

THE EFFECTS OF A SPECIFIC TRAINING PROGRAM ON THE KINEMATIC PARAMETERS OF THE JUMP SHOT AMONG ELITE FEMALE HANDBALL PLAYERS

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Abstract. *The aim of this research was to determine the effects of an eight-week specific training program on the kinematic parameters of the jump shot at 9m from the goal, among elite female handball players. The sample of participants consisted of 30 female handball players (height: 1.73 ± 0.08 m; mass: 69 ± 8.9 kg; body mass index-BMI 22.9 ± 2 kg/m²; training experience: 12.3 ± 6.2 yrs), competing in the first national handball league of the Republic of Serbia. The research was longitudinal in nature, with an initial and final measuring. The experimental treatment included a 30 min replication of the regular training session, with specifically designed exercises (work with medicine balls, stabilizer training, and strength training in a gym). 12 kinematic variables of the jump shot were analyzed using the Kinovea software program, ver. 0.8.2. The analysis of covariance and the effect size (ES) determined a positive effect of the specific program on the kinematic parameters of the jump shot, especially on the variables of height and maximal ball flight velocity.*

Key words: *Specific Training Program, Kinematic Analysis, Jump Shot, Handball*

INTRODUCTION

It is a widely known fact that each sport, and thus handball, is specific and differs based on its unique movement structure, more precisely based on its technique. One of the most important parts of the technique in handball is the shooting technique, which is used to score a goal and thus achieve the most important aim of the game. Taking part in handball requires well-developed motor skills, primarily speed, strength, and agility (Živković et al., 2019). It is precisely this combination of shot velocity and precision that is the most important factor in scoring goals since a precise and quick shot leaves little time for the defensive players and goalkeeper to react (Gorostiaga, Granados, Ibanez, & Izquierdo, 2005).

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Each type of human movement and motion can be broken down into biomechanical parameters, with the aim of realizing the optimal management of the movement structures of athletes (Malacko & Rađo, 2004). A biomechanical analysis of sports technique, in this case of shooting in handball, provides kinematic information which describes the technique itself and enables the formation of a specific training program which will improve the performance and realization of the shot in handball. Marković (2014) studied the maximal velocity of the ball during a jump shot at 9m from the goal following release, among elite female handball players, which was determined to have a value of 25 m/s; however, the best female handball player in the world in 2013 achieved a ball velocity of 23 m/s, and a 122° angle of the elbow joint. Van den Tillaar & Ettema (2007) analyzed the bounced shot at 7m from the goal and concluded that the angle of internal rotation of the shoulder joint was approximately 65° among elite female handball players, and that participants who had a quicker shot also achieved greater velocity of internal rotation.

There are several papers which studied the influence of various types of training on the velocity of the shot in handball over the last ten years, and based on their analyses, we can conclude that a small number of studies focused on a precisely specified set of handball exercises during the experimental training program (Manchado, García-Ruiz, Cortell-Tormo, & Tortosa-Martínez, 2017; Sabido, Hernández-Davó, Botella, & Moya, 2016; Raeder, Fernandez-Fernandez, & Ferrauti, 2015; Hermassi, Van den Tillaar, Khelifa, Chelly & Chamari, 2015; Chelly, Hermassi, Aouadi, & Shephard, 2014; Van den Tillaar & Marques, 2011; Hermassi, Chelly, Tabka, Shephard, & Chamari, 2011; Saeterbakken, Van den Tillaar, & Seiler, 2011; Chelly, Hermassi, & Shephard, 2010; Hermassi, Chelly, Fathloun, & Shephard, 2010; Ettema, Gløsen, & Van den Tillaar, 2008). However, there are no studies which dealt with the influence of a specific training program on the kinematic parameters of the jump shot among elite female handball players.

The aim of this research was to determine the effect of a specific training program on the kinematic parameters of the jump shot at 9m from the goal, among elite female handball players.

METHODS

The sample of participants

The sample of participants consisted of 30 female handball players (height: 1.73±.08 m; mass: 69±8.9 kg; body mass index-BMI: 22.9±2 kg/m²; training experience: 12.3±6.2 yrs; Mean±SD), competing in the first national handball league of the Republic of Serbia. The female participants were female handball players of the Jagodina handball club from Jagodina (n=15) and the female handball players of the Naissa club from Niš (n=15). The female participants were divided into an experimental (EG, n=15) and control group (CG, n=15). The EG consisted of the female handball players of the H.C. Naissa from Niš, while the CG consisted of the female handball players of the H.C. Jagodina from Jagodina. At the time of the experimental program, the female participants were at the top of their national competition ranking.

