JUMP SHOT PERFORMANCE IN TEAM HANDBALL – A KINEMATIC MODEL EVALUATED ON THE BASIS OF EXPERT MODELLING

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Abstract:

The jump shot is one of the most important elements of specific handball motor behaviour. We wanted to assess it with the method of expert modelling. The sample of subjects consisted of ten male elite handball players, members of the national Slovenian teams that play in the first national handball division (average height - 191.1 ± 4.48 cm; average body mass - 90.0 ± 4.40 kg, average age - 23.4 ± 4.2 years; average training experience in senior teams - 5.3 ± 2.1 years). We analysed six backcourt players, two wing players and two pivots. Each of the subjects executed, after a 20-minute warm-up, three jump shots. Data processing was performed by APAS (Ariel Dynamics, California, USA). Expert modelling was performed with the SPEX expert system. We formed a success tree containing 17 variables, representing all five phases of the jump shot. In order to assess the validity of this kinematic model, three independent referees also assessed the quality of the jump shot. The ranks obtained from their marks were then compared with the ranks obtained with the SPEX expert model. On the basis of the obtained results we then constructed an expert mark for each analysed player. The level of concordance of the referees was high (W = 0.875), the coefficient of correlation between the actual ranks and the referee ranks was statistically significant (0.912). Our final finding is that a kinematic model of the jump shot constructed in this way can also be a good criterion for assessing the quality of the basic technique of the jump shot for seniors.

Key words: *team handball, jump shot, kinematic model, expert modelling*

SPRUNGWURFAUSFÜHRUNG IM HANDBALL – EIN AUF DER GRUNDLAGE DER EXPERTMODELLIERUNG BEWERTETES KINEMATISCHES MODELL

Zusammenfassung:

Der Sprungwurf ist ein der wichtigsten Elemente von der spezifischen Handballmotorik, das in dieser Untersuchung nach der Methode der Expertmodellierung bewertet wurde. Zehn Handballspieler, Mitglieder der slowenischen Nationalmannschaft, die in der ersten Nationaldivision spielen (Durchschnittsgröße 191,1 ± 4,48 cm; durchschnittliche Körpermasse 90,0 ± 4,40 kg, Durchschnittsalter 23,4 ± 4,2 Jahre; durchschnittliche Trainingerfahrung in Seniorenmannschaften 5,3 ± 2,2 Jahre), haben nach einer Aufwärmungszeit von 20 Minuten drei Sprungwürfe ausgeführt. Die Datenbearbeitung wurde mit APAS (Ariel Dynamics, California, U.S.A.) und die Expertmodellierung mit dem SPEX-Expertsystem durchgeführt. Danach wurde ein Erfolgsbaum mit 17 Variablen geformt, die alle fünf Phasen des Sprungwurfs darstellen. Um die Gültigkeit des ausgewählten kinematischen Modells zu prüfen, wurde die Sprungwurfsqualität auch von drei unabhängigen Schiedsrichtern bewertet. Die aus ihren Bewertungen erworbene Reihenfolge wurde dann mit der mit dem SPEX-Expertmodell erworbenen Reihenfolge verglichen. Auf der Grundlage der erworbenen Ergebnisse wurde dann für jeden analysierten Spieler eine Expertnote erstellt festgelegt. Die Übereinstimmung zwischen den Noten der einzelnen Schiedsrichter war hoch (W = 0,875) und der Korrelationskoeffizient der tatsächlichen und der von den Schiedsrichtern ermittelten Reihenfolge statistisch bedeutend (0,912). Als Endergebnis ergab die Untersuchung, dass das auf diese Weise konstruierte kinematische Sprungwurfmodell auch ein gutes Kriterium zur Beurteilung der Qualität der Grundtechnik des Sprungwurfs bei Senioren sein kann.

Schlüsselwörter: *Handball, Sprungwurf, kinematisches Modell, Expertmodellierung*

Introduction

Kinematic analyses of elements of specific sport-related motor behaviour (technique) ensure important information, representing the basis for an in-depth and precise knowledge of their actual structure. Only on the basis of such findings can we precisely describe the technique of executing the elements and connect it to tactics. In this way, we can also more easily construct didactic procedures in teaching and training, especially if we connect this knowledge with findings in the physiology of sport.

All activities in team handball are performed in specific conditions, with the presence of players of the opposing team and while observing playing regulations. Their selection and execution therefore depend mostly on the situations in the match. Even if a player can execute the individual elements sometimes in a non-typical way, certain kinematic parameters do exist for most elements that show a greater or lesser efficiency of the element's execution.

