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BASIC KINEMATIC DIFFERENCES IN ARM ACTIVITY BETWEEN TWO TYPES OF JUMP SHOT TECHNIQUES IN HANDBALL

PRIMERJAVA DELOVANJA ROKE PRI DVEH RAZLIČNIH TEHNIKAH STRELA V SKOKU PRI ROKOMETU

Abstract

The aim of this study is to identify differences in some basic kinematic parameters of arm activity between two different jump shot (JS) techniques used in handball. We compared the jump shot performed after the take-off from the leg opposite to the throwing hand (JS1) and the jump shot performed after the take-off from the throwing-side leg (JS2). Ten top-level male handball players executed six JS (three shots of each technique). Among all attempts performed, the two JS were chosen for each player (one for each technique) for further analysis. Two SVHS video cameras, operating at 25 frames per second, were used for data acquisition. Data processing was performed by APAS (Ariel Dynamics, California, USA). The basic statistical parameters for variables were computed and t-test for paired dependent samples and analysis of variance were used to assess statistical significance of the differences between the kinematic variables. The release ball velocity was significantly greater in JS1. In spite of the significant differences in times necessary for reaching the peak velocity of the wrist, elbow and shoulder of the throwing arm, there were no significant differences among the maximal velocities in the mentioned joints. At the final points of take-off and release, there were statistically significant differences between the angles of shoulder and hip axes in transversal plane. The differences were probably due to the take-off styles. The JS1 enabling better energy transfer from the distal to proximal body parts and better use of elastic muscle and ligament capacities in shooting from the opposite leg.

Key words: kinematic analysis, handball, jump shot, arm activity

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Izvleček

Cilj raziskave je bil ugotoviti razlike v delovanju roke pri dveh različnih izvedbah strela v skoku. Primerjali smo strel v skoku po odrivu z nasprotne noge ter strel iz skoka po odrivu z iste roke od noge s katero streljamo. Deset vrhunskih rokometašev je po določenem postopku izvedlo šest strelov v skoku (po tri strele z vsako tehniko). Vse strele smo posneli z dvema video kamerama s frekvenco 25 posnetkov na sekundo. Med vsemi poskusi smo izbrali po eno izvedbo vsake tehnike strela za nadaljnjo analizo. Za analizo kinematičnih spremenljivk smo uporabili sistem APAS (Arial Dinamics, Kalifornija, ZDA). Za vse spremenljivke smo izračunali osnovne statistične parametre. S t-testom za vezane vzorce in analizo variance smo ugotavljali statistično pomembne razlike med obema streloma. Hitrosti žoge ob izmetu so bile v povprečju statistično značilno večje pri strelu z nasprotne noge. Kljub statistično značilnim razlikam v časih za doseganje najvišjih hitrosti v zapestju, komolcu in ramenu, statistično značilnih razlik v najvišjih absolutnih hitrostih v omenjenih sklepih nismo zasledili. Med velikostjo kotov v ramenski in kolčni osi v tlorisu transverzalne ravnine v zadnji točki odriva in izmeta so se pojavila statistično značilne razlike. Razlike pripisujemo predvsem načinu odriva ki omogoča pri tehniki strela z nasprotne noge boljši prenos energije iz distalnih na proksimalne dele telesa ter ustvarjanje tako boljših pogojev za izkoriščanje elastičnih potencialov mišic in tetiv.

Ključne besede: kinematična analiza, rokomet, strel v skoku, delovanje roke

INTRODUCTION

All activities in handball are performed in specific conditions, characterised by the presence of players of the opposing team and obligation to play in line with the rules. Selection and execution of activities therefore depend mostly on various situations in a match. Even if a player may sometimes execute an element in a non-typical way, subject to the situation-related conditions, certain kinematic parameters still do exist and can be recognized for most elements in execution of which one can notice higher of lower performance efficiency.

The jump shot technique is probably the most typical among various shooting techniques used in handball. Usually, the jump shot take-off is performed from the leg opposite to the throwing hand (JS1 – for the right-handed players the left leg is the take-off leg). In this case a player is able to demonstrate the correct natural co-ordination, which allows successful – forceful and accurate - throw towards the goal. But during a game we can also see playing situations where players are forced to perform the jump shot after a take-off from the throwing side leg (JS2). This kind of jump shot is biomechanically more complex and demands well developed inter- and intramuscular coordination (Šibila, 1999).