Experimental design

The research was of a longitudinal character, with an initial and final measurement. The volume of training of the control subsample consisted of eight in-club training sessions and

one match per week, each week over a period of eight weeks. The EG trained with the same volume and intensity as the CG, but had an additional three specific training sessions which replicated in one (final) part the regular training session. Each specific part of the training session lasted 30 min and was carried out every other day. The first training session included medicine balls, the second a stabilizer training session, and the third included strength training in the gym. The training intensity increased from easier to harder, while during the last few weeks it decreased to the optimal level.

Instruments and procedures

The measurement of the kinematic parameters of the shot and strength of the handball players was carried out over two phases: the first phase – the *initial measurement* was carried out prior to the beginning of the experimental treatment; the second phase – the *final measurement*, was carried out following a period of eight weeks, more precisely, after the completion of the experimental treatment.

All of the measurements were taken in a sports hall, in which the female participants carried out their regular training sessions, in the afternoon hours, at approximately the same time, by using a Casio Exillim F1 camera (the jump shot was recorded in the sagittal plane), while a high-speed radar (Pocket Radar, Santa Rosa, California) recorded the flight velocity of the ball. For the evaluation of the biomechanical parameters of the jump shot, the tests presented by Wagner, Pfusterschmied, Von Duvillard, & Müller (2011) and Van den Tillaar & Ettema (2003) were used, after the necessary corrections, which were made in accordance with the testing requirements. The female participants performed the jump shot from a line marked 9 m from the goal line, with maximal force and velocity. The task was to hit the top half of the goal, which was horizontally divided into two parts with an elastic band. For further analysis, the software for kinematic analysis Kinovea version 0.8.2 was used. The video recordings of the greatest ball flight velocity achieved by the participants were included in further analysis.

Considering that the jump shot could be divided into five phases, the subjective choice of the researcher was to analyze the kinematic parameters in the release phase of the ball (the moment when the ball is released from the hand of the participant). The variables (12), analyzed by using the software for biomechanical data analysis, included: ANFKJSLz-angle of flexion in the knee joint of the swing leg (°), ANFKJTOLo-angle of flexion in the knee joint of the takeoff leg (°), ANFHSL1-the angle of flexion in the hip joint of the swing leg (°), ANBUBAS-the angle between the upper body and the surface (°), ANIRSJ-the angle of internal rotation in the shoulder joint (°), ANFEJ-angle of flexion in the elbow joint (°), MHHJ-maximal height of the hip joint (cm), MHSJ-maximal height of the shoulder joint (cm), MHEJ-maximal height of the elbow joint (cm), MHW-maximal height of the wrist (cm), MBH-maximal ball height (cm), MBFV 9 m-maximal ball flight velocity from the moment of release during the jump with a run up at 9 m from the goal (km/h).

The size of the ball is 54-56 cm, 325-400 g, size 2 for women.

Statistical analysis

The data analysis was carried out using the IBM SPSS Statistics 19 software (Statistical Package for Social Sciences, v19.0, SPSS Inc., Chicago, IL, USA). The normality of the data distribution was determined using the Kolmogorov-Smirnov test. Basic descriptive parameters were calculated for all the variables: means (MEAN), minimal (MIN), maximal

(MAX) value of the numerical result, standard deviation (SD). The Analysis of Covariance (ANCOVA) method and effect size (ES), were used to determine the effect between the groups, interpreted as: trivial, <.2; small, .2–0.59; moderate, .6–1.19; large, 1.2–1.99; very large, >2 (Hopkins, Marshall, Batterham, & Hanin, 2009).

RESULTS

The basic statistical parameters for the kinematic variables of the jump shot at 9 m from the goal for the experimental and control group at the initial and final measurement are shown in Table 1.