The key characteristics, which are stressed as their findings by most authors studying the biomechanical characteristics of throws in handball (Küster, 1973; Kastner, Pollany, & Sobotka, 1978; Zvonarek & Hraski, 1996; Zahalka, Tuma, & Bunc, 1997; Šibila, & Bon, 1999; Šibila, Bon, & Štuhec, 1999; Taborsky, Tuma, & Zahalka, 1999), are as follows:

- The correct order of recruitment of the individual parts of the body is important, allowing the development of maximal velocity and control of these parts – this order is from the proximal (central) parts to the distal (distant) parts of the body. The most proximal part begins the action; it is then followed by the next, and so on till the most distal part – the wrist or the palm. The velocity of movement of the smaller and lighter parts of the body with lesser inertia is added to the velocity of the bigger ones, achieving the greatest possible velocity at the end part of the kinetic chain (each proximal part offers support for the next, more distal part). The increase of angular velocity of the individual segment of the kinetic chain is connected to the stoppage of the proximal part (angular velocity of the elbow is greater after stopping the movement of the shoulder, the wrist after stopping the elbow, etc).
- When executing the shot, it is very important to take into account certain physiological characteristics of muscular effort and try to perform the shot with an eccentric-concentric type of muscular effort since it is more appropriate in the production of greater force. Therefore, at least for some muscular groups (or muscles involved in the shot) there should be the shortest possible time between extension and contraction. Electromyography measurements showed that (in ideal conditions) agonistic muscles are completely contracted till the time of maximal velocity of the individual link in the kinematic (throwing) chain and then completely relax with maximal recruitment of antagonists (Müller, 1982). It is important to stress that extensors in the wrist of worse players participate much less in the wrist part of the shot than those of better players. The delaying effect of the antagonistic (opposite) muscles is obviously not completely utilised in this case.

The development of computer technology, kinematics methods, expert knowledge and the associated artificial intelligence have enabled a completely new approach of studying the successfulness of athletes on the basis of expert modelling (Jošt, Dežman, & Pustovrh, 1995).

The main aim in this contribution is to analyse a kinematic model of the jump shot, one of the most important elements of the specific handball-related motor behaviour, and evaluate it with an expert modelling method.

Methods

The sample of subjects consisted of ten male elite handball players, members of the national Slovenian teams that play in the first national handball division (average height - 191.1 ± 4.48 cm; average body mass - 90.0 ± 4.40 kg, average age - 23.4 ± 4.2 years; average training experiences in seniors teams - 5.3 ± 2.1 years). Six backcourt players, two wing players and two pivots were analysed. Each subject executed, after a 20-minute warm-up, three jump shots. First, they chose a starting position for approach in the middle of the playing court. Their approach consisted of two parts. First they made three steps, bounced the ball and after that they made three steps of approach. They performed a take-off in the area which was marked on the free-throw line. They performed all shots with maximal effort. From among all the attempts, one jump shot, being the most characteristics for the analysed technique for each player, was chosen for further analysis. Two SVHS Video cameras operating at 25 frames per second were used for the acquisition of the data (Figure 1). The cameras were positioned in such a way that, after the registration of eight points, a reference frame (500cm x 100cm x 100cm) provided the possibility of an analysis in 3D space. Data processing was performed by APAS (Ariel Dynamics, California, USA). A fifteen-segment model of the human body was defined by digitised co-ordinates of 16 reference points. Reference points represented in the 3D space the joint centres of the limbs on both sides of the body, and, additionally, atlas, vertex and the ball. The centre of body gravity (CG) was calculated from Dempster's via Miller and Nelson anthropometric model (Winter, 1990).

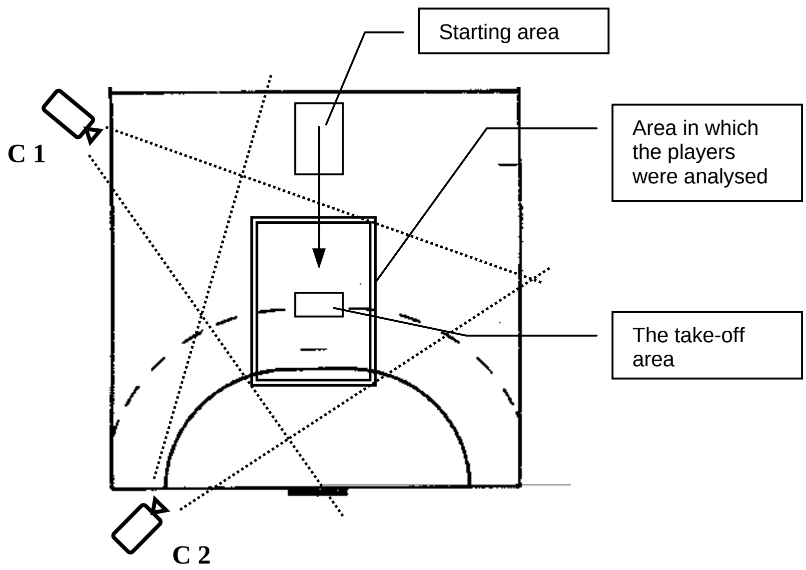

Figure 1. Schematic representation of the measurement procedure (C1, C2 – camera 1 and 2).