Ballistic muscle contraction is characteristic of shots towards a goal. That type of muscle contraction enables an athlete or equipment to develop maximum mass velocity. In handball, all types of shots are driven by ballistic muscle contraction. In all types of shots it is very important that different body parts are included into action in a proper time sequence. The major biomechanical factor enabling all types of shots is the quality of transmission of impulses from the lower to upper body parts (pelvis, shoulders, elbow, wrist and ball). Velocity in single joints has to increase stepwise. In the course of a shot, therefore, the highest velocity should be reached first in a pelvis and later in a shoulder, first in a shoulder and then in an elbow, etc. Rotations of single segments are also included in a shot in the same order. The proximal segments start rotating before the distal ones (Enoka, 1998). The proximal – distal action of single parts of a body results in the velocity of a ball, which is the highest in the final part of a release. Eccentric–concentric type of muscle contraction is characteristic of both shots (Kastner, Pollany & Sobotka, 1978; Küster, 1973; Müller, 1982; Šibila & Bon, 1999; Šibila, Bon & Štuhec, 1999; Taborsky, Tuma & Zahalka, 1999; Zahalka, Tuma & Bunz, 1997; Zvonarek & Hraski, 1996). The main characteristic of such muscle action is a possibility to increase the force in the phase of concentric contraction or do more work with smaller consumption of chemical energy of muscles at the expense of their elasticity (Strojnik, 1990). The work done during eccentric–concentric contraction is strongly influenced by the speed of muscle extension. If an eccentric contraction is not followed by a concentric contraction quickly enough, the force in muscle ligament complexes starts to decrease. That is probably due to the loss of elastic energy stored in cross bridges (Enoka, 1998).

The objective of the research was to establish basic kinematic differences in arm activity between the two different jump shot techniques. We were mostly interested in differences between the absolute peak velocities of the so-called "throw chain" (shoulders, elbow, wrist and ball) and the times needed for generation of these velocities. We also compared changes of angles in hip and shoulder axes occurring in both types of jump shot techniques. In our opinion, the main source of the differences between the two jump shot techniques lies in two different types of take-off styles.

METHOD

Participants

Participants were ten male handball players, playing in the first national league. Their average height was 191.1 ± 4.48 cm, average body mass was 90.0 ± 4.40 kg. On average they were 23.4 years old (SM = 4.2 years).

Instrument

The sample of variables consisted of the following parameters: maximal height of the CG peak (cm) (CGmax); horizontal move of CG until the moment of release (cm) (hCGt); height of a throw (cm) (hthr); velocity of a throw (m/s) (vt); decrease of a maximal CG peak until the throw (cm) (decmax); peak velocity in the wrist joint (m/s) (pvelwr); peak velocity in the elbow joint (m/s) (pvelelb); peak velocity in the shoulder joint (m/s) (pvelsho); time elapsed from a take-off till the peak velocity in the wrist joint (ms) (ttopvwr); time elapsed from a take-off till the peak velocity in the elbow joint (ms) (ttopvelb); time elapsed from a take-off till the peak velocity in the shoulder joint (ms) (ttopvsho); angle in the hip axis at the end of a take-off (^{0}) (ahato); angle in the shoulder axis at the end of a take-off (^{0}) (ashoato); angle in the hip axis at the moment of a release (^{0}) (ahath); angle in the shoulder axis at the moment of release (^{0}) (ashoath).

All angles in shoulder and hip axes were given in transversal plane. The starting point at 0° was defined as the central body position without any rotation (Figure 1).

