

Characteristics of specific training in elite handball players specialized in goalkeeper position

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Abstract

Background and Study Aim Elite handball goalkeepers undergo intensive training for reflexes and advanced techniques. They develop mental toughness to handle the pressure and responsibility at key moments of the game. Thus, they protect the goal of the team. This study aims to investigate and highlight the specific training characteristics of elite handball players specialized in the goalkeeper position.

Material and Methods The best 4 goalkeepers specialized in elite handball in Romania, aged between 22 and 33 years, were selected. Specific motor tests were used: Test 1 - Jumps 15 seconds; Test 2 – Reaction speed to visual stimulus; Test 3 – Execution speed. Technical tests were used: Test specific to goalkeeper, Triangle moving, The Ten Jump, Ball throwing, Standing long jump, Passes to a fixed point; The Cooper test. To improve specific training, there were applied strategies for training optimization which include stretching for mobility, segmental muscle strength, goalkeeping specific exercises and plyometrics. The nonparametric Spearman's correlation coefficient was used to evaluate the relationship between technical training and motor skills parameters. The statistical significance level was set at $p < 0.05$.

Results The performance of elite handball players specializing in goalkeeper position highlighted significant improvements in the Jumps 15 sec test. Contact time decreased by 0.13 seconds while the jump height increased by 0.55 cm, showing improved efficiency and power. In the Reaction speed to visual stimulus test, waiting time and reaction time decreased considerably, while the foot rising height increased. In the right and left leg Execution speed test, the differences observed reveal individual adaptations. The overall time is low in the right foot and there is a significant increase in the left foot. The nonparametric Spearman correlation analysis showed the relationship between the indices of technical fitness tests and the strength and speed motor skills. During Test 1 - Jumps 15 sec - 49 correlations were identified, of which 5.36% were statistically significant, highlighting strong connections between certain parameters. The analysis of Test 2 showed 56 correlations, but the lack of statistical significance reveals the absence of connections between the technical tests and the parameters of reaction speed manifestation. Regarding Test 3, a number of 28 correlations were identified. The lack of statistical significance suggests the absence of significant correlations between the technical tests and the execution speed.

Conclusions The performances of elite handball goalkeepers show significant improvements in motor and technical skills, highlighting the effectiveness of specific training and its adaptability. The progress in jumping and reaction speed indicates essential improvements for goalkeeping success, emphasizing the necessity for personalized and holistic training.

Keywords: elite athletes, tests, physical fitness, performances, correlation analysis, training strategies

Introduction

Success in competitive sports is influenced by

a wide range of factors, including constitutional, conditional, coordinative, technical, psychological and tactical ones. These factors are specific to each position in team handball and are particularly important in the dynamics of the game [1]. The evolution of elite handball led to significant

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improvements in the speed and complexity of the game. The goalkeeper is less used in the attack phase; the outstanding performances result from the close collaboration between attacking and defending actions. To reach an elite level in handball requires extraordinary physical and psychological characteristics [2, 3, 4].

Sports training becomes crucial in the evolution of modern handball. The training is adapted to the diversity and complexity of the game. In order to study the various aspects of ball handling, the goalkeeper must benefit from systematic training sessions. The increased requirements of the game lead to the necessity of a specific training meant to improve performance. Training recommendations include strength and power, coordination and endurance exercises adapted to the specifics of elite handball. Goalkeeper training should focus on developing the playing position specific skills to cope with the various demands of the game [5, 6, 7, 8].

Handball is characterized by frequent changes of intensities and by different complex movements during games. Physical performance is often tested predominantly, using standardized general tests. Determining the relationship between specific and general physical performance and also between specific aerobic capacity and agility is relevant to the specialists in strength and conditioning. In the context of the handball game, general motor training, for goalkeeper inclusively, is essential in sports performance. It is subordinated to other individual aspects such as specific training, attitude and behavior. The training and development of the general motor capacity of the goalkeeper is a fundamental objective in preparation and competition. Specialized programs, including plyometric exercises for explosive power, reaction speed and dexterity, contribute to the improvement of players' performance. These programs have a significant impact on the dynamics of handball game at national and international level [9].

The complexity of handball actions, characterized by fast and demanding executions at muscular level, requires a general and specific physical training able to improve the playing strength. These exercises help to improve the performance in the game. They facilitate the body rapid adaptation to game requirements, while protecting the joints and muscle structures [9].

Handball, a fast and dynamic sport, foregrounds the essential role of the goalkeeper, but scientific research pays little attention to the development of this one. The efficiency of each player during a match is very important for victory. The goalkeeper has a vital role in the team defense. For understanding the interactions between goalkeeper and opposing players, a proper analysis is required. The development and training of goalkeepers in elite handball is a priority. It must be addressed with

special attention in order to ensure superior results for the team in competition [1, 10, 11].

According to Rizescu, the main task of handball goalkeeper is to prevent the ball from entering his own goal. This requires conscious activity based on clear tactical rules, developed through observation and analysis and supported by experience and tactical intuition, on the part of the athlete and the coach as well [16].