edge database (according to the set kinematic model of successfulness in the jump shot) was defined, we formed also a suitable model tree. This tree included the chosen dimensions, which formed a system, according to the kinematic model. The tree and the decision rules (decision tree), with which we defined the contribution of the individual parameters to the final mark of successfulness of the branch in question, are shown in Table 5. The basis for determining the criteria was expert knowledge, experience, scientific research of the field and observance of basic biomechanical principles. For a formalised presentation of the expert system kinematic model of the jump shot we used the so-called success tree. For this purpose we used the computer program SPEX (Leskošek, 1995).

In order to find the validity of this kinematic model, we asked three independent referees, experts in handball, to assess the quality of the jump shot. The ranks obtained in this way were compared with the ranks obtained with the expert model SPEX.

To increase the objectivity of the referees' assessments, the referees assessed the individual

According to its basic structure, the handball jump shot was divided into five phases: approach, take-off, flight, throw and landing (Table 1).

Seventeen 17 variables which represent the basic kinematic structure of jump shots at all phases were also chosen (Table 2).

The modelling then proceeded according to the didactical steps defined in advance (Čoh, Čuk, & Boršnik, 1993). After the formalism of the knowl-

Table 1. Descripton of individual phases of jump shot

Approach	Length of the last stride, lowering of CG in the last stride, rhythm
Take-off	Placement of the take-off leg; direction of the take-off, explosiveness and elasticity of the take-off
Flight	Preserving the lateral position; action of the swing leg
Throw	Height of the elbow during the throw; sequence of inclusion of joints and muscle groups in the throw
Landing	Landing on the take-off leg or on both legs; stopping the eccentric movement of the legs; balance

Table 2. Sample of variables, defining the kinematic model of the jump shot

Parameters of approach (A):	*Vertical change of CG height in the last step (cm)* (vCGhls) *Change of horizontal CG velocity in the last step (m/s)* (hCGvls) *Change of vertical CG velocity in the last step (m/s)* (vCGvls)
Take-off parameters (TO):	*Decrease of horizontal velocity (m/s* (dhv) *Increase of vertical velocity (m/s)* (ivv) *Duration of take-off contact (s)* (toc) *Height of CG at the end of the take-off (cm)* (hCGto) *Angle between CG and contact leg at the end of the take-off (^{0})* (aCGcl)
Parameters of flight (F):	*Maximal height of the flight (cm)* (hmax) *Time for reaching thepeak height of flight (s)* (thmax) *Horizontal move of CG till the moment of the release (cm)* (hCGt) *Duration of flight (s)* (tflg)
Parameters of throw (T):	*Height of the throw (cm)* (hthr) *Velocity of the throw (m/s)* (vt) *Decrease of maximal CG height till the throw (cm)* (decrmax) *Period from the take-off tillthe release (s)* (tdto/t)
Parameter of landing (L):	*Height of CG in the moment of landing, contact with the ground (cm)* (hCGlan)

Legend: CG - centre of gravity

phases of the jump shot (approach, take-off, flight, throw, landing). On the basis of the average mark, we therefore obtained a common assessment of the quality of the jump shot for the individual subject. Since the motor action in the jump shot is of relatively short duration, we defined those parameters in the individual phases which we felt could be visually assessed with sufficient precision (Table 3).

In order to achieve a better homogeneity between the referees, we defined the common criteria for assessing the individual phases, after determining the parameters and a precise definition of the execution of the jump shot.

We used a five-level criterion scale; its values are descriptive (1 – unacceptable; 5 – excellent).

The SPSS statistical package was used for other statistical data analyses. Kendall's concordance coefficient (W) was computed to assess the congruity of the referees in assessing the quality of the jump shot. In order to find the correlation between the ranks obtained by the expert system SPEX and the ranks of the referees (assessing the validity of the expert model of the jump shot) we used the Spearman's correlation coefficient.

Results

The absolute values of the kinematic parameters (Table 4) represent the basis of those input values (data) with which it is possible to construct and evaluate a kinematic model of performance of the jump shot, from the viewpoint of technique on the basis of expert modelling.