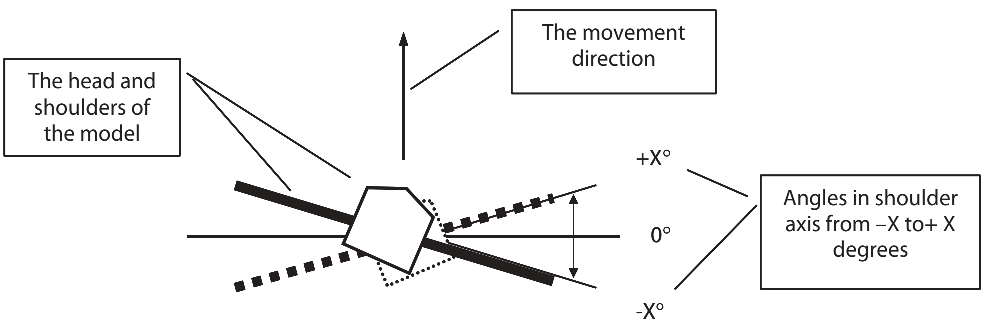

Figure 1: Determination of angles in ground plan of the transversal plane for the right-handed players.

Procedure

After 20 minutes of warming-up, participants executed two sets of three shots, using two different techniques. Firstly, they chose a starting position for approach in the middle of the playing court. Their approach consisted of two phases. First they performed three steps, bounced the ball and after that they performed three steps of the approach. Take-offs were made in an area marked on the free-throw line. All the shots were performed with maximal effort. Out of all attempts the authors chose two jump shots for further analysis, one of each technique for each player. Two SVHS video cameras, operating at 25 frames per second, were used for data acquisition. The cameras were positioned in such a way that after the registration of eight points a reference frame (500 cm x 100 cm x 100 cm) allowed analyses in a 3D space. Data processing was performed by APAS (Ariel Dynamics, California, USA). The fifteen-segment model of human body was defined by digitised co-ordinates of 16 reference points. Reference points represented joint centres of the limbs on both sides of the body and additionally the atlas, the vertex and the ball. The centre of body gravity (CG) was calculated from the Dempster's via Miller and Nelson anthropometrical model (Winter, 1990).

The basic statistics for the variables were computed. The t-test for paired depending samples and one-way between subjects ANOVA were used to assess significance of the obtained differences in the kinematic variables between the two jump shot performance techniques. Statistical significance was set at $\alpha < .05$. In the text, the data are reported as a mean ± standard deviation.

RESULTS

Figure 2 shows the path of the ball and body centre of gravity on y-axis during both jump shots. On average, the players reached higher body centre of gravity when shooting from the opposite leg than when shooting from the same leg (Table 1). The differences, however, were not statistically significant ($p = .054$). The differences that were statistically significant occurred during horizontal displacement of the body centre of gravity from the beginning of the take-off to the release ($p = .013$). The average move of the body centre of gravity from the beginning of the take-off to release in shooting from the same leg was longer for as much as 23 cm.

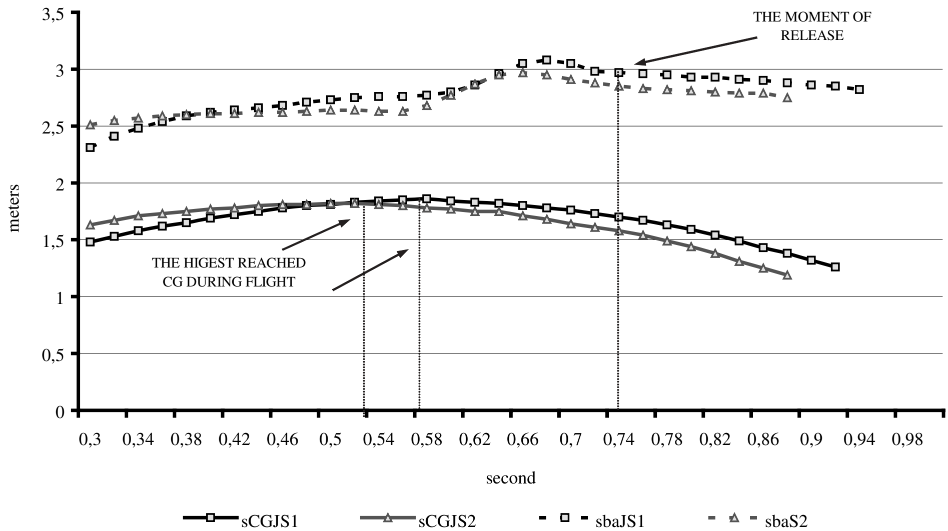

Figure 2: The path of the ball and of the body centre of gravity on the y-axis

Legend:
sCGJS1 – CG trajectory in JS1; sCGJS2 – CG trajectory in JS2; sbaJS1 – ball trajectory in JS1; sbaJS2 – ball trajectory in JS2.