In handball, the training of the players specialized in goalkeeper position usually starts at the age of 10 - 12 years. It involves the accumulation of technical-tactical skills useful for both field players and goalkeepers. Coaches face difficulties in selecting and training goalkeepers as most debutants want to play in attacking positions. Advanced players focus on diversifying the shots towards the goal and anticipating the movements of the opponents. Goalkeepers must understand the intentions of the opposing players and adapt the defense technique according to the type of shot. In the advanced stages, goalkeepers must have thorough knowledge of the game and be able to influence the final result of the game. The coach has a key role in the development of goalkeepers, tailoring the training to the individual needs of these ones [1, 10, 17].

In elite handball, the need to increase strength and speed in the technical-tactical executions entails the rapid adaptation of the training to the requirements of each body segment involved in playing. This aspect is one of the training priorities for the specialized goalkeepers. The use of specific exercises for general and special physical training can generate significant improvements in their motor skills. A training aiming at the development of the specific motor capacity, focused on the strength-speed ratio, can have a major impact on the goalkeeper's performance in all levels of elite handball [10, 18].

Purpose of the Study. The study purpose was the investigation and highlighting of the specific training characteristics in elite handball goalkeepers.

Materials and Methods

Participants

The best 4 players (P) of the Romanian elite handball specialized in goalkeeper position participated in this experiment. The subjects are: P1 (33 years old), player at the Saint Raphael Club, France – member of the Romanian National Team; P2 (24 years old), player at the Tatabanya Club, Hungary – University World Champion; P3 (22 years old), player in H.C. Minaur Baia Mare, Romania – member of the Romanian National Team and P4 (26 years old), player at HC Vaslui, Romania – member of the Romanian National Team. The consent of the subjects was required and signed before starting the research according to the Declaration of Helsinki.

It was approved by the Ethics Committee of the Doctoral School of Sport Science and Physical Education (ID: 07/24.07.2023), University of Pitesti, Romania.

Research Design

The longitudinal experiment was conducted along the 2017-2018 competitive year at the Romanian National Handball Team level, with players specialized in goalkeeper position (n=4).

The fitness tests selected for the assessment of specific motor ability were also validated by the national team coaches. Some of these tests are also used as means of specific training. These fitness tests were passed by the research subjects during the centralized training stage in Cluj Napoca. They were also passed within the Human Performance Research Center of the Doctoral School of Physical Education and Sport Science, University of Pitesti.

Due to the small sample of subjects, it was agreed to choose the study of case as research method. In our opinion, this method will be able to create a representative database. This one could be used for other players specialized in goalkeeper position of equivalent or even lower performance levels.

Tests specific to the evaluation of motor skills:

Test 1: Jumps 15 seconds. It consisted in the continuous execution, for 15 seconds, of vertical jumps on both legs. The starting and returning position was a semi-flexion at the knee joint level. The following parameters were measured for each jump: contact time (TCont. [s]); flight time (TFlight. [s]); jump height (Height [cm]); power (Power [W/Kg]); pace (Pace [step/s]); reactive strength index (RSI [m/s]).

Test 2: Reaction speed to visual stimulus. It was measured using the Opto Jump Next optical system. It consisted in the measurement of the following parameters expressed in seconds and centimeters: Twait [s] – waiting time between signals; TReac. [s] – reaction time; TFlight [s] – flight time (time when the subject is not in contact with the ground); Height [cm] – the height at which the foot (sole) rises from the ground. The visual stimulus was represented by the color change of a graphic element that could be viewed on the computer monitor. When the color changed (from red to green), the subject had to lift his foot off the ground as quickly as possible. The system measured simultaneously the parameters mentioned above.

Test 3: Execution speed. It was measured by means of Witty timing electronic system. The test involved the execution during 10 sec of successive entero-lateral flexion movements of the thigh on the trunk, specific to goalkeepers. The movements were performed so that the knee of the swinging leg passed in front of the Witty system. This one measured the number of passes and the time in which they were done.

Fitness tests for technical training:

1) *Test specific to goalkeeper (PS, sec).* The goalkeeper is in basic position in point 1 of the triangle. He takes side steps to points 2, 3 and returns to point 1. Then he sprints sideways 3 m from point 1 and picks up one ball in the sequence a; b; c; d. He throws the ball into the opponent's goal without going beyond the semicircle of 6 m. After each throw, the triangle is repeated starting from point 1. The same is done until all 4 balls are thrown. The period elapsed between the departure from point 1 up to the dropping of the last ball is timed.

2) *Triangle moving (DT, sec).* A triangle is drawn whose base is the 3 m straight line of the 6 m semicircle. From the middle of the base, a perpendicular of 3 m rises up to the dotted semicircle. This will be the height of the isosceles triangle. The sides of the triangle are marked by joining the 3 points thus obtained. A 30 cm diameter circle is drawn at the top of each of the 3 angles and tangent to them. The athlete is initially facing the top of the triangle. His left foot is placed in the center of the circle to the left of the triangle base. When the test starts, the athlete moves with side steps to the right, forwards, backwards and to the left. He must touch successively all the circles, in a complete route there and back formed of the triangle sides. The test entails covering this route 3 times, without stopping. The moving technique with side steps, forwards and backwards, specific to defense playing in handball, is constantly used.