After this we formed a suitable model of a decision tree. On the left side is the tree structure: individual phases of the jump shot were given in capital letters, the variables in the individual phases in small letters (Table 5). The highest node represents an assessment of performance of the subject in the jump shot. The weights are then given, showing the importance of the individual kinematic parameters (nodes).

Table 3. Description of criterion values for assessing jump shot quality

	DESCRIPTION OF THE CRITERION VALUES				
Mark	**Approach**	**Take-off**	**Flight**	**Throw**	**Landing**
5 EXCELLENT	Optimal length of the last stride and simultaneous lowering of CG; execution is fluent, rhythmic	Placement of take-off leg precisely towards the goal; take-off is vertical, explosive, elastic	Preservation of optimal lateral position and action of swing leg throughout the flight phase till the throw,	In the throw phase the elbow is high and travels at head height; correct order of inclusion of muscle groups into the throw; explosive execution	Optimal landing on take-off leg or on both legs simultaneously with evident amortisation – stiffness of musculo-tendon apparatus is optimal and allows relaxed forward running at once
4 VERY GOOD	Very good, but certain departures from the optimal execution can be seen	Very good technical execution, but small deviations in execution dynamics appear	Very good, but some deviations from optimal execution can be seen, especially in the action of the swing leg	Execution very good, but some departure from an ideal execution is seen	Execution very good, but some deviation from ideal execution is seen, especially in the amortisation phase
3 GOOD	Somewhat too short or too long last stride; execution still fluent, rhythmic	Placement of take-off leg somewhat apart from the goal; take-off directed a little too forward	Execution good but amplitudes of movements average (poor flexibility)	During the throw the elbow travels a little too low, technique and dynamics of execution good	Average execution, with slight loss of balance, which can mean a worse starting point in the game
2 ACCEPTABLE	Execution not fluent, non-rhythmic; breaks in the movement are seen, uncontrolled lowering of CG	Take-off oriented markedly forward, take-off execution not elastic (bad transition from the eccentric to the concentric muscular contraction)	Just satisfactory trunk unwinding, consequence of the action of swing leg in forward direction	Satisfactory height of elbow during throw; evident errors in throw technique	Landing unreliable, athlete staggers after landing
1 UNACCEPTABLE	Evident departures in length of the last stride and lowering of CG; execution not fluent, non-rhythmic; intermittent movement	Placement of take-off leg is significantly away from the goal, take-off directed markedly forward, execution very non-elastic	Unsatisfactory lateral position, swing leg remains too low and acts only in forward direction, too quick opening for a throw	Elbow travels markedly too low (at or below the shoulders), throw performed only from the elbow, dynamics unsatisfactory	Landing on non-take-off leg; co-ordinatively completely wrong, usually consequence of bad execution of previous phases

Table 4. Parameters of the kinematic model of the jump shot and values achieved by the subjects

		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
A	**vCGhls** (cm)	-1.0	-0.9	-1.1	-1.2	-2.4	-2.2	-0.8	-2.1	-2.0	-2.3
	hCGvls (m/s)	-1.20	-1.34	-1.32	-1.26	-1.25	-1.59	-1.42	-1.82	-1.52	-1.59
	vCGvls (m/s)	3.07	3.01	3.17	2.77	2.45	2.69	2.93	3.01	2.30	2.56
TO	**dhv** (m/s)	-0.78	-0.77	-0.74	-0.85	-0.85	-0.69	-0.77	-0.76	-0.87	-0.77
	ivv (m/s)	0.42	0.39	0.41	0.34	0.33	0.31	0.37	0.34	0.34	0.35
	toc (s)	0.24	0.25	0.25	0.27	0.26	0.26	0.25	0.24	0.28	0.27
	hCGto (cm)	142	143	132	140	124	125	131	126	135	134
	aCGcl (^{0})	58	60	56	52	54	55	52	53	64	61
F	**hmax** (cm)	179	187	184	177	156	166	177	171	167	171
	thmax (s)	0.26	0.29	0.29	0.30	0.26	0.28	0.31	0.31	0.25	0.28
	hCGt (cm)	105	116	162	124	114	114	122	156	149	116
	tflg (s)	0.68	0.67	0.75	0.62	0.59	0.65	0.67	0.68	0.60	0.65
T	**hthr** (cm)	291	308	284	285	262	274	282	251	243	283
	vt (m/s)	24.5	25.5	25.0	25.0	24.9	24.7	23.6	22.0	21.3	23.6
	decrmax (cm)	3.1	2.9	14.7	9.3	6.1	5.6	5.1	20.4	23.1	7.3
	tdto/t (s)	0.33	0.35	0.45	0.43	0.37	0.39	0.42	0.52	0.52	0.38
L	**hCGlan** (cm)	118	132	123	127	116	118	117	108	115	121