Table 1: Statistical parameters for both jump shot techniques describing the differences of the body and ball centre of gravity.

	JS1		*JS2*		*p*
	M	***SD***	***M***	***SD***	
CGmax	174.00 cm	9.22 cm	168.00 cm	8.99 cm	**.054**
hCGt	128.00 cm	20.12 cm	151.00 cm	13.73 cm	**.013**
hthr	276.00 cm	19.41 cm	258.00 cm	18.95 cm	**.001**
deccmax	10.00 cm	7.19 cm	29.00 cm	13.57 cm	**.001**

Legend:
CGmax – maximal height of the CG during the flight (cm); hCGt - horizontal move of CG until the moment of release (cm); hthr – height of a throw (cm); decmax – decrease of maximal CG height until the release (cm); M – mean, SD – standard deviation, p – significance of t-test

Table 1 shows higher release point in shooting from the opposite leg. The release in shooting from the opposite leg usually starts at the highest point of a flight, which was on average at 276 ± 19.41 cm, and was statistically significantly higher ($p = .001$) than in shooting from the same leg (258 ± 18.95 cm). In JS1, the loss of the height of the body centre of gravity to release was 10 ± 7.19 cm, while in JS2 that loss was 29 ± 13.57 cm. The average difference between both jump shot techniques in decreasing of a maximal centre of gravity peak till the release height was 19 cm. Those findings were confirmed by statistically significant difference ($p = .001$). The average horizontal move of the body centre of gravity until the moment of release was also statistically significantly longer in JS2 ($p = .013$).

Table 2: Statistical parameters of both jump shot techniques describing the differences in maximal ball velocity, the wrist, elbow and shoulder velocities, as well as the times needed for generation of those velocities.

	JS1		**JS2**		**p**
	M	***SD***	***M***	***SD***	
vt	24.14 m/s	1.29 m/s	22.32 m/s	2.00 m/s	**.006**
pvelwr	13.55 m/s	0.69 m/s	12.98 m/s	1.26 m/s	**.151**
ttopvwr	0.392 s	0.08 s	0.486 s	0.05 s	**.002**
pvelelb	10.70 m/s	0.63 m/s	10.04 m/s	1.53 m/s	**.249**
ttopvelb	0.330 s	0.08 s	0.424 s	0.06 s	**.001**
pvelsho	5.53 m/s	0.33 m/s	5.48 m/s	0.44 m/s	**.793**
ttopvsho	0.310 s	0.07 s	0.404 s	0.05 s	**.001**

Legend:
|vt - velocity of a throw (m/s); pvelwr - peak velocity in wrist joint (m/s); ttopvwr - time from take-off until peak velocity in wrist joint (ms); pvelelb - peak velocity in elbow joint (m/s); ttopvelb time from take-off until peak velocity in elbow joint (ms); pvelsho - peak velocity in shoulder joint (m/s); ttopvsho - time from take-off until peak velocity in shoulder joint (ms); M – mean, SD – standard deviation, p – significance of t-test

The highest average shoulder, elbow and wrist velocities were achieved in JS1. Those differences, however, were not statistically significant (Table 2). It can be foreseen that time needed for reaching maximal velocities of single joints will increase together with the increase of the velocities themselves. The highest average shoulder velocities were therefore reached in 0.31 ± 0.07 second and in 0.40 ± 0.05 second after the take-off from the opposite leg in shooting from the same leg, respectively. The maximal average elbow velocity was reached in 0.33 ± 0.07 second after take-off in shooting from the opposite leg and 0.42 ± 0.06 second in shooting from the same leg. The maximal average wrist velocity was reached in 0.39 ± 0.07 second after take-off in JS1 and 0.48 ± 0.05 second in JS2. In contrast to the maximal average velocity of single joints, the average times needed for reaching those velocities were statistically significant.