3) *The Ten jump (DS, m).* It consists of taking 10 jumping steps, from standing position, one foot placed on the ground, behind the starting line. The subject is allowed a single take-off and the jumps must be performed without interruptions – 10 jumps in a row. It is forbidden to stop and stand between jumps. The distance will be measured from the starting line up to the last mark left by the athlete's heel when landing.

4) *Throwing the ball at a long distance, with 3 step run-up (AMH, m).* The throw shall be performed from behind a line drawn on the ground. This line cannot be touched or crossed before the ball has gone beyond the hand of the thrower. The run-up can use the technique of crossed step, side step or leap step.

5) *Standing long jump (SLL, cm).* It is executed from behind a line drawn at the center of the court. The distance is measured between the tip of the shoes at jumping moment and their heel at the landing moment.

6) *Passes to a fixed point (PPF, no. of reps).* The goalkeeper is in the center of the goal, in basic position. At the signal, he picks up a ball and throws it towards a fixed point (a 200cm x 150 cm mat) placed vertically in the center of the court. The number of passes to a fixed point from 10 attempts is counted.

7) *The Cooper test* (TC, m): a 12 minute run test. The covered distance is measured.

Strategies to optimize the training:

1) Stretching exercises meant to improve coordination, balance, mobility and flexibility of joints, strength of different muscle groups; exercises to improve dexterity; exercises with rubber bands.

2) Exercises for the development of segmental muscle strength:

- exercises for abdominal and thigh muscles with 10 kg dumbbell on shoulders;

- exercises consisting of jumping on and over small obstacles of 40 cm;

- low-weight exercises to improve strength-speed ability for the upper body muscles;

- exercises for the physical training of strength-speed ability for abdominal and back muscles;

3) Exercises specific to goalkeeper's playing in the handball goal. The purpose is to improve the movements in goal area and to complete the basic positions of the goalkeeper play. Exercises used: quick left-right movements with side steps across the handball goal width; standing in the center of the goal; alternately moving the leg to the left and to the right etc.

4) Plyometric exercises (single leg exercises: jumping from one cube to another from standing on one leg; alternate jumping from one foot to the other over 7 cubes 40 cm high placed at a distance of 50 cm one from another; standing on one leg, the hands put on the gym bench – jumping from one foot to the other in a limited area; standing in the middle of the handball goal, with balls suspended

left and right side, at 1 m from the goalkeeper. Alternate swings are performed with the leg on the same side, accompanied with arm movements up and down).

Statistical Analysis

The statistical indicators were calculated using the KyPlot 6.0 (©1997-2020, KyensLab Inc) program, in terms of Median, Standard Deviation (SD), Coefficient of Variation (CV%), Confidence Level of Mean (0.95) and Confidence Limit of Mean. The nonparametric Spearman's correlation coefficient was applied to evaluate the relationship between technical training and motor skills parameters in the elite handball goalkeepers. Statistical significance was set at $p < 0.05$.

Results

The specific training particularities in the elite handball players specialized in goalkeeper position were highlighted. This was done by evaluation and comparative analysis of the manifestation characteristics of strength and speed combined motor skills and their technical training level.

The results of the research are shown in tables 1, 2, 3 and 4.

The results of test 1 (Jumps 15 sec, table 1) reveal the improvement in performances of the measured parameters. Thus, the median increased by 2 jumps and the Confidence Level of Mean (0.95) (CLM) decreased by 0.47. There is a decrease by 0.33 in Confidence Limit of Mean Lower & Upper (CLM-L&U) of the size of intervals between tests. TCont. (sec) decreases by 0.13 sec between tests and both

Table 1. The results of lower limbs power in Jumps 15 seconds testing of elite handball players specialized in goalkeeper position, n=4

Variables		Median ± SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
					Lower	Upper
No. of jumps	Initial	12.00 ±2.48	21.44	1.05	10.53	12.63
	Final	14.00 ±1.38	10.29	0.58	12.79	13.96
TCont. (sec)	Initial	0.61 ±0.09	14.15	0.07	0.58	0.71
	Final	0.59 ±0.08	12.44	0.05	0.54	0.65
TFlight (sec)	Initial	0.47 ±0.02	3.82	0.01	0.45	0.48
	Final	0.47 ±0.02	4.72	0.01	0.46	0.48
Height (cm)	Initial	27.01 ±1.99	7.49	1.29	25.36	27.94
	Final	27.56 ±2.44	9.14	1.45	25.84	28.74
Power (w/kg)	Initial	19.89 ±1.46	7.50	1.01	18.46	20.47
	Final	20.49 ±1.84	9.19	1.14	19.49	21.76
Pace (step/s)	Initial	0.92 ±0.07	7.53	0.05	0.86	0.95
	Final	0.95 ±0.05	6.01	0.03	0.91	0.98
RSI (m/s)	Initial	0.44 ±0.06	14.78	0.04	0.38	0.47
	Final	0.46; ±0.07	15.79	0.04	0.43	0.52

Values are expressed as Median ± Standard Deviations (SD), CV – coefficient of variation; RSI – reactive strength index.