Legend: **S1….S10** – subjects; **A** – approach; **TO** – take off; **F** – flight; **T** – throw; **L** – landing; **vCGhls** - vertical change of CG height in the last step *(cm)*; **hCGvls** - change of horizontal CG velocity in the last step *(m/s)*; **vCGvls** - change of vertical CG velocity in the last step *(m/s)*; **dhv** - decrease of horizontal velocity *(m/s)*; **ivv** - increase of vertical velocity *(m/s)*; **toc** - duration of take-off contact *(s)*; **hCGto** - height of CG at the end of the take-off *(cm)*; **aCGcl** - angle between CG and contact leg at the end of the take-off *(^{0})*; **hmax** - maximal height of the flight *(cm)*; **thmax** - time for reaching the maximal height of flight *(s)*; **hCGt** - horizontal move of CG till the moment of throw *(cm)*; **tflg** - duration of flight *(s)*; **hthr** - height of throw *(cm)*; **vt** - velocity of throw *(m/s)*; **decrmax** - decrease of maximal CG height till the throw *(cm)*; **tdto/t** - time duration from take-off till throw *(s)*; **hCGlan** - height of CG in the moment of landing contact *(cm).*

Table 5. Decision tree of the kinematic model of the jump shot evaluated by expert modelling

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                          ┌────────N o r m a l i s e r s --──────────┐
Mark:                     >=4.0       >=3.5       >=3.0       >=2.0
Weight                    excellent   very good   good        adequate
-----  ----------- ----------- ----------- -----------
MARK           100.0
├─APPROACH       8.4
│ ├─vCGhls       3.2       <=0.9       <=1.3       <=1.9       <=2.4
│ ├─hCGvls       3.2      <=1.23      <=1.33      <=1.53      <=1.63
│ └─vCGvls       2.1      >=3.05      >=2.93      >=2.69      >=2.57
├─TAKE-OFF      31.6
│ ├─dhv          5.3      <=0.59      <=0.71      <=0.83      <=0.95
│ ├─ivv          6.3     >=0.416     >=0.378      >=0.34     >=0.302
│ ├─toc         10.5      <=0.23      <=0.25      <=0.27      <=0.29
│ ├─hCGto        4.2        >=145       >=137       >=129       >=121
│ └─aCGcl        5.3       56-58       55-59       53-61       50-64
├─FLIGHT        17.9
│ ├─hmax         6.3        >=191       >=179       >=167       >=155
│ ├─thmax        3.2      <=0.22      <=0.26       <=0.3      <=0.34
│ ├─hCGt         4.2        <=102       <=116       <=130       <=144
│ └─tflg         4.2      >=0.75      >=0.69      >=0.63      >=0.57
├─THROW         38.9
│ ├─hthr        10.5        >=300       >=288       >=264       >=252
│ ├─vt          12.6         >=26      >=24.8      >=23.6      >=22.4
│ ├─decrmax      9.5       <=1.1       <=8.1      <=15.1      <=22.1
│ └─tdto/t       6.3      <=0.31      <=0.38      <=0.45      <=0.52
└─LANDING        3.2
  └─hCGlan       3.2     >=131.5     >=123.5     >=115.5     >=107.5
```

Legend: **vCGhls** - vertical change of CG height in the last step *(cm)*; **hCGvls** - change of horizontal CG velocity in the last step *(m/s)*; **vCGvls** - change of vertical CG velocity in the last step *(m/s)*; **dhv** - decrease of horizontal velocity *(m/s)*; **ivv** - increase of vertical velocity *(m/s)*; **toc** - duration of take-off contact *(s)*; **hCGto** - height of CG at the end of the take-off *(cm)*; **aCGcl** - angle between CG and contact leg at the end of the take-off *(^{0})*; **hmax** - maximal height of the flight *(cm)*; **thmax** - time for reaching the maximal height of flight *(s)*; **hCGt** - horizontal move of CG till the moment of throw *(cm)*; **tflg** - duration of flight *(s)*; **hthr** - height of throw *(cm)*; **vt** - velocity of throw *(m/s)*; **decrmax** - decrease of maximal CG height till the throw *(cm)*; **tdto/t** - time duration from take-off till throw *(s)*; **hCGlan** - height of CG in the moment of landing contact *(cm).*

In the node *"mark"* we therefore weighted the individual phases of the jump shot. Table 5 shows that the greatest importance was given to the throwing phase (39%). It is followed by the take-off phase (32%) and flight phase (18%). The lowest importance was given to the approach and landing phases. The former because the kinematic analysis included too few important parameters, and the latter, because it really does have a minimal import on performance in the jump shot, that is, it does not affect much the actual quality of the shot execution.

The most important parameters in the individual phases were defined as *duration of a take-off contact* (10.5%), *height of a throw* (10.5%) and *velocity of a throw* (12.6%).