Table 1 The basic statistical parameters of kinematic variables of the shot at 9m from the goal for the EG and CG at the initial and final measurement

Variables	Groups	MEAN		MIN		MAX		SD	
		initial	final	initial	final	initial	final	initial	final
ANFKJSLz (°)	EG	131.67	131.27	83.00	113.00	169.00	159.00	19.04	11.57
	CG	134.67	133.27	94.00	93.00	178.00	180.00	21.18	23.58
ANFKJTOLo (°)	EG	156.40	166.27	108.00	144.00	177.00	180.00	21.85	10.12
	CG	166.40	169.13	127.00	152.00	180.00	180.00	14.01	9.33
ANFHJSL1 (°)	EG	89.13	54.00	-177.00	-176.00	179.00	178.00	135.81	164.63
	CG	-118.40	-140.07	-172.00	-176.00	170.00	161.00	113.85	83.82
ANBUBAS (°)	EG	70.80	71.00	58.00	58.00	83.00	82.00	8.54	6.47
	CG	73.80	77.07	50.00	64.00	87.00	92.00	9.81	8.54
ANIRSJ (°)	EG	40.00	41.60	11.00	13.00	72.00	69.00	18.29	14.98
	CG	44.27	46.07	16.00	24.00	72.00	72.00	14.60	15.28
ANFEJ (°)	EG	136.27	142.53	109.00	115.00	153.00	171.00	12.69	13.34
	CG	133.80	137.73	108.00	117.00	153.00	155.00	13.74	12.59
MHHJ (cm)	EG	127.52	135.17	106.19	118.55	152.08	166.63	12.16	11.89
	CG	125.00	127.07	108.75	117.49	155.45	153.70	12.85	10.96
MHSJ (cm)	EG	172.55	179.82	145.55	150.96	209.34	198.93	16.26	14.62
	CG	169.73	169.34	152.05	151.49	204.73	197.41	16.32	14.61
MHEJ (cm)	EG	176.38	191.62	149.16	168.71	214.14	228.64	17.05	15.29
	CG	177.56	178.28	159.77	152.58	198.03	228.10	12.83	19.35
MHW (cm)	EG	205.82	216.56	175.24	189.36	263.56	264.59	22.82	18.09
	CG	210.61	211.82	182.48	173.66	245.90	257.72	17.65	20.99
MBH (cm)	EG	221.68	237.24	195.41	214.16	282.33	266.96	23.79	13.32
	CG	225.15	227.81	209.18	190.54	255.55	277.47	11.22	21.01
MBFV 9 m (km/h)	EG	77.53	84.20	69.00	75.00	92.00	95.00	6.13	5.62
	CG	73.13	73.20	64.00	66.00	86.00	85.00	5.63	5.31

Legend: N-the number of participants; MEAN-means; MIN-minimal value; MAX-maximal value; SD-standard deviation; INITIAL-initial measurement; FINAL- final measurement; ANFKJSLz-angle of flexion in the knee joint of the swing leg (°), ANFKJTOLo-angle of flexion in the knee joint of the takeoff leg (°), ANFHSL1-the angle of flexion in the hip joint of the swing leg (°), ANBUBAS-the angle between the upper body and the surface (°), ANIRSJ-the angle of internal rotation in the shoulder joint (°), ANFEJ-angle of flexion in the elbow joint (°), MHHJ-maximal height of the hip joint (cm), MHSJ-maximal height of the shoulder joint (cm), MHEJ-maximal height of the elbow joint (cm), MHW-maximal height of the wrist (cm), MBH-maximal ball height (cm), MBFV 9 m-maximal ball flight velocity from the moment of release during the jump with a run up at 9 m from the goal (km/h).

Table 2 shows the results of the univariate analysis of covariance and the effects on the kinematic parameters of the jump shot at 9 m from the goal.

Table 2 Univariate analysis of covariance (ANCOVA) and Effect Size of the experimental and control group at 9 m

Variables	ANCOVA		ES (90% CI)		
	F	p	EG	CG	
ANFKJSLz	.004	.950	-.03	(-.74; .69)	-.06 (-.78; .66)
ANFKJTOLo	.006	.941	.58	(-.17; 1.29) [†]	.23 (-.49; .94) [†]
ANFHJSL1	3.189	.085	-.23	(-.94; .49) [†]	-.22 (-.93; .51) [†]
ANBUBAS	4.163	.051	.03	(-.69; .74)	.36 (-.38; 1.07) [†]
ANIRSJ	.252	.620	.10	(-.62; .81)	.12 (-.60; .83)
ANFEJ	.768	.389	.48	(-.26; 1.19) [†]	.30 (-.43; 1.01) [†]
MHHJ	10.346	.003*	.64	(-.11; 1.35) ^{*‡}	.17 (-.55; .89)
MHSJ	6.618	.016*	.47	(-.27; 1.18) [†]	-.02 (-.74; .69)
MHEJ	5.856	.023*	.94	(.16; 1.67) ^{*‡}	.04 (-.67; .76)
MHW	5.907	.022*	.52	(-.22; 1.23) ^{*†}	.06 (-.65; .78)
MBH	3.709	.065	.81	(.04; 1.53) [‡]	.16 (-.56; .87)
MBFV 9 m	47.459	.000*	1.13	(.33; 1.87) ^{*§}	.01 (-.70; .73)

Legend: F - the value of the F-test for testing the significance of the differences in the arithmetic means; p - the coefficient of significance of the difference in means; * statistically significant difference $P < .05$; † small effect; ‡ moderate effect; § large effect

It was determined that there is a statistically significant difference at the univariate level between the participants from the experimental and control group following the experimental treatment for the variables MBFV 9 m ($F=47.459$; $p=.000$; $ES=1.13$, *great*), MHHJ ($F=10.346$; $p=.003$; $ES=.64$, *moderate*), MHSJ ($F=6.618$; $p=.016$; $ES=0.47$, *small*), MHEJ ($F=5.856$; $p=.023$; $ES=.94$, *moderate*), and MHW ($F=5.907$; $p=.022$; $ES=.52$, *small*). The results determined that there is a small effect for the variables ANFKJTOLo ($ES=.58$), ANFHJSL1 ($ES=-.23$), ANFEJ ($ES=.48$), and a moderate one for the variable MBH ($ES=.81$). The regular training program, following 8 weeks, showed a small effect for the variables ANFKJTOLo ($ES=.23$), ANFHJSL1 ($ES=-.22$), ANBUBAS ($ES=.36$) and ANFEJ ($ES=.30$), for the CG.

DISCUSSION

The aim of this research was to analyze the effects of a specific training program on the kinematic parameters of the jump shot at 9m from the goal among female handball players. The experimental treatment was carried out during the competition period, where the primary task of the players was to maintain or increase their physical fitness, previously developed during the preliminary period. Considering that during the competition period the main goal is to realize the best results possible at the competition itself, the need to find new methods of working with players is obligatory.

The training volume of the control subsample was eight in-club training sessions and one game a week. The EG trained with the same volume and intensity as the control group, but had an additional three specific training session which made up the experimental treatment of this research. The EG trained following a regular training program prescribed by the club trainer, but three times a week after their regular training took part in a specific

training program aimed at increasing shot velocity and improvement of the kinematic parameters of the shot, as well as the strength of the female handball players. The CG followed a regular training plan and program which was based on a technique which consisted of offensive and defensive elements, and defensive and offensive tactics, both individual and collective. The CG did not follow an additional, specific training program.

Following an eight-week specific training program (3 times a week) for a duration of 30min, its effects on certain kinematic parameters of the jump shot were determined analyzed using a 2 D kinematic analysis at the moment of ball release.

The bounced shot with a running start and jump shot at 9 m are the most frequently used technical elements in contemporary handball, especially among wingers and fullbacks. The great effect of the experimental treatment on ball flight velocity indicates an exceptional practical significance and can be used as a reliable method of the development of release velocity during the training cycle of the competition period. Using modification, that is, an increase in the intensity of the experimental treatment included in this research, it is possible to create a training program which could be applied during the preliminary period, considering that the results can already be seen on the existing fitness levels of the athletes. Previous research has determined that the greatest velocity of the ball is realized from a bounced shot with a running start (100%), then a bounced shot without a running start (93%), and the jump shot (92%) (Wagner et al., 2011). It was proven that stabilizer training for a period of 6 weeks has a positive effect on the improvement of the velocity of ball release (Saeterbakken et al., 2011). However, we cannot with any certainty estimate which part of the specific training process had the greatest influence on the development of release velocity, considering that the female participants of the EG also took part in training with a medicine ball, strength training in the gym, and stabilizer training for a period of 8 weeks. When it comes to stabilizer development part of the experimental treatment, in this study the following exercises were used: the *Low Plank* (the activation of large groups of muscles which at the same time take part in performing the jump shot), *High Plank with wobble board*, *Side Plank*, *Bird Dog*, *Bridge T Fall-off*, *Stability Ball Roll-out*, *Stability Ball Jackknife*, *Complete alphabet with shoulder*, *Table top circles with medicine ball*, and *Wall circles with medicine ball*. The final three exercises were used to increase the stability of the shoulders and are considered a significant part of stabilizer training in handball, considering that the frequency of injury of the shoulders is great, and often caused by the lack of stability of the bone and joint part of the arm. The exercises which were used to improve the stability of the body in specific positions included: the *One leg kettlebell press*, *One leg front push*, *One leg bent over row*, *Over head walk* and *Suitcase carry*. Previous studies have proven that applying the bench-press during the competition period just two times a week (for 8 weeks), could significantly increase the velocity of the shot and the strength of the upper extremities (Hermassi et al., 2011). The strength training in this research in addition to the bench-press also included exercises such as the box jump, sit-ups, triceps extensions on the LAT machine, and bicep curls on the Scott bench.