Table 2. Results of left and right foot speed of reaction to visual stimulus in the elite handball players specialized in goalkeeper position, n=4

Variables			Median ± SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
						Lower	Upper
Right foot	TWait (sec)	Initial	4.43 ±0.75	16.72	0.48	4.02	4.97
		Final	4.32 ±0.84	18.69	0.53	3.97	5.04
	TReac. (sec)	Initial	0.45 ±0.04	9.98	0.03	0.42	0.48
		Final	0.42 ±0.04	9.80	0.03	0.41	0.46
	TFlight (sec)	Initial	0.19 ±0.05	24.39	0.03	0.17	0.23
		Final	0.21 ±0.07	36.9	0.04	0.14	0.23
	Height (cm)	Initial	4.50 ±2.36	47.26	1.49	3.49	6.49
		Final	5.70 ±2.83	56.56	1.79	3.21	6.81
Left foot	TWait (sec)	Initial	4.86 ±0.74	15.61	0.47	4.26	5.20
		Final	4.79 ±0.67	14.58	0.43	4.21	5.07
	TReac. (sec)	Initial	0.44 ±0.02	5.43	0.01	0.43	0.46
		Final	0.43 ±0.02	5.28	0.01	0.42	0.45
	TFlight (sec)	Initial	0.20 ±0.07	34.01	0.20	0.17	0.26
		Final	0.22 ±0.07	33.11	0.05	0.17	0.27
	Height (cm)	Initial	5.15 ±4.09	63.43	2.59	3.85	9.05
		Final	5.75 ±4.41	67.17	2.80	3.76	9.37

Values are expressed as Median ± Standard Deviations (SD), CV – coefficient of variation.

Table 3. Results of execution speed of the right and left foot in the handball players specialized in the goalkeeper position, n=4

Variables			Median ± SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
						Lower	Upper
Right foot	No. of reps	Initial	13.5 ±3.11	23.03	4.95	8.55	18.45
		Final	13.5 ±2.94	21.03	4.68	9.31	18.68
	Time (sec)	Initial	9.75 ±0.29	3.01	0.46	9.20	10.13
		Final	9.74 ±0.17	1.76	0.27	9.47	10.01
Left foot	No. of reps	Initial	14.5 ±1.71	11.98	2.72	11.53	16.97
		Final	15.00 ±1.91	13.20	3.05	11.45	17.55
	Time (sec)	Initial	9.48 ±0.35	3.69	0.56	8.95	10.07
		Final	9.67 ±0.41	4.28	0.65	8.97	10.28

Values are expressed as Median ± Standard Deviations (SD), CV – coefficient of variation

CLM and CLM-L&U have a decrease by 0.02 sec. TFlight (sec) keeps the value of 0.47 sec; CLM and CLM-L&U decrease by 0.01 sec. Height (cm) increases the median by 0.55 cm, CLM increases by 0.16 cm and CLM-L&U by 0.32 cm. Power (w/kg): it increases the median by 0.6 w/kg; CLM increases by 0.13 w/kg and CLM-L&U increases by 0.26 w/kg. Pace (step/s) increases by 0.03 step/s, CLM and CLM-L&U decrease by 0.02 step/s. RSI (m/s) increases by 0.02 m/s; CLM has the same value of 0.04 m/s and CLM-L&U has 0.09 m/s. All these differences between tests in the analyzed parameters highlight the characteristics of lower limbs power in a short time. This is considered a specific particularity of the elite handball players specialized in goalkeeper position.

The results of test 2 (left and right foot speed of reaction to visual stimulus) of elite handball goalkeepers are shown in table 2. The analysis of the differences in the measured parameters reveals the following values:

- *right foot* – Twait (sec): the wait time decreases by 0.11 sec, CLM increases by 0.05 sec and CLM-L&U increases by 0.12 sec the size of intervals between tests. TReact. (sec): the reaction time decreases by 0.03 sec, CLM has the value of 0.03 sec and CLM-L&U has 0.02 sec. TFlight (sec): the flight time increases by 0.02 sec, CLM increases by 0.01 sec and CLM-L&U increases by 0.03 sec. Height (cm): the height of sole rising increases by 1.2 cm, CLM increases by 0.3 cm and CLM-L&U by 0.6 cm.

Table 4. Results of technical training of elite handball players specialized in goalkeeper position, n=4

Variables		Median \pm SD	CV (%)	Confidence Level of Mean (0.95)	Confidence Limit of Mean	
					Lower	Upper
PS (sec)	Initial	32.01 \pm 2.17	6.72	3.45	28.87	35.79
	Final	28.82 \pm 1.43	4.71	2.27	28.07	32.61
DT (sec)	Initial	15.17 \pm 0.58	3.83	0.93	14.31	16.17
	Final	14.45 \pm 0.35	2.39	0.55	13.98	15.08
DS (m)	Initial	29.00 \pm 1.11	3.83	1.77	27.23	30.77
	Final	29.8 \pm 1.21	4.05	1.92	27.83	31.67
AMH (m)	Initial	47.75 \pm 2.90	5.95	4.62	44.13	53.37
	Final	49.75 \pm 2.96	5.83	4.71	46.04	55.45
SLL (cm)	Initial	252.5 \pm 12.5	4.93	19.89	233.86	273.64
	Final	265.0 \pm 8.16	3.08	12.99	252.01	277.99
PPF (no. of passes)	Initial	6.50 \pm 1.29	19.86	2.05	4.44	8.55
	Final	8.00 \pm 0.82	10.21	1.29	6.70	9.29
TC (m)	Initial	2825 \pm 64.55	2.28	102.71	2722.28	2927.71
	Final	2925 \pm 47.87	1.63	76.17	2861.33	3013.67

Values are expressed as Median \pm Standard Deviations (SD), CV – coefficient of variation.

All differences between the measured parameters in tests highlight the characteristics of left and right foot reaction speed to visual stimulus.

- *left foot* - TWait (sec): wait time decreases by 0.07 sec, CLM decreases by 0.04 sec and CLM-L&U increases by 0.08 sec in the size of intervals between tests. TReact. (sec): the time of reaction decreases by 0.01 sec, CLM maintains the value of 0.01 sec and CLM-L&U has 0.03 sec. TFlight (sec): the flight time increases by 0.02 sec, CLM decreases by 0.21 sec and CLM-L&U increases by 0.01 sec. Height (cm): height of sole rising increases by 0.6 cm, CLM increases by 0.21 cm and CLM-L&U by 0.41 cm.

The results of test 3 (execution speed of right foot and left foot, 10 sec) of elite handball goalkeepers are presented in table 3. The analysis of the differences in the measured parameters highlights, for the right foot, the following values: the same number of reps (13.5) between tests, a decrease of CLM by 0.27 reps and a decrease by 0.53 reps of CLM-L&U in the size of intervals between tests. The execution time decreases by 0.01 sec, CLM decreases by 0.19 sec and CLM-L&U decreases by 0.54 sec. Regarding the left foot, the number of reps increases by 0.5 executions. CLM increases by 0.33 reps and CLM-L&U by 0.66 reps. The execution time increases by 0.19 sec, CLM increases by 0.09 sec and CLM-L&U by 0.19 sec. These differences in the measured parameters show the characteristics of the execution speed between segments (right and left foot) in the elite handball players specialized in goalkeeper position.

The results of technical training in the elite handball players specialized in goalkeeper position are listed in table 4. The comparative analysis reveals differences in the fitness tests as follows: in the case of PS (sec) – specific test - the median

value decreases by 3.18 sec, CLM decreases by 1.18 sec and CLM-L&U decreases by 2.38 sec in the size of intervals between tests. As for DT(sec) – triangle moving – it decreases by 0.72 sec, CLM decreases by 0.38 sec while the size of the intervals between tests at CLM-L&U decreases by 0.76 sec. In DS (m), ten-jump test increases by 0.8 m, CLM increases by 0.15 m while the size of the intervals between tests at CLM-L&U increases by 0.3 m. In terms of AMH (m), throw of the handball – it increases by 2.0 m, CLM increases by 0.09 m and CLM-L&U increases by 0.17 m in the size of the intervals between tests. In SLL (cm) - standing long jump – it increases by 12.5 cm, CLM decreases by 6.9 cm while the size of the intervals between tests at CLM-L&U decreases by 13.8 cm. Regarding PPF (no. of passes)- passes to a fixed point – it increases by 1.5 passes, CLM decreases by 0.76 passes while CLM-L&U decreases by 1.52 passes in the size of the intervals between tests. TC (m) - the Cooper test – increases the distance by 100 m, CLM decreases by 26.54 m and the size of the intervals between tests at CLM-L&U decreases by 53.09 m.

The relationship between the indices of the technical tests and the strength-speed motor skills was determined through the nonparametric Spearman's correlation analysis. The results of the analysis are presented in Figures 1, 2 and 3.