We expected that the duration of the take-off contact would point to quick and elastic strength of the subjects and, indirectly, would affect the height of a throw and velocity of the ball at the ball release moment (actual moment of a throw). A very interesting kinematic parameter, from the aspect of technique and tactics of the jump shot performance, was doubtless the parameter *decrease of maximal height of the CG till the throw* (9.5%). Here we can notice the differences among the individual subjects in the technique of the jump shot execution since we tried to keep the difference between the peak CG height and the height of CG at the time of release to a minimum.

After the basic variables were transformed into scales, the data on the individual subjects were entered into the next phase on the higher levels of the decision tree. The computer (program) can give us both a numerical as well as a descriptive mark and rank for each subject (Table 6).

Table 6. Ranks, numerical and descriptive values of marks, obtained by the subjects on the kinematic model by expert modelling

Rank	SUBJECTS	Mark	
1	**S2**	3.70	very good
2	**S1**	3.68	very good
3	**S3**	3.40	good
4	**S7**	3.31	good
5	**S4**	3.28	good
6	**S6**	3.18	good
7	**S10**	3.15	good
8	**S5**	3.05	good
9	**S8**	2.62	adequate
10	**S9**	2.29	adequate

In Table 7 we can see the ranking of the individual subjects from 1 to 10, according to the mark given by the three independent referees (1 – best; 10 – worst). The referees were asked to rank the subjects according to the jump shot performance assessments.

Table 7. Marks of three independent referees

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
R1	2	1	3	5	6	8	4	7	10	9
R2	2	1	4	5	9	8	3	7	10	6
R3	1	2	4	6	8	5	3	9	10	7

Legend: R1...R3 - Independent referees; S1....S10 - subjects

The Kendall coefficient of concordance (W), which was used to find the actual and maximal congruence between the referees, was statistically significant (0.875, critical value of W = 0.56). This means that the three referees were very congruent in their assessments in spite of the rather complex system. The Spearman's correlation coefficient between the two ranks (rank according to the expert model and according to the referees) was also statistically significant.

Table 8. Computation of Spearman's correlation coefficient

			RANKA	RANKM
Spearman's rho	**RANKA**	Correlation Coefficient	1.000	.912**
		Sig. (2-tailed)	.	.000
		N	10	10
Spearman's rho	**RANKM**	Correlation Coefficient	.912**	1.000
		Sig. (2-tailed)	.000	.
		N	10	10

*** Correlation is significant at 0.01 level (2-tailed).*

Legend:
RANKA – actual rank; RANKM – rank given by referees

Table 8 and previous computations (coefficient of concordance) clearly showed that a high correlation existed between the two rankings. The high and statistically significant association is seen from the correlation coefficient (0.912).

Discussion and conclusions

In sport diagnostics, we rarely use measurements which would help us in assessing the efficiency of an athlete's technique. Such measurements are namely complicated, and most of all, the criteria used in the assessment are often unclear. This is especially true for handball, where the individual technical elements are carried out in the presence of team-mates and the opposing team players, while observing playing regulations (Šibila, 2004). In spite of this, mastering the basics of the playing technique is a prerequisite for effective performance of typical and untypical variants of the individual technical element in the game. It is especially important to discover and evaluate those parts of the individual technical element which are particularly important for an efficient execution of that element.

The success of shots (expressed as the goal shot efficiency, i.e. the percentage of throws/scores from the entire number of shots), belongs to the principal factors that influence the results or outcomes of matches in team handball (Zvonarek & Hraski, 1996). Approximately one half of all shots during a handball match are executed from the backcourt position and in 60% of them by means of the jump shot technique (Šibila, 2004). The jump shot from a straight-on approach undoubtedly belongs to the most basic technical elements of handball, taught to the youngest, and often seen at any elite handball match.