In this study we analyzed only one phase of the jump shot at 9 m from the goal, the flight phase at the moment of release. Pori, Bon, & Šibila (2005) carried out a study of all 5 phases of the shot jump, analyzing 17 different variables and setting the criteria for the evaluation of the quality of the jump shot technique for the population of male players. The results obtained following the realized experimental treatment in this study can be taken as the relevant model for the evaluation of the quality of the sports technique of the

jump shot for the women's senior population, considering that the sample of participants were elite handball players at the moment of testing.

During the jump shot with a single-leg take-off, the angle between the knee joint and the hip of the swing leg was flexed compared to the angles of the knee joint of the take-off leg, and the hip of the take-off leg was more hyperextended (Wagner et al., 2011). The obtained results of the kinematic analysis of the jump shot at 9m from the goal support these findings, and so the flexion in the knee joint of the swing leg of the EG group following the experimental treatment was $131.27 \pm 11.57^\circ$, while the flexion of the knee of the take-off leg was $166.27 \pm 10.12^\circ$. However, the experimental treatment had only a small effect on the UFZKo (ES=.58). The small effect of the regular training program for this variable was also found for the control subsample, which confirms the fact that the differences in the technical abilities between elite athletes are exceptionally small and they cannot be influenced to a great extent during that period.

The experimental treatment had a significant effect on the improvement of maximal joint height (MVK, MVR, MBH and MVS) and a moderate effect on the maximal flight height of the ball at the moment of release (ES=.81). The replacement of the final part of the training session (the final 30 min) in the gym with training using medicine balls, as well as stabilizer training and the application of specific strength training in the gym led to a significant improvement in the tested maximal height for the jump shot at 9 m. The assumption is that such results are in a high correlation with the increase in the strength of the lower extremities, which should be studied further.

CONCLUSION

Based on the results obtained it can be concluded that there is a positive effect on the kinematic parameters of the jump shot among the female participants who took part in an eight-week specifically designed training program, especially for the height and maximal flight velocity of the ball. The obtained data can be of great use to researchers in the design of future studies, but also to coaches in planning and programming the training program, both during the competition and preliminary cycles.

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EFEKTI SPECIFIČNOG TRENAŽNOG PROGRAMA NA KINEMATIČKE PARAMETRE SKOK ŠUTA VRHUNSKIH RUKOMETAŠICA

Cilj ovog istraživanja bio je da se utvrdi efekat osmonedeljnog specifičnog trenažnog programa na kinematičke parametre rukometnog skok šuta sa 9 m udaljenosti od gola. Uzorak ispitanika je sačinjavalo 30 rukometašica (visine: 1.73 ± 0.08 m; mase: 69 ± 8.9 kg; indeks telesne mase BMI 22.9 ± 2 kg/m²; trenažno iskustvo: 12.3 ± 6.2 godina), prve lige saveznog ranga takmičenja Republike Srbije. Istraživanje je bilo longitudinalnog karaktera, sa inicijalnim i finalnim merenjem. Eksperimentalni tretman podrazumevao je 30 minuta repliciranog dela redovnog treninga specifično dizajniranim vežbama (trening sa medicinkama, stabilizacioni trening i trening snage u teretani). 12 kinematičkih varijabli skok šuta analizirano je softverskim programom „Kinovea“ verzija 0.8.2. Analizom kovarijanse i veličinom efekta, utvrđen je pozitivan efekat specifičnog programa na kinematičke parametre skok šuta, posebno na varijable visine i maksimalnu brzinu leta lopte.

Ključne reči: *specifičan trenažni program, kinematička analiza, skok šut, rukomet*