The analysis of the technical tests' indices with the parameters of manifestation of lower limbs power in test 1 - Jumps 15 sec (fig. 1) – reveals 49 correlations (65.3% negative and 42.8% positive). In terms of statistical significance of correlations, one can observe 5.36% strong connections at $p < 0.05$ ($r = 1.00$) between PS with TWait (left foot) and DS with TFlight, Height (right foot) and TWait (left

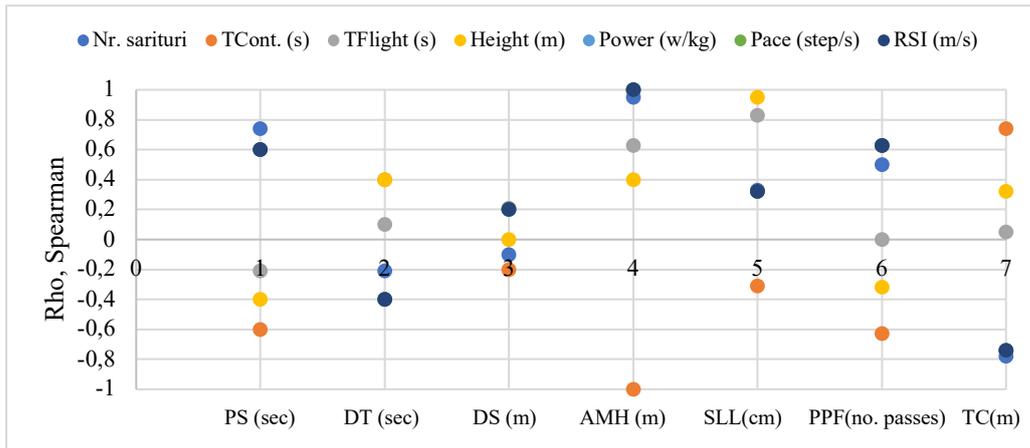


Figure 1. Relationship between technical training indices and parameters of the Test no 1, Jumps 15 sec, in the elite handball players specialized in goalkeeper position

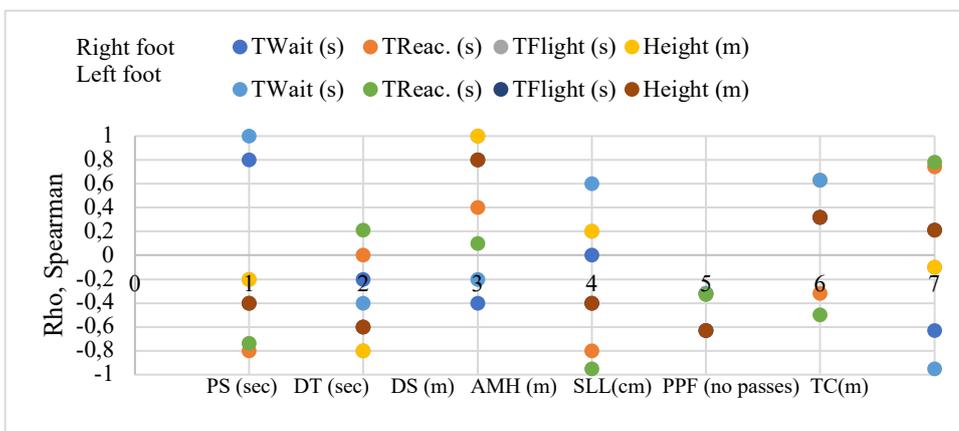


Figure 2. Relationship between the technical training indices and the test parameters of the reaction speed to visual stimulus in the case of the elite handball players specialized in goalkeeper position

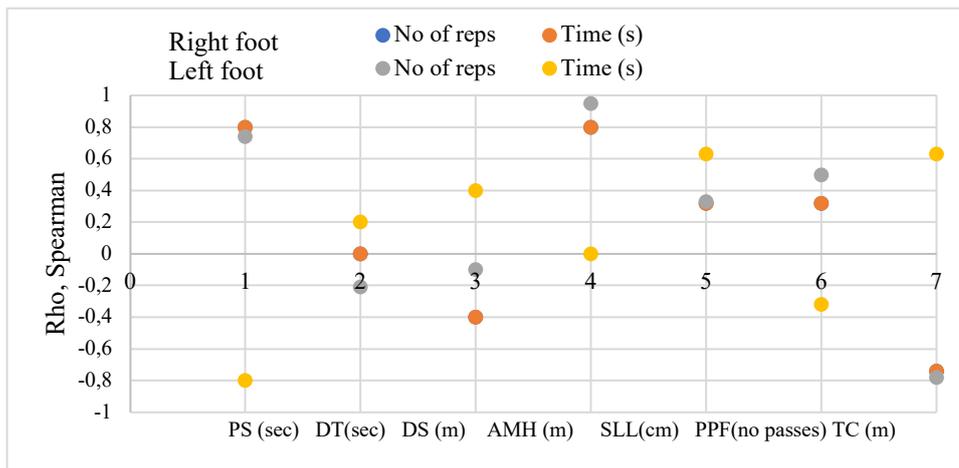


Figure 3. Relationship between the indices of technical training with the parameters of execution speed test in the elite handball players specialized in goalkeeper position

foot). The statistically insignificant correlations at $p > 0.05$ ($r > 0.75$) have 4.08% strong connections and 32.6% ($r > 0.5 < 0.75$) moderate connections.

The analysis of the technical tests' indices with the manifestation parameters of the reaction speed of the left and right foot to visual stimulus in test 2 (fig. 2) shows 56 correlations (57.2% positive and 34.7% negative). As for the statistical significance,

there is a lack of correlations. The statistically insignificant correlations at $p > 0.05$ ($r > 0.75$) are 16.07% strong connections and 23.2% ($r > 0.5 < 0.75$) moderate connections.

The analysis of the technical tests' indices with the manifestation parameters of the execution speed with the right foot and left foot - test 3 (fig.

3) – highlights 28 correlations (71.4% positive and 28.6% negative). Regarding the degree of statistical significance, one can observe the absence of correlations. In terms of statistically insignificant correlations at $p > 0.05$ ($r > 0.75$) there are 25% strong connections and 21.4% ($r > 0.5 < 0.75$) moderate connections.

All these correlation relationships express the degree of connection between the measured variables. They can be considered characteristics of the specific training of elite handball players specialized in goalkeeper position.

Discussion

The characteristics of the specific training of elite handball goalkeepers were highlighted through the comparative analysis of the motor tests parameters and the applied technical tests. The fitness tests are recommended by the specialists in the field [11]. These tests were part of those imposed by the Romanian Handball Federation for participation in the National Championships. Each test had minimal performance scales.

Regarding the characteristics of motor tests evaluation, a significant improvement in the performance of elite handball goalkeepers is noticed in the Jumps 15 sec Test. The Contact time (TCont.) decreased by 0.13 seconds, suggesting better ground contact efficiency during jumps. Flight time (TFlight) remained constant at 0.47 seconds, which proves that stability is maintained during flight. Jump height (Height) recorded an important increase of the median by 0.55 cm, while (Power) increased by 0.6 w/kg, indicating an improvement in the ability to generate power during jumps. Also, the reactive strength index (RSI) increased by 0.02 m/s, highlighting an improvement in the rate of power generation during jumps. These results reveal a positive evolution of short-term characteristics of lower limbs strength in these players specialized in goalkeeper position. Studies point out the similarity of performance abilities between the positions of elite handball players. It is suggested that one-foot horizontal jump distance may be an index of sprinting ability [19]. Anthropometric and strength level analysis shows that the position in team is influenced by these characteristics. High-intensity interval system is preferred for performance improvement due to greater specificity of the game [20]. In Test 2 – Reaction speed to visual stimulus, a significant improvement in waiting time and reaction time at both legs was observed in the elite handball goalkeepers. This improvement reveals specific adaptations and adjustments in the process of reaction and execution of the jump. Also, the height of sole rising (both feet) recorded significant increases that point out an improvement in jumping performance. In Test 3 – Execution speed on right and left leg, important differences

were noticed between the right and left leg in terms of number and time of repetitions. They indicated individual adaptations and changes in the execution technique at the level of each leg. These results highlight the specific characteristics of the reaction and execution speed of each leg. The results also reflect the individual adaptations of the elite handball goalkeepers in the context of evaluation tests. Studies analyze morphologic characteristics and motor skills according to the playing position in handball game. Notable differences were revealed between positions in terms of physical characteristics and motor performance. The results provide coaches with essential information that enable them to design efficient training programs for success in handball [21, 22, 23, 24].

Elite handball goalkeepers had significant improvements in fitness tests, namely a decreased time in the specific tests, such as PS and DT, showing greater efficiency and agility. Additionally, the increase in distance in the DS and AMH tests demonstrate an improvement in power and accuracy. The increased height in the SLL test proves better jumping ability. Furthermore, the increase in the number of passes in the PPF test suggests an improvement in the accuracy and efficiency of the passes. The increase of the distance in the Cooper Test indicates better endurance and running ability. This progress highlights the sustained efforts and the dedication of the players in developing the skills needed to reach high performance in handball game.

The training of handball goalkeeper is essential and should be varied for mobilizing the entire energy potential of the body. There were applied strategies for training optimization that led to better results. The training is meant to build the technique elements; excellent physical fitness and constant commitment are required for this purpose [25]. Some specialists studied the elite handball goalkeepers' actions during shots. They concluded that the shots from all positions should be taken into consideration in order to increase the area of saves [26]. To improve the sports performance of all handball players (including goalkeepers), individualized training programs are highly important. These ones focus on specific physical and technical requirements on the playing field, aiming to develop techniques and tactical activities. These programs are adapted to the dynamics of the game and the particularities of the playing positions [27, 28]. The importance of adequate rotations of the players for keeping an optimal level of physical performance in elite men's handball was also analyzed [29].

The Spearman's nonparametric correlation analysis for elite handball players specialized in goalkeeper position reveals the following findings. Test 1 - *Jumps 15 sec* - shows notable correlations between the specific tests and the waiting time for left leg. Significant correlations were identified

between the Ten jump and the flight time, the height for the right leg and the waiting time for the left leg. But there were found out statistically insignificant correlations as well. As for Test 2 – *Reaction speed to visual stimulus* - the lack of significant correlations indicates the absence of connections between technical tests and parameters of reaction speed manifestation. Similarly, in Test 3 – *Execution speed* – the lack of statistical significance highlights the absence of significant correlations between technical tests and the parameters of execution speed manifestation. These correlation relationships suggest a changing degree of connection between the variables measured in technical tests and the strength and speed motor skills. A relevant insight is provided into how technical skills may or may not relate to motor characteristics. The detailed analysis of these correlations contributes to a deeper understanding of the specific training of elite handball goalkeepers.