In our study, we tried to construct a kinematic model of the handball jump shot tehnique, formed on the basis of expert modelling, to help us in assessing the execution efficiency of this technical element. On the basis of the obtained data we can conclude that the level of congruence between the referees was high (W = 0.875), and that the coefficient of correlation between the actual ranks (ranks obtained on the basis of expert modelling) and the ranks given by the referees was statistically significant (0.912). The referees quite easily separated the various qualitative levels of the jump shot execution. They were aided in this by the well-conceptualised criteria which the referees used to assess the quality of the jump shot in its individual phases.

Despite the fact of not comparing kinematic data of the subjects jump shot performaces with statistical analysis, we can notice differences between the individual executions of the jump shots. Differences are seen in the results of the SPEX program as well as in the evaluations of the jump shot performances made by the independent referees. Most of the differences are probably due to the level of morphological characteristics and motor abilities of the analysed subjects (Pori & Šibila, 2003), as well as of the specificities of the playing positions (Šibila, Vuleta, & Pori, 2004). We did not want to favour a certain playing position, even though the sample of subjects consisted of six backcourt players, two wing players and two pivots. The chosen technical element - the jump shot with a straight-on approach – is namely one of the most fundamental technical elements of handball-specific motor behaviour. In the process of the gradual training of young handball players (aged 10-13 yrs) this jump shot technique is the first to be taught and learned. At that age the players should master only the elementary shots. It is true that in the process of specialisation the players get more information (knowlegde) about specific shots. But in spite of that, every well-trained handball player (regardless of his/her specialisation to specific playing positions) should be able to demonstrate the technically correct basic jump shot technique used in the present study.

The obtained results are promising since they show that this approach gives a good assessment of the kinematic structure in analysing the element. Therefore, this model can be used also in diagnosing the execution efficiency of the jump shot. An examination of individual's data and its comparison with the model norms allow one to recognise imperfections in any part of the shot execution. In future, it would also be worthwhile to evaluate other elements of handball-specific skills (especially the basic shots) in a similar way. It might make sense to construct models also by playing positions (back players, wings, pivots), especially for those elements which are specific for the playing position in question (e.g. sideways inclination shot from the wing position). It must be made clear here that such a model cannot include all the relevant variables that affect efficiency, for example, precision of targeting. And above all, the game efficiency of certain technical element in a match does not depend exclusively on the fact that a player may perform perfectly its proper kinematic structure in an isolated testing environment.

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IZVEDBA SKOK ŠUTA U RUKOMETU – KINEMATIČKI MODEL PROCIJENJEN EKSPERTNIM MODELIRANJEM

Sažetak

Uvod

Skok šut jedan je od najvažnijih specifičnih elemenata motoričkog ponašanja u rukometu pa je zbog toga vrlo važno poznavati njegovu strukturu, pri čemu nam pomaže kinematička analiza. Samo na temelju znanstvenih analiza možemo podrobno opisati tehniku izvođenja dotičnog elementa i povezati je s taktikom igre, ali i izraditi metodičke postupke za učenje i vježbanje, usavršavanje toga tehničkog elementa.

Stoga je glavni cilj ovoga rada analizirati kinematički model rukometnoga skok šuta i vrednovati ga metodom ekspertnoga modeliranja.

Metode

Uzorak ispitanika sastojao se od desetorice rukometaša, članova slovenskih nacionalnih izabranih momčadi koji svi igraju u prvoj ligi (prosječna tjelesna visina: 191.1 ± 4.48 cm; prosječna tjelesna masa: 90.0 ± 4.40 kg, prosječna dob: 23.4 ± 4.2 godine; prosječno igračko i trenažno iskustvo u seniorskim momčadima: 5.3 ± 2.1 godine), od toga šest vanjskih igrača, dva krila i dva kružna napadača.

Svaki je ispitanik, nakon 20-minutnog zagrijavanja, izveo tri skok šuta punom snagom. Za prikupljanje parametara potrebnih za kinematičku analizu koristili smo uređaj APAS (Ariel Dynamics, California, USA). Za ekspertno modeliranje koristio se Ekspertni sutav SPEX. Oblikovali smo stablo od 17 varijabli koje su predstavljale pet faza skok šuta (zalet, odraz, let, izbačaj lopte, doskok) (tablica 1).