The analysis of variance of the variables describing time needed for reaching the maximal absolute velocities of single joints confirms the existence of a difference between the mentioned variables within the results of a single shot. Statistically significant differences occurred between all the variables (Table 3).

Table 3: Univariate differences in times needed for generation of maximum absolute velocities of the wrist, elbow and shoulder during the same shot.

	JS1		JS2	
	F	***p***	***F***	***p***
ttopvwr **ttopvelb** **ttopvsho**	21.5	0.13	24.3	0.19

Legend:
ttopvwr - time from take-off until peak velocity in wrist joint (ms); ttopvelb - time from take-off until peak velocity in elbow joint (ms); ttopvsho - time from take-off until peak velocity in shoulder joint (ms); F – F coefficient; p – significance of f-test.

The main product of the mentioned velocities and times in single joints is the speed at the moment of release. The average generated speed of the ball, weighting 0.45 kg according to the rules of the International Handball Association, was 24.14 ± 1.29 m/s in shooting from the opposite leg. It was statistically significantly higher than 22.32 ± 2.00 m/s generated in shooting from the same leg (p = .006) (Table 2).

We also analysed the angles in shoulder and hip axes (Figure 3). The shapes of the curves show that both jump shot techniques differ in terms of changes in angles. In shooting from the opposite leg, the shoulder axis curve decreases regularly to negative direction. The average shoulder axis angle at the moment of take-off is -63°. This means that players move their hand into the starting point for a shot in that phase. When maximal body distortion is achieved, players are ready for a shot, which is followed by a steep increase of angles, even after the release of the ball. In shooting from the same leg, there is a delay of arm swing, which is shown in a delay of curve decrease in negative direction. The curve increase in positive direction after the lowest point in the phases of flight achieved is not as steep as in the case of shooting from the opposite leg. In shooting from the opposite leg, the angle in the moment of take-off was averaged -63°, while in case of shooting from the same leg it averaged -20°. The difference is statistically significant (p = .000) (Table 4). Angles in shoulder axis at moment of release during both shots were statistically significantly different (p = .012) as well.

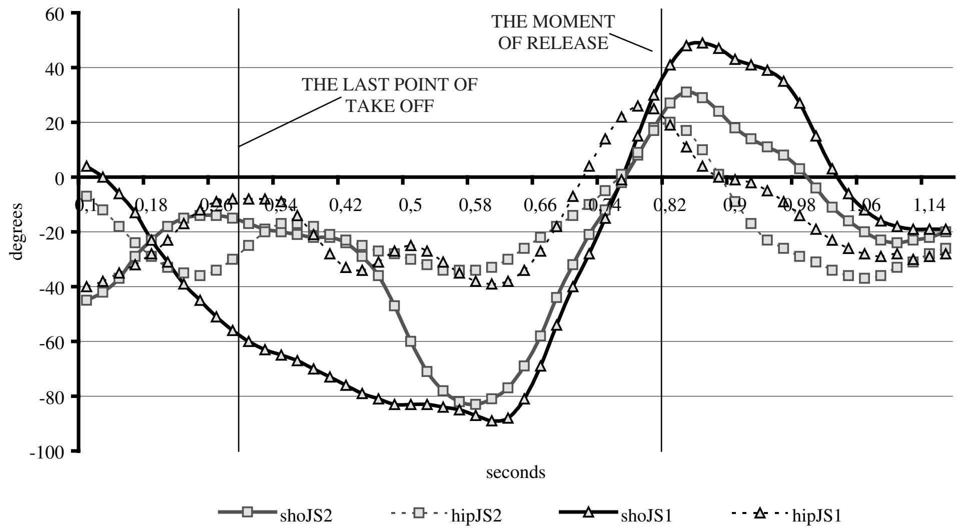

Figure 3: Angles in shoulder and hip axes in transversal plane.

Legend:
sho2 – angles in shoulder axis in JS2; hipJS2 – angles in hip axis in JS2; shoJS1 – angles in shoulder axis in JS1; hipJS1 – angles in hip axis in JS1;

Table 4: Statistical parameters of both jump shot techniques describing the differences in position of shoulder and hip axes at the final point of take-off and release.

	JS1		JS2		*p*
	M	***SD***	***M***	***SD***	
ahato	-12°	7.49°	-22°	11.34°	**.038**
ashoato	-63°	12.50°	-20°	6.48°	**.000**
ahath	19°	7.29°	16°	8.90°	**.235**
ashoath	38°	8.77°	23°	10.06°	**.012**

Legend:
ahato – the angle in hip axis at the end of take-off (^{0}); ashoato – the angle in shoulder axis at the end of take-off (^{0}); ahath – the angle in hip axis at the moment of throw (^{0}); ashoath – the angle in shoulder axis at the moment of throw (^{0}); p – significance of t-test

The curve of angles in the hip axis in case of the JS1 was also regularly increasing in positive direction to the very last moment of the take-off (Figure 3), which is due to the preparation for take-off. Take-off is followed by a slight decrease of the curve into negative direction, which is a consequence of the arm swing. The curve increase continues to the moment of release and reaches the highest point at the moment just before the release. In case of JS2, the shape of the angle curve is similar, only that the changes in curve appear slightly differently with regard to the JS1 curve dynamics. Statistical analysis confirms the differences in hip axis position in the final point of take-off for both shooting techniques (Table 4). During the execution of JS1, the angle in hip axis in the final point of take-off was -12°, while during the execution of JS2 it was -22° (p = .038). There were no statistically significant differences between both shots at the moment of release. The angle in the hip axis at the end of the take-off was 19° and 16° (p = 0,235) in JS1 and JS2, respectively.

DISCUSSION

The objective of our research was to determine basic kinematic differences in arm activity between the two types of jump shot techniques. We found out that the speed of ball at release was statistically significantly higher when shot was made from the opposite leg (shooting from opposite leg – 24.1 m/s; shooting from the same leg – 22.3 m/s). Although there were statistical differences between the release speeds, we did not determine any statistically significant differences between the maximal speeds of wrist, elbow and shoulder during the release phase. Interestingly, some statistical differences existed between the times in which maximal speeds of single joints were achieved. There were also statistically significant differences between the angles in transversal plane in the shoulder and hip axes in the final point of take-off and release. The differences between the two types of jump shot techniques have their origins in a type of a take-off, which has an impact on kinematic energy of a throw, and on the transfer of the energy from the distal to the proximal parts of the body. This can be a reason for a greater release speed.

During the execution of a jump shot from the opposite leg, the body is in a side position from the beginning of take-off. That enables a player to develop quicker and more energetic take-off, as well as a quicker transfer of the arm to backswing, preparation for shooting and a quicker transfer between backswing and forward swing (or shot) (Šibila, & Bon, 1999). That type of take-off also enables larger amplitude in the performance of muscle chain. Longer path of the muscle chain action in the concentric phase enables production of force on a longer distance and consequently greater speed (Enoka, 1998). That fact can be proven by statistically significant differences between the angles at release in both shots. Those angles were statistically significantly larger in case of shooting from the opposite leg.

Although the execution of a jump shot after the take-off from the same leg is ideal from the point of view of the use of muscle elastic capacities, in our opinion the execution of the shot is not very effective due to the take-off style. During the take-off from the same leg the hip and shoulder are in a closed position. Although the results show that the angle is statistically significantly larger in the final point of the take-off, it is decreasing for some time after the take-off. When executing that type of a jump shot the players need more time to move the arm into the starting point for a shot. The highest average body centre of gravity was therefore lower than during the execution of opposite leg type of a shot. The same is true for release height, as well as the body movement towards release, which was also better in case of opposite-leg type of shot.

For effective execution of a shot and release velocities it is essential that the player stretches his/her musculature up to the optimum degree and in optimum time. The accumulation of elastic energy in the eccentric phase (returning in the concentric phase) (Enoka, 1998) depends on that. The opposite-leg type of take-off with its favourable position of hip and shoulder axes at the end of the take-off enables players to use their elastic muscle capacities more effectively. On the other hand, the same-leg type of shot with its closed position of hip and shoulder at the end of the take-off hinders incorporation of particular body segments into the shot kinematic chain. That was proven by lower release speed during the execution of that type of a shot.

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