Recent studies point out significant statistical relationships in elite handball that can influence the selection of players, the training and match strategies. Almeida et al. found that the efficiency of wings and the blocking were key variables that changed over several editions. The top teams had taller players, with international experience and higher efficiency in the actions from 9 meters and wing. They blocked more defense throws [30]. The study of Horníková et al. focused on the relationship between reactive agility and other performance components in handball players. Significant connections were identified between Y-shaped agility and the 20 m sprint running. Also, important connections were found between reactive agility and force-time ratio but not with reaction speed [31]. Regarding the study of Hatzimanouil et al., there were analyzed statistics about goalkeepers' playing and their relevance to the team final ranking in the European Men's Handball Championship 2020. The importance of saves and the efficiency from 9 m proved to be significant for the success of the team [32]. Other specialists) compared the anthropometric data and physical performance characteristics between different playing positions in professional team handball. Close correlations were found between these aspects, providing useful information for talent identification and assessment. The information provided was also used for the development and optimization of the necessary training programs specific to the playing position [33, 34].

Several studies addressed the concerns regarding the training and performances of handball goalkeepers. Pori et al. examined the connections between motors skills and performance in goalkeepers. The authors suggested that other characteristics, like perceptual skills or experience, could influence competitive effectiveness more

than the analyzed motor skills [35]. Santos and Menezes investigated the ages recommended for the specialization of handball players. They also offered helpful information about the planning of the training and the long-term specialization in handball [36]. Justin et al. focused on the impact of height and body mass on the performance of goalkeepers. The specialists concluded that tall goalkeepers are preferred, but other aspects such as perceptual-motor skills must be also considered [37]. The study of Mohoric et al. revealed the differences in morphological and performance characteristics of elite handball players according to playing positions and age categories. Valuable data are provided for the development of talent identification and training programs [38]. Massuca et al. demonstrated the influence of aerobic capacity on handball players' performance depending on the playing positions [39]. Hansen et al. identified a significant relationship between the statistics of the saves made by goalkeepers' and the final ranking of teams. They identified the importance of individual performance in the success of the team [40]. Le Menn et al. analyzed how an expert handball goalkeeper manages incertitude during competitions. They offered a more thorough understanding of the performances of an expert in sport [4]. Michalsik et al. highlighted the physical requirements that elite handball players must meet, with an emphasis on the position-specific training and on the anaerobic and strength training [41]. Bøgild et al. examined anthropometric and physiological characteristics of performance in national handball teams, revealing differences between playing positions [42].

The comprehensive training program aims to optimize handball goalkeeping performance. It addresses physical fitness and skill development through various exercises. These include stretching exercises, segmental muscle strength exercises, goalkeeper-specific drills, and plyometric exercises. This well-rounded approach ensures success in the position. [43].

These studies contribute to the complex understanding of the training and performance of handball goalkeepers, providing essential information for coaches and sport researchers.

Conclusions

Performances of elite handball players specialized in the goalkeeper position had important improvements in Jumps 15 sec test. Thus, the number of jumps increased, the contact time decreased, the height and strength increased, showing an improved efficiency and stability during jumps. It was also found out a better rate of strength development.

The reaction speed to visual stimulus test recorded significant decreases in waiting time and reaction time in both legs. The flight time

increased slightly. The height of sole rising of both legs recorded increased. So, the manifestation characteristics of speed reaction of both legs to visual stimulus were revealed.

Regarding the test on Execution speed of the right and left leg, the number of repetitions remained constant in the right leg. The total time in which the repetitions were performed decreased. As for the left leg, the number of repetitions increased significantly and the total time of the reps had also a serious increase. This fact highlighted the execution speed characteristics of the right and left foot in the elite handball goalkeepers.

The results of technical training in the elite handball goalkeepers show important improvements in several fitness tests, reflecting progress in their technical skills. These differences indicate the progress made in the technical training of the elite handball players specialized in goalkeeper position. They reflect the players' efforts and dedication in developing the skills necessary for higher performance in the game.

The conclusion of the correlation analysis suggests that the connection between technical skills and motor characteristics may vary depending on the test type. So, a notable insight into the specific training of elite handball goalkeepers is provided.

Limitations of the research

- Insufficient research papers on the individualized training at the level of elite handball teams.
- Lack of easily accessible specialized equipment for the evaluation of performance capacity, with a high degree of applicability in increasing the handball players' performance.
- Lack of specialized coaches for the individualized training of handball players specialized in the goalkeeper position.

Considering these limitations is essential for the correct interpretation of the results and for the formulation of relevant and valid conclusions within the research on the specific training of the elite handball goalkeepers.

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Conflict of interest

There are no conflicts of interest to declare.

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