Da bi se provjerila valjanost kinematičkog modela, tri su neovisna suca također procjenjivala kvalitetu izvedbe skok šuta svakog ispitanika. Kvaliteta izvedbe skok šuta pojedinog ispitanika izražena je prosječnom ocjenom. Definirali smo one parametre za koje smo smatrali da se mogu vizualno dovoljno kvalitetno procijeniti budući da izvedba skok šuta traje vrlo kratko (tablica 3). Tako dobiven poredak ispitanika usporedili smo s poretkom dobivenim ekspertnim modelom SPEX. Na temelju dobivenih rezultata konstruirali smo ekspertnu ocjenu za svakog ispitanika.

Rezultati

Apsolutne vrijednosti kinematičkih parametara (tablica 4) bili su osnovni ulazni podaci pomoću kojih je bilo moguće konstruirati i procijeniti kinematički model izvedbe skok šuta sa stajališta tehnike i na temelju ekspertnog modeliranja.

Nakon unosa podataka oblikovan je odgovarajući model stabla odlučivanja. Na lijevoj strani je prikazana struktura stabla: individualne faze skok šuta napisane su velikim slovima, a varijable u pojedinim fazama napisane su malim slovima (tablica 5). Najviši čvor predstavlja procjenu izvedbe pojedinog ispitanika. Nakon toga su pojedini kinematički parametri ponderirani, čime je svakom čvoru pridijeljena određena razina važnosti.

U čvoru “mark” ponderirane su pojedine faze skok šuta. U tablici 5 vidi se da je najveća važnost pripisana fazi izbačaja (39%), potom fazi odraza (32%) i fazi leta (18%). Najmanja je važnost pripisana zaletu i doskoku.

Najvažniji parametri za pojedine faze izvedbe skok šuta definirani su kao “trajanje kontakta s podlogom za vrijeme odraza” (10.5%), “visina izbačaja” (10.5%) i “brzina lopte” (12.6%).

U tablici 6 prikazan je poredak pojedinog ispitanika od prvog do desetog prema ocjenama dobivenima iz kinematičkog modela ekspertnim modeliranjem, a u tablici 7 prikazan je poredak prema procjenama triju nezavisnih sudaca (1. – najbolji; 10. - najlošiji). Stupanj slaganja sudaca bio je vrlo visok (W = 0.875), a korelacijski koeficijent između stvarnog (kinematičkog) poretka i sudačkog poretka bio je statistički značajan (0.912).

Rasprava i zaključak

Mjerenja učinkovitosti izvedbe pojedinog tehničkog elementa vrlo su komplicirana, a ni kriteriji nisu uvijek potpuno jednoznačni. To osobito vrijedi za rukomet gdje se pojedini tehnički element izvodi u nazočnosti i djelovanju suigrača i protivnika, uz obvezno poštovanje pravila igre. Usprkos tomu, svaki igrač na svakoj poziciji mora usavršiti sve tehničke elemente kako bi ih mogao izvoditi kao tipične i netipične varijante. Pri tome je jako važno odrediti one dijelove pojedinog tehničkog elementa koji su osobito važni za njegovu učinkovitu izvedbu.

Uspješnost izvedbe udaraca na vrata (izražena kao postotak šuta) jedan je od ključnih čimbenika uspješnosti u rukometnoj utakmici – otprilike polovina svih udaraca na vrata izvede se s pozicija vanjskih igrača, a od toga 60% tehnikom skok šuta.

Igrači se međusobno razlikuju po načinu izvedbe skok šuta, što se vidi i iz rezultata programa SPEX i iz ocjena sudaca. Većina razlika vjerojatno proizlazi iz razlika u morfološkim i motoričkim obilježjima pojedinih ispitanika, ali i iz specifičnosti pojedinih igračkih mjesta za koja su se ispitanici već specijalizirali. U stvaranju kinematičkog modela nismo željeli dati prednost nijednoj igračkoj poziciji zato jer smatramo da je skok šut iz ravnog zaleta na zonu osnovni element, jedan od onih elemenata rukometne igre koji se prvi uče u stupnjevitoj izobrazbi rukometaša u dobi od 10 do 13 godina. Istina je da igrači kasnije, tijekom specijalizacije za pojedina igračka mjesta, stječu i usavršavaju puno širi repertoar udaraca na vrata, no opisani skok šut

i dalje ostaje osnovni udarac na vrata i svaki obrazovani rukometaš mora biti sposoban ispravno demonstrirati dotični element.

Dobiveni rezultati su obećavajući jer pokazuju da se tim pristupom može dobro ocijeniti kinematička struktura skok šuta. Usporedba podataka o izvedbi skok šuta pojedinog igrača s modelnim vrijednostima (modelom) omogućuje da se otkriju nepravilnosti u izvedbi. Ubuduće bi bilo dobro da se jednako procijene i drugi rukometni tehnički elementi (osobito sve vrste udaraca na vrata). Bilo bi dobro da se konstruiraju modeli tehničkih elemenata specifični za pojedinu igračku poziciju. Pritom valja imati na umu da takav model nikako i nikada ne može obuhvatiti sve relevantne varijable koje utječu na učinkovitost, primjerice preciznost. I, što je još važnije, učinkovitost primjene pojedinog tehničkog elementa u utakmici ne ovisi samo o kinematičkoj ispravnosti izvedbe. Konačno, držimo da je tako konstruiran kinematički model skok šuta dobar kriterij za procjenu kvalitete izvedbe osnovnih tehničkih elemenata kod seniora.