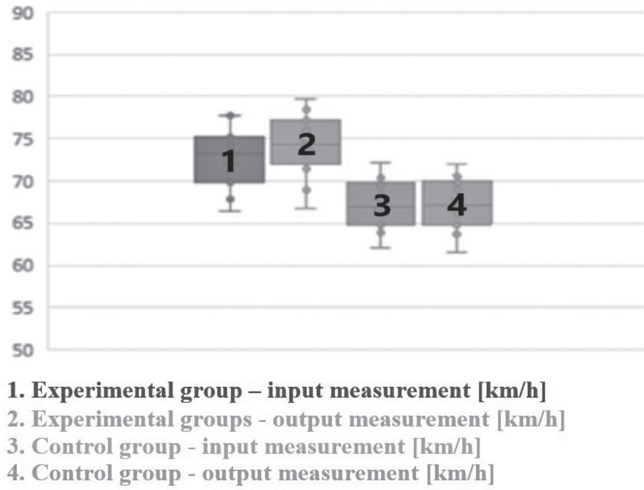


**Graph 3.** The difference between the input and output measurement of the velocity of the projectiles when shooting overhead one-handed from a jump from a 9 m distance

The distribution of the input data was first checked using the Shapiro-Wilk normality test. The level of statistical significance was chosen to be 5%. The test results are recorded in Table 6.

According to the performed Shapiro-Wilk normality test, we found that the input data distribution in one case does not correspond to a normal distribution. Thus, the Mann-Whitney U-test was used to test the hypotheses. The level of statistical significance for the tests was chosen to be 5%. By subsequently performing the Mann-Whitney U-test on the data set, p-values were obtained. The test results are recorded in Table 7.

**Table 6.** Shapiro-Wilk normality test

| Throw | 1 | | 2 | | 3 | |
|---|---|---|---|---|---|---|
| Group | Experimental group | Control group | Experimental group | Control group | Experimental group | Control group |
| p-value | 0.92 % | 0.02 % | 0.38 % | 0.64 % | 0.75 % | 0.63 % |
| Normal distribution | Yes | No | Yes | Yes | Yes | Yes |

**Table 7.** Mann-Whitney U-test

| Shooting | A | B | C |
|---|---|---|---|
| p value | <0.001 (U=225. Z=82.26) | <0.001 (U=209. Z=3.98) | <0.001 (U=219. Z=4.40) |

A - one-handed overhead shot from the ground from a 7 m distance (penalty throw), B - one-handed overhead shot from the ground after a run-up from a 9 m distance, C - one-handed overhead shot from a jump from a 9 m distance.

By the test, it was proven that the speed of the throw increased significantly due to the effect of 8 weeks of exercise aimed at activating the DSS muscles in all 3 types of shots. In all three investigated cases, the mean of the measurement differences was higher than the standard deviation of the differences. Therefore, differences are factually significant (Table 8).

**Table 8.** Factual significance

| Difference in measurements [%] | Experimental Group | | |
|---|---|---|---|
| Shooting | A | B | C |
| M | 3.82 | 2.23 | 2.38 |
| SD | 1.11 | 1.43 | 0.99 |

M – Mean average, SD - standard deviation, A - one-handed overhead shooting from the ground from the spot from 7 m distance (penalty throw), B - one-handed overhead shooting from the ground after a run-up from a 9 m distance, C - one-handed overhead shooting from a jump from 9 m distance.

## Discussion

As part of our research, we evaluated the effect of the DSS of spine activation on the shot speed in professional female handball players. In an experimental investigation, we tried to verify the effect of an 8-week intervention aimed at activating the DSS of the spine on the shot speed in a group of 30 adult female handball players who play top-level competition in the Czech Republic. The experimental group had special blocks with exercises to activate the DSS included in regular handball training.

We found that in the experimental group, after applying the center activation exercise, there was an improvement and an increase in the velocity of all shots. We did not notice any improvement in the control group. In the experimental group, the speed of the shot increased by 3.82% during the one-handed overhead shooting from the ground from a distance of 7 m (free throw), on average; the control group, on the other hand, worsened by -0.34% during the output measurement. Thus, for this shooting method, we recorded the highest rate of improvement in the experimental group out of all 3 shooting methods. In the one-handed overhead shooting from the spot after a run-up from a distance of 9 m, the experimental group improved on average by 2.23% in the final measurement; the control group worsened on average by -0.1% in the second measurement. We recorded the slightest improvement in the experimental group on average with this shooting method. From the third shooting position, the overhead one-handed jump shot from a distance of 9 m, the experimental group improved in the output measurement by 2.38%.

In contrast, the control group saw a slight improvement of 0.03%. So this was the only shooting method in which there was no deterioration in the control group, but the improvement was really small. Overall, there was an average increase in the speed of bullets by 2.81% in the experimental group, while in the control group, we noticed a slight deterioration by -0.14% on average.

The measured data were processed using mathematical-statistical methods, where the Shapiro-Wilk normality test was first used, which proved that in 1 case the data distribution did not correspond to a normal distribution, and therefore the Mann-Whitney U-test was used for subsequent data analysis. After the calculation of this test, we after performing the tests found that due to the effect of 8 weeks of exercise on the activation of the DSSS muscles, the velocity of the shots increased statistically significantly. Furthermore, in all three examined cases, the average of the measurement difference was higher than the standard deviation of the differences, and the differences can therefore be considered factually significant. Thanks to this, we were able to reject the null hypothesis and accept the assumption we made that the experimental group would have a higher speed of all three shots measured on average in the output measurement than the control group.

In the Czech Republic, we have not noticed any research devoted to this issue in handball; only Vojtěchovská's final thesis (2022) examines the effect of center activation exercises on shot speed in hockey. Some foreign authors, such as Manchado et al. (2017) and Saeterbakken et al. (2011), demonstrated in young athletes that the DSSS muscles activation indeed affects handball players' shot velocity. More specifically, for example, in the research of Manchado et al. (2017), the shooting rate of the experimental group increased on average by 4.3% after 10 weeks of DSSS muscle activation exercises 3 times per week. The authors of this study recommended following up on research with elite athletes. Compared to our results, there was a more significant improvement, which may be due to the two weeks longer duration of the intervention and the choice of exercises. Despite the solid theoretical basis supporting the use of specific training and the studies cited here to support this theory, inconsistent views still persist in the literature regarding the effect on performance or injury prediction in athletes (Danneels et al., 2001, Gorostiaga et al., 2004, Luo et al., 2022, McGill, 2001, Shelly, 2010). No or insignificant effect with regard to performance improvement in different sports disciplines may explain the poor design of the progression of selected basic exercises (Brull-Muria et al., 2021, Hibbs et al., 2008, Junker, 2019, Stanton et al., 2004). For this reason, we strictly followed the sequence of the three described exercise levels during core training. We progressed from simpler exercises to more complex ones, from static to dynamic, and from exercises in stable positions to balance.

The results of our study and the aforementioned research investigations confirm the importance of specific strength training for increasing the activation of the DSS, or strengthening the core muscles, in the training process. At the same time, they show an improvement in game performance, the key factors of which are the speed of the shot, which, together with accuracy, determines the effectiveness of performance in handball.

We found that in the experimental group, after applying exercises to activate the DSS of the spine, there was a significant increase in the speed of all three measured shots. We did not notice any improvement in the control group. A one-handed overhead shot from the ground from a distance of 7 m (penalty shot) increased the speed the most by 3.82%, a one-handed overhead shot from the ground after a run-up from a distance of 9 m increased its speed by 2.23%, and one-handed jump shots from 9m by 2.38%.

Targeted activation of the DSS muscles led to increased shot speed in handball. We recommend implementing strength training programs aimed at targeted activation of the deep stabilizers in training not only for handball but also for other team sports.

## Bioethical clearance

The study was designed in accordance with the Helsinki Declaration, and conducted following the approval of the Ethics Committee of the Faculty of Education UJEP (1/2019/01).

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