EBM. RECIDE E-Balonmano.com: Revista de Ciencias del Deporte
E-balonmano.com: Journal of Sport Science / ISSN: 1885–7019
Abrev: Ebm. Recide / Ebm. JSS
Año: 2013 / Vol: 9

INFLUENCE OF THE THROWING DIRECTION ON BIOMECHANICS OF MOVEMENT PATTERNS IN HANDBALL THROWS

Influencia de la dirección de lanzamiento en la biomecánica de los patrones de movimiento en el lanzamiento en balonmano

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Recibido: 09/05/2013
Aceptado: 04/07/2103

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Abstract

The purpose of this study was to compare players' intra-individual variability in the movement pattern of four throwing directions, which were realized to one of the corners of the goal, in presence of the goalkeeper in handball. Five players participated at the first division of Spanish Handball. Each thrower completed 35 throws in different directions. 3D video techniques were used to determine the rectangular components of the spacial positions between 5 body markers and the ball. An analysis of variance was used to detect the changes produced by the direction of the throw. An additional analysis of variance was used to measure the temporary differences of the direction of the throw using the positions of the 5 body markers used by the 3 specialist throwers. The data showed that when the throw was directed to the left side, the time for the throw was significally longer, and when the throw was directed to lower zones, the time of release tended to increase even more, because the ball is released higher.

Key words: variability, movement patterns, kinematics

Resumen

El propósito de este estudio ha sido comparar la variedad intraindividual del los patrones de movimiento para cuatro direcciones de lanzamiento realizadas a cada una de las cuatro esquinas de la portería en presencia de un portero de balonmano. Los participantes han sido cinco jugadores de Primera División Española. Cada jugador efectuó 35 lanzamientos a diferentes direcciones. Se han utilizado técnicas fotogramétricas tridimensionales para determinar las componentes rectangulares de la posición espacial de 5 marcadores corporales y el balón. Se ha efectuado un análisis de varianza para detectar los cambios producidos en la dirección de lanzamiento y un análisis de la varianza complementario para medir las diferencias temporales de los marcadores corporales para los 3 lanzadores especialistas. Los datos obtenidos muestran que cuando los lanzamientos se dirigen a la zona izquierda de la portería el tiempo de lanzamiento es significativamente mayor y cuando el lanzamiento se dirige a zonas bajas, el tiempo hasta la suelta del balón tiende a incrementarse, debido a que el balón es lanzado desde una mayor altura.

Palabras clave: variabilidad, patrones de movimiento, cinemática

Most research on the detection of thorw direction indicators has used movement patterns associated with sequential kinetic chains, which begin with the mobilization of the proximal segment going to the most distal (PD sequence). To enable the most distal segment to reach a high final velocity, this model uses the angular momentum transfer from one segment to another and a greater contribution from moments of contraction of the muscles involved (Herring and Chapman, 1992; Putnam, 1993). The necessary energy transfer from the most proximal to the most distal segment requires a temporal sequence that determines some individual stability in the pattern of the throw, so that cognitive theories of learning and motor control have considered it as an invariant motor schema (Schmidt, 1985).

Where there is interaction between goalkeeper and throwers, the former should anticipate the direction of release from cues obtained from the thrower's movement pattern while the throwers should hide that information to deceive the goalkeeper. Specifically, for the throws on goal in handball, Schorer, Baker, Fath and Jaitner, (2007) have distinguished between variability caused by chance, which is reduced with practice, and active functional variability related to the changes made in the movement pattern in order to trick the opponent, at which expert throwers become very adept.

In general, it has been shown that expert players are able to anticipate the direction and intercept the ball successfully on the basis of the information given by the opponent moments before the release of the ball (Lidor, Argov, and Daniel, 1998; Vignais et al., 2009; Gutiérrez-Dávila, Rojas, Ortega, Campos and Parraga, 2011). The fact that goalkeepers can make this prediction implies that there is a degree of stability in the thrower's movement pattern of release. Schorer et al., (2007) have considered the existence of a set of patterns determined by the direction of release and where the thrower can use two types of strategies to mislead the goalkeeper: a) use different movement patterns to throw in a specific direction and b) use the same movement pattern to throw in different directions. However, this option requires the movement pattern to be modified at some point to aim the ball in the desired direction. Bearing in mind the efficiency of the PD model used in throws that seek to achieve high tangential velocity of the most distal segment and the interaction between goalkeeper and thrower, it seems that the thrower should delay any necessary changes or adjustments in the movement pattern until moments close to the ball release depending on the goalkeeper's movements. This complex strategy could change the temporal sequence of the PD model and, consequently, ball release velocity (Herring and Chapman, 1992).

Despite the importance of the goalkeeper-thrower interaction on the active functional variability of throwing patterns in handball, most research has ignored such interaction. This present research establishes a strategy closer to reality, linking possible changes in the throwing pattern to the goalkeeper's movements, and expecting the variability of movement patterns used for each throw direction to increase as a result of the uncertainty provided by the goalkeeper's presence.

In the light of the above, this paper has the objective of the detection of the intraindividual variability in the movement pattern the thrower uses for ten-metre throws aimed at four different in the presence of the goalkeeper.

Methods

Participants

Twelve maleteam handball players, all of them free of injuries, took part in this research, all of whom were playing for Spanish first division handball teams. The 5 throwers had an average experience of 14.2 ± 1.7 years and they were active in Spanish first division handball during the data collection . Two of them (S1 and S2) have played in the specific position of pivot (age = 25 ± 2 years; size = 1.91 ± 0.04 m, mass = 94.36 ± 4.26 kg). Three others (S3, S4, S5), have played in specific first line (left side) positions, specialising in distance shooting (age = 23 ± 1 years, height = 1.84 ± 0.05 m, mass = 82.91 ± 7.71 kg). They were chosen taking into account the similarity of their physical and anthropometric characteristics, that they were all right-handed and . The seven goalkeepers had over eight years experience (age = 28 ± 5 years, height = 1.86 ± 0.03 m, mass = 89.79 ± 9.93 kg). The protocol was fully explained before testing began, after which they signed an informed consent document. This document and the experimental protocol were approved by and followed the guidelines of the Ethics Commitee of the University of Granada and the current national law and regulations.

Design

Accepting the suggestions made by Button, Davids, and Schöllhorn (2006) and Bartlett, Wheat and Robins (2007), about the best methodology for analysing the variability and structure of movement patterns, we decided to use an intra-subject rather than an inter-subject design. Each player made 35 throws at goal in four different directions. In all cases the thrower's dominant side was his right side and the directions of the throws were: a) the top right hand corner of the goal (RH), b) the bottom right hand corner of the goal (RL), c) the top left hand corner of the goal (LH) and d) the bottom left hand corner of the goal (LL).

Procedure

After a preliminary warm-up, they were instructed to throw with the front foot on the ground, seeking maximum velocity of ball release, but aiming each time at one of the four pre-determined targets. Despite the restrictions set by the experimental situations, we intended to reproduce the real situation. Consequently, the throwers were informed that they could perform their usual pre-throw run-up and were free to choose the direction of throw most appropriate in each case, changing direction during the throw if they saw fit. The trials were conducted in blocks of five, using a different goalkeeper for each block and with the same order for all throwers. Thus, each thrower performed thirty-five valid attempts.

All the goalkeepers were instructed to stand in their usual positions and not to move prior to making the final action to intercept the ball. After the usual warm-up, each goalkeeper tried to intercept the throws. After recording the thirty-five valid throws from each thrower we selected for analysis those throws whose trajectory did not deviate more than 0.4 m from the four outer corners of the goal.

Data Collection

The field players made their final throw adjusting their final steps within an area 10 m from goal. This had previously been delimited by a reference system (SR1) where the horizontal axis (x) was along the ground and perpendicular to the goal; the transverse axis (y) was along the ground and perpendicular to the former and the vertical axis (z) was perpendicular to the other two. The throws were filmed using two high speed digital video cameras, 30 m apart, Motion Scope Redlake PCI 1000S (Relake Corporation, San Diego, CA) at a frequency of 500 Hz, located on the thrower's right side 25 m from the geometric centre of the throwing area. An electronic signal was used for the synchronization of the two cameras. The accuracy of the throws was recorded with a third digital camcorder, MV730i (Canon Inc, Japan) shooting at a frequency of 25 Hz, and located 15 m behind the goal and perpendicular to it.

Data analysis and variables

We determined the distance between the geometric centre of the ball and the outer corner of the goal or external base of the goal post from the image showing the goalkeeper intercepting the ball or it approximately reaching its position, using a system for calculating 2D references associated with the goal. The calculated distance was inversely associated with throwing precision.

For all attempts selected for analysis, three-dimensional coordinates were determined for the five body points (left toe and right hip, shoulder, elbow and wrist) plus the geometric centre of the ball. Bearing in mind the suggestion of Bartlett Bussey and Flyger (2006) on the use of tracers to determine movement variability, we used markers on the five points of the body, as a useful aid for the operator. Similarly, to facilitate the digitization process for the operator and considering the performance characteristics of the cameras used, we chose to adjust the field of vision to the dimension of the reference system RS1 (2.32x1.58x2.00 m), which enabled us get a clear image of the thrower, although pictures of the run-up were lost.

The calculation process was conducted in three phases: a) the positions of the six points were digitised from images from two high speed video cameras at a frequency of 125 Hz; b) the direct linear transformation method (Abdel-Azir and Karara, 1971) was used to obtain three-dimensional coordinates and c) quintic spline functions (Wood and Jennings, 1979) were applied to the spatial coordinates obtained in the previous phase to smooth and interpolate them at the same frequency at which they were filmed (500 Hz). To determine the instantaneous tangential velocity of the ball at the approximate time of its release ($Vt_{(RELEASE)}$), which occurred between two consecutive images (a time interval of 0.002 s) the first time-derivative of the quintic spline functions was used. Throwing time ($T_{(THROW)}$) was considered as the period between the instant when the front foot makes full contact with the floor and the release of the ball.

In order to compare the three-dimensional coordinates of digitized points for every release, there was a transformation with respect to a reference system (RS2), whose origin was located at the coordinates of the left throwers' toe when it was fully supported on the ground and both directions of their axes coincided with RS1. Finally, we stored the spatial coordinates of the markers of the hip, shoulder, elbow, wrist, and the geometric centre of the ball, which we repeated for the 35 throws analysed for each thrower. For each point, data were grouped into three data sets (one for each coordinate) of 35 series with 140 data in each throw. Figure 1 represents the two reference systems utilized in the analysis (RS1 and RS2) and the four possible throwing directions to the goal.

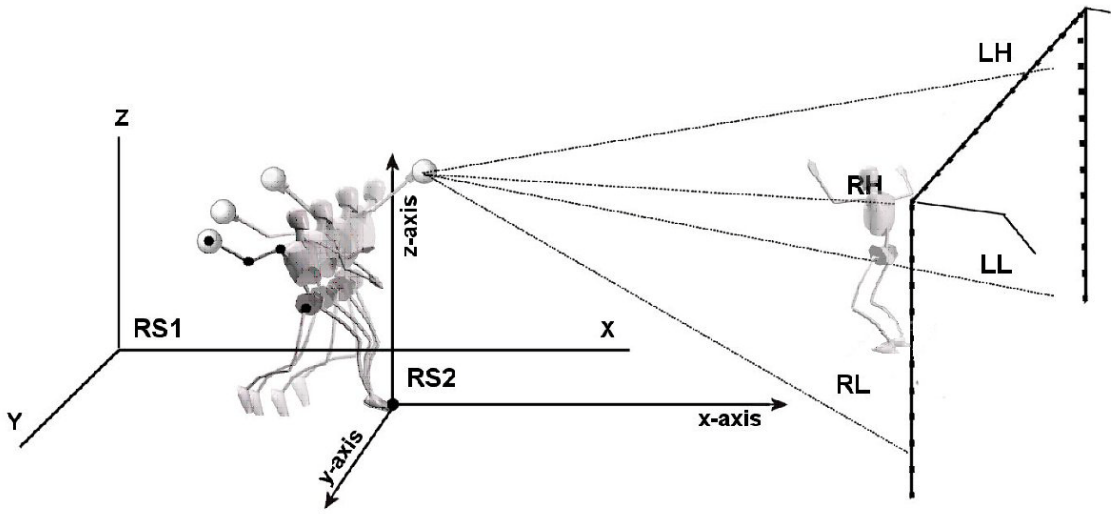

Figure 1 – Graphic representation of the two Coordinate Systems used (SR1 and SR2) and the four possible throwing directions to the goal (RH, RL, LH, and LL).

Statistics Analysis

Considering the time of the ball´s release from the hand of the thrower with the time zero (t=0), each set of data, was applied an analysis of factorial variance to the corresponding time data: t=0, t= -50 ms; t= -100 ms, t= -150 ms; t= -200 ms y t= -250 ms (the negative value indicates that it was produced before the release). The following factors were utilized: a) the side of the goal, RIGHT and LEFT and b) the height of the goal: TOP and LOW.

This procedure enabled us to detect the effect produced by the different throwing directions in the temporal structure of each data set. For the statistical treatment of data we have used the software Statgraphics 5.1 Statistical Graphics Corporation (STCs, Inc. 2115 East Jefferson Street, Rockville, Maryland, 20852. USA).

Results

Table 1 presents records of the central tendency, together with the effect produced by the direction of the throw (RIGHT-LEFT and TOP-LOW) over the velocity of the ball in the moment of release ($Vt_{(RELEASE)}$) and the time of the throw (T_{THROW}). For the four throwers, the data showed that when the throw was directed to the left side, T_{THROW} was significally longer ($p<0.01$), and when the throw was directed to lower zones, $Vt_{(RELEASE)}$ tended to increase even more. Only the thrower S4 maintained similar records in all throwing directions.

Table 1 – Descriptive statistics and analysis of the variance of the tangential mean of velocity of the ball at the time of release ($Vt_{(RELEASE)}$) and the time of the throw (T_{THROW}) for the directions of the proposed throws (RIGHT-LEFT and TOP-LOW).

VARIABLES	*RIGHT* (N=22)	LEFT (N=7)	F	TOP (N=16)	LOWER (N=13)	F
$Vt_{(RELEASE)}$ ($m \cdot s^{-1}$)	23.99±1.13	24.29±1.75	0.29	23.51±1.11	24.66±1.24	6.35*
$T_{(THROW)}$ (ms)	220±13	236±9	9.47**	225±15	223±12	0.08
			S2			
	RIGHT (N=20)	LEFT (N=13)	F	TOP (N=16)	LOWER (N=17)	F
$Vt_{(RELEASE)}$ ($m \cdot s^{-1}$)	23.52±0.91	24.58±1.12	2.38	23.71±0.93	24.78±1.01	5.06*
$T_{(THROW)}$ (ms)	223±11	238±10	10.34**	228±10	235±12	2.12
			S3			
	RIGHT (N=15)	LEFT (N=16)	F	TOP (N=16)	LOWER (N=15)	F
$Vt_{(RELEASE)}$ ($m \cdot s^{-1}$)	23.27±1.34	24.16±1.11	3.84	22.98±0.99	24.65±0.96	20.70***
$T_{(THROW)}$ (ms)	185±11	201±10	17.32***	191±14	196±13	1.06
			S4			
	RIGHT (N=16)	LEFT (N=11)	F	TOP (N=11)	LOWER (N=16)	F
$Vt_{(RELEASE)}$ ($m \cdot s^{-1}$)	25.83±1.29	25.21±0.90	1.81	25.41±1.40	25.63±1.02	0.20
$T_{(THROW)}$ (ms)	240±17	244±8	0.54	245±7	239±16	0.95
			S5			
	RIGHT (N=17)	LEFT (N=10)	F	TOP (N=8)	LOWER (N=19)	F
$Vt_{(RELEASE)}$ ($m \cdot s^{-1}$)	24.06±1.70	25.26±1.61	2.96	23.28±1.50	25.18±1.58	9.29**
$T_{(THROW)}$ (ms)	187±12	207±17	10.80**	191±12	196±19	0.59

*** p<0.001; ** p<0.01; * p<0.05

Tables 2-3 present the analysis of variance done together with all three sets of data (x-axis, y-axis, z-axis) collected from the markers with positions on the hip, shoulder, elbow, and ball, in six selected moments (in order to simplify the data, the moments and the markers that were obtained were presented as follows, p<0.05 or higher, in some of the axis analyzed). At the top, the information presents the differences found between the sides of the throw (RIGHT – LEFT), and at the bottom, the differences between the two heights of the throws (TOP – LOW).

Thrower S1 shows clear differences (p<0.01) in the x-axis of the body marker placed on the hip, from -250 ms until the release of the ball from the hand of the thrower (t=0), advancing farther forward when done on the left side. This same behavior was maintained from the marker located on the elbow, from t=-150 ms and the ball, from t=-50 ms. With respect to the y-axis, from -250 ms, a tendency for the four markers to be farther from the origin SR2 was observed, when the throw was directed to the left side, changing the tendancy from t=-50. Finally, the vertical axis (z-axis) presents the clear differences from -100 ms, where the markers were higher, when the throw was directed to the left. With respect to the height of the throw, certain differences were found in the time t=0 for the x-axis with the body markers on the elbow and the ball, farther when the throw was directed to lower zones.

Thrower S2 (table 2) shows a similar behavior in relation to the description of thrower S1. Therefore, the x-axis showed differences for the four markers from -150 ms, until the release of the ball from the hand of the thrower (t=0), with all of the markers advancing in distance when the throw was directed to the left side of the goal. With respect to the y-axis, from -150 ms, a tendency to maintain from the elbow and the ball a larger distance when the thrower directed the ball to the left side, changing the tendency from t=-50 ms.

Finally, the vertical axis (z-axis) shows clear differences between the sides of the throws from -50 ms, where the markers of the shoulder, elbow, and ball were higher, when the throw was directed to the left side.

With respect to the height of the throw, certain differences were found in the markers on the elbow and the ball ($p<0.05$) from t=-50 in the three axises. In the x-axis the two markers were farther from the body when the throw was directed to a lower zone, in the y-axis they were further separated from the thrower when the throw was directed to higher zones, and the z-axis both of the markers maintained positions higher when t=-50, although a significant statistic from the final throw was not present.

Thrower S3 (table 3) continued to maintain the same kinematic pattern of movement described for both throwers S1 and S2, although the changes found were closer to the point of release of the ball (t=0). On the x-axis clear differences ($p<0.01$) were found for the markers on the elbow and the ball from -100 ms, both markers were farther advanced when the throw was directed to the left side. This difference in increase ($p<0.001$), from t=-50. With respect to the y-axis from -150 ms, observed a tendency to maintain the ball and the elbow farther separated from the thrower when the throw was directed to the left side, changing this tendency to t=-50 ms. On the vertical axis significant statistical differences were not obtained.

With respect to the height of the throw, certain differences ($p<0.01$) were found from the time t=-50 ms on the y-axis for the marker of the ball, occupying a position farther to the right when the throw was directed to the higher zones.

Thrower S4 (table 3), maintained a similar pattern throwing to both sides of the goal. On the x-axis clear differences ($p<0.01$) were obtained from the marker of the ball at the final throw (t=0), the said marker being farther when the throw was directed to the left side. With respect to the y-axis, the only clear differences found in t=0 ms for the three markers more distal (shoulder, elbow, and ball), being more to the left from the thrower when the throw was from the same side. On the vertical axis no significant statistical differences were found.

With respect to the height of the throw, clear differences ($p<0.01$) were found on the x-axis for the marker of the ball in t=0 ms, going farther when the throw is directed to the higher zones. On the y-axis, the ball tended to go further to the right when the throw was directed to higher zones, and for the z-axis the ball maintained higher positions between t=-100 ms ($p<0.001$) y en t=-50 ms ($p<0.01$) when directed to the lower zones, eliminating these differences to the final moments of the throw.

Finally, thrower S5 (table 3) produced clear statistical differences found only on the y-axis. Therefore, when t=0.150 ms, the marker from the elbow was more to the right of the thrower when the throw was aiming towards the left side, changing the tendency from t=50, to the final. A similar behavior was maintained from the marker of the ball, being more to the right of the thrower when t=-100, and when the throw was aiming to the left side ($p<0.05$), changing this tendency to the finish of the throw ($p<0.001$). With respect to the height of the throw, certain differences were obtained from the x-axis when t=0, meaning the ball advanced farther when the throw was aimed to the left side.

Table 2 – Analysis of variance in function of the side of the throw (top zone) and the height of the throw (lower zone) for the three parts of data taken from the markers (x-axis, y-axis, z-axis) corresponding to the S1 and S2 thrower.

S1										
		x-axis (m)			y-axis (m)			z-axis (m)		
Time (ms)	Marker	RIGHT	LEFT	*p*	RIGHT	LEFT	*p*	RIGHT	LEFT	*p*
-250	Hip	-0.99±0.07	-0.90±0.06	**	0.13±0.04	0.19±0.05	**	0.93±0.03	0.97±0.03	*
	Shoulder	-1.12±0.07	-1.03±0.10		0.15±0.06	0.22±0.06	*	1.53±0.03	1.55±0.01	
	Elbow	-1.38±0.08	-1.31±0.09		0.16±0.06	0.20±0.06		1.44±0.04	1.45±0.03	
	Ball	-1.52±0.10	-1.37±0.12	*	0.54±0.07	0.64±0.07	**	1.41±0.10	1.38±0.09	
-200	Hip	-0.90±0.06	-0.82±0.05	**	0.14±0.04	0.19±0.04	*	0.93±0.03	0.96±0.03	
	Shoulder	-1.00±0.06	-0.98±0.10		0.15±0.06	0.22±0.06	*	1.53±0.03	1.56±0.02	
	Elbow	-1.30±0.07	-1.22±0.08	*	0.17±0.06	0.21±0.05	*	1.45±0.04	1.46±0.04	
	Ball	-1.36±0.10	-1.22±0.12		0.53±0.07	0.65±0.07	***	1.57±0.09	1.54±0.09	
-150	Hip	-0.76±0.06	-0.68±0.05	**	0.16±0.04	0.21±0.04	**	0.91±0.03	0.94±0.03	
	Shoulder	-0.83±0.06	-0.75±0.09	*	0.15±0.05	0.21±0.06	*	1.52±0.02	1.54±0.02	*
	Elbow	-1.13±0.06	-1.04±0.08	**	0.24±0.06	0.32±0.03	**	1.41±0.04	1.44±0.05	
	Ball	-1.17±0.11	-1.07±0.13		0.41±0.08	0.52±0.08	**	1.84±0.05	1.85±0.05	
-100	Hip	-0.63±0.07	-0.54±0.04	**	0.18±0.04	0.23±0.05	**	0.88±0.04	0.92±0.04	*
	Shoulder	-0.60±0.05	-0.54±0.07	*	0.19±0.05	0.22±0.04		1.51±0.03	1.54±0.02	**
	Elbow	-0.83±0.06	-0.70±0.08	**	0.45±0.05	0.52±0.04	**	1.49±0.04	1.54±0.05	*
	Ball	-1.01±0.08	-0.94±0.10		0.27±0.07	0.37±0.05	**	1.88±0.04	1.91±0.06	
-50	Hip	-0.51±0.05	-0.42±0.04	***	0.21±0.05	0.27±0.06	*	0.88±0.04	0.92±0.05	*
	Shoulder	-0.36±0.06	-0.28±0.08	*	0.17±0.05	0.17±0.07		1.52±0.03	1.58±0.02	***
	Elbow	-0.30±0.06	-0.17±0.07	***	0.49±0.06	0.44±0.05	**	1.59±0.03	1.67±0.04	***
	Ball	-0.69±0.07	-0.58±0.07	**	0.43±0.06	0.48±0.05		1.86±0.03	1.92±0.04	***
0	Hip	-0.45±0.06	-0,36±0.04	**	0.23±0.07	0.29±0.08		0.90±0.04	0.95±0.06	*
	Shoulder	-0.15±0.06	-0.10±0.07		0.13±0.05	0.11±0.04		1.52±0.04	1.58±0.02	***
	Elbow	0.04±0.05	0.12±0.06	**	0.38±0.06	0.28±0.05	***	1.56±0.04	1.64±0.03	***
	Ball	0.25±0.07	0.38±0.08	***	0.66±0.06	0.47±0.07	***	2.00±0.05	2.09±0.04	***
		TOP	LOWER	*p*	TOP	LOWER	*p*	TOP	LOWER	*p*
0	Elbow	-0.03±0.08	-0.08±0.07	*	0.34±0.05	0.33±0.07		1.60±0.03	1.60±0.03	
	Ball	0.26±0.08	0.32±0.07	*	0.57±0.05	0.54±0.06		2.06±0.06	2.03±0.04	

S2										
		x-axis (m)			y-axis (m)			z-axis (m)		
Time (ms)	Marker	RIGHT	LEFT	*p*	RIGHT	LEFT	*p*	RIGHT	LEFT	*p*
200	Elbow	-1.40±0.06	-1.32±0.10		0.14±0.06	0.17±0.06		1.40±0.05	1.40±0.06	
	Ball	-1.48±0.10	-1.34±0.12		0.49±0.06	0.61±0.08	**	1.54±0.07	1.49±0.08	
150	Shoulder	-0.92±0.07	-0.84±0.08	*	0.12±0.05	0.16±0.06		1.49±0.04	1.49±0.03	
	Elbow	-1.22±0.07	-1.13±0.09	*	0.21±0.05	0.28±0.04	*	1.39±0.05	1.41±0.06	
	Ball	-1.28±0.08	-1.16±0.10	*	0.38±0.08	0.49±0.07	**	1.81±0.05	1.79±0.06	
-100	Hip	-0.72±0.07	-0.64±0.05	*	0.16±0.06	0.20±0.05		0.86±0.03	0.87±0.04	
	Shoulder	-0.71±0.07	-0.62±0.08	*	0.16±0.05	0.18±0.05		1.49±0.04	1.48±0.02	
	Elbow	-0.93±0.07	-0.78±0.07	**	0.43±0.05	0.50±0.05	**	1.47±0.05	1.50±0.04	
	Ball	-1.12±0.08	-1.03±0.08	*	0.24±0.06	0.34±0.06	**	1.85±0.04	1.87±0.05	
-50	Hip	-0.60±0.05	-0.53±0.05	*	0.19±0.06	0.23±0.06		0.85±0.04	0.87±0.05	
	Shoulder	-0.48±0.05	-0.38±0.05	**	0.15±0.05	0.13±0.06		1.49±0.04	1.54±0.04	*
	Elbow	-0.40±0.07	-0.25±0.08	***	0.47±0.05	0.41±0.05	**	1.56±0.04	1.62±0.04	**
	Ball	-0.81±0.08	-0.68±0.08	**	0.40±0.06	0.45±0.06		1.80±0.04	1.86±0.05	*
0	Hip	-0.53±0.06	-0,46±0.05	*	0.20±0.06	0.25±0.06		0.88±0.04	0.90±0.06	
	Shoulder	-0.23±0.05	-0.20±0.06		0.10±0.05	0.08±0.05		1.50±0.04	1.55±0.02	*
	Elbow	-0.05±0.06	0.03±0.05	*	0.36±0.05	0.25±0.05	***	1.53±0.05	1.58±0.04	*
	Ball	0.15±0.08	0.26±0.06	***	0.63±0.06	0.43±0.07	***	1.98±0.05	2.06±0.04	**
		TOP	LOWER	*p*	TOP	LOWER	*p*	TOP	LOWER	*p*
-50	Elbow	-0.37±0.07	0.27±0.08	*	0.48±0.06	0.39±0.07	*	1.54±0.05	1.64±0.06	*
	Ball	-0.73±0.07	-0.65±0.08	*	0.47±0.06	0.43±0.07	**	1.77±0.06	1.86±0.05	*
0	Elbow	-0.03±0.08	0.04±0.07	*	0.32±0.05	0.23±0.06	*	1.56±0.05	1.54±0.06	
	Ball	0.17±0.05	0.23±0.06	*	0.56±0.06	0.46±0.06	*	2.04±0.06	2.00±0.05	

*** p<0.001; ** p<0.01; * p<0.05

On the y-axis when the t=50, the elbow and the ball maintained a position more to the left of the thrower when the throw was directed to lower zones. For the z-axis the ball maintained higher positions between the times of t=-100 ms ($p<0.001$) y t=-50 ms ($p<0.01$), when the throw was directed to lower zones, therefore in the final moments of the throw, there are no differences.

Table 3 – Analysis of the variance of the function of the side of the throw (top zone) and the height of the throw (lower zone) for the three parts of data taken from the position of the markers (x-axis, y-axis, z-axis) corresponding to the S3, S4 and S5 thrower.

S3										
		x-axis (m)			y-axis (m)			z-axis (m)		
Time (ms)	Marker	RIGHT	LEFT	*p*	RIGHT	LEFT	*p*	RIGHT	LEFT	*p*
-150	Ball	-1.46±0.06	-1.42±0.07		0.32±0.06	0.39±0.06	**	1.51±0.06	1.49±0.06	
-100	Elbow	-1.05±0.05	-0.99±0.06	**	0.31±0.05	0.34±0.05		1.30±0.04	1.30±0.04	
	Ball	-1.15±0.04	-1.10±0.06	**	0.29±0.06	0.37±0.07	**	1.72±0.04	1.72±0.04	
-50	Shoulder	-0.45±0.06	-0.40±0.06	*	0.15±0.05	0.14±0.06		1.33±0.04	1.33±0.04	
	Elbow	-0.51±0.04	-0.40±0.06	***	0.50±0.05	0.46±0.05	*	1.42±0.05	1.44±0.05	
	Ball	-0.73±0.05	-0.65±0.06	***	0.42±0.06	0.45±0.06		1.78±0.04	1.80±0.04	
0	Shoulder	-0.19±0.9	-0.14±0.08	*	0.09±0.04	0.07±0.05		1.36±0.04	1.37±0.03	
	Elbow	-0.02±0.04	0.06±0.04	***	0.36±0.05	0.25±0.05	***	1.42±0.05	1.43±0.04	
	Ball	0.13±0.07	0.28±0.07	***	0.60±0.08	0.43±0.07	***	1.82±0.05	1.83±0.05	
		TOP	LOWER	*p*	TOP	LOWER	*p*	TOP	LOWER	*p*
-50	Elbow	-0.46±0.05	-0.44±0.06		0.50±0.05	0.46±0.04	*	1.43±0.04	1.42±0.06	
	Ball	-0.73±0.05	-0.65±0.06		0.47±0.06	0.40±0.05	**	1.78±0.04	1.80±0.04	
0	Ball	0.17±0.09	0.24±0.08		0.55±0.08	0.46±0.08	**	1.84±0.04	1.82±0.05	
S4										
		x-axis (m)			y-axis (m)			z-axis (m)		
Time (ms)	Marker	RIGHT	LEFT	*p*	RIGHT	LEFT	*p*	RIGHT	LEFT	*p*
-100	Ball	-0.69±0.04	-0.76±0.06	*	0.26±0.05	0.20±0.08	*	1.68±0.05	1.70±0.06	
-50	Elbow	-0.01±0.06	0.04±0.08		0.28±0.06	0.22±0.05	*	1.69±0.04	1.68±0.04	
0	Shoulder	0.30±0.5	0.29±0.08		0.01±0.05	-0.05±0.04	**	1.45±0.05	1.44±0.05	
	Elbow	0.40±0.06	0.42±0.06		0.29±0.07	0.16±0.06	***	1.56±0.06	1.55±0.04	
	Ball	0.54±0.05	0.62±0.09	**	0.44±0.09	0.26±0.10	***	2.07±0.07	1.98±0.05	
		TOP	LOWER	*p*	TOP	LOWER	*p*	TOP	LOWER	*p*
-100	Ball	-0.70±0.04	-0.72±0.07		0.23±0.06	0.24±0.06		1.64±0.05	1.72±0.06	***
-50	Ball	-0.41±0.07	0.38±0.07		0.19±0.04	0.16±0.07		1.76±0.05	1.83±0.05	**
0	Ball	0.52±0.04	0.62±0.07	**	0.42±0.08	0.33±0.07	*	2.00±0.07	1.98±0.05	
S5										
		x-axis (m)			y-axis (m)			z-axis (m)		
Time (ms)	Marker	RIGHT	LEFT	*p*	RIGHT	LEFT	*p*	RIGHT	LEFT	*p*
-150	Elbow	-1.20±0.06	-1.18±0.09		-0.02±0.06	0.05±0.03	*	1.30±0.05	1.30±0.04	
-100	Ball	-1.10±0.08	-1.10±0.08		-0.10±0.07	-0.03±0.07	*	1.65±0.05	1.64±0.03	
-50	Elbow	-0.32±0.08	-0.26±0.09		0.25±0.05	0.19±0.06	*	1.53±0.05	1.56±0.03	
0	Elbow	0.12±0.08	0.14±0.09		0.19±0.05	0.10±0.07	**	1.42±0.04	1.42±0.03	
	Ball	0.27±0.10	0.33±0.10		0.29±0.07	0.14±0.09	***	1.88±0.05	1.87±0.03	
		TOP	LOWER	*p*	TOP	LOWER	*p*	TOP	LOWER	*p*
-100	Elbow	-0.88±0.07	-0.81±0.10		0.18±0.03	0.15±0.06		1.40±0.05	1.47±0.03	**
-50	Elbow	-0.35±0.08	-0.28±0.10		0.28±0.04	0.20±0.06	**	1.51±0.04	1.55±0.03	*
	Ball	-0.36±0.06	-0.28±0.09		0.24±0.05	0.18±0.5	**	1.80±0.05	1.84±0.04	*
0	Elbow	0.12±0.07	0.14±0.09		0.23±0.04	0.13±0.06	**	1.42±0.03	1.42±0.04	
	Ball	0.21±0.07	0.32±0.10	*	0.32±0.06	0.20±0.09	**	1.89±0.03	1.87±0.04	

*** p<0.001; ** p<0.01; * p<0.05

Discussion

The temporal stability intrasubject shows the data from the time of movement (T_{THROW}) for each of the directions of the throw (table 1), together with the reduced variability intrasubject of the three groups of data referred to from the spatial positions of the analyzed markers (tables 2-3) permitted us to consider the existence of the stable patterns of movement for the five throwers and the four directions of the analyzed throws.

The factorial analysis of variance applied to the temporal data for each data set has enabled us to assess the temporal effect produced by different throwing directions on the movement pattern and consequently the amount of information the thrower provides to the goalkeeper. In this sense, the statistics were clear that the specialized players of exterior throwing (S3, S4, and S5) obtained lower levels of significance and the differences are closer to the instant of the ball release. Equally, it demonstrates that the markers more distal obtained the greatest differences between all means of the try for each direction of the throw. On the other hand, the players who were not specialists (S1 and S2) obtained levels significantly higher between both means of the attempts directed from the different directions of the throw and with more time in advance than the specialist throwers. (at least -200 ms before the release).

The data also demonstrates that the side selected of the throw (RIGHT and LEFT) produce more changes in the pattern of movement and with greater advance in time than the height of the throw (TOP and LOW), which permits us to consider that the thrower shows less indications in height, and consequently, the goalkeeper would have more difficulty predicting the height of the throw. These suggestions coincide with the contributions of Savelsbergh, Williams, Van der Kampand, Ward (2002) and Gutiérrez-Dávila, et. al., (2011) to make clear that the goalkeepers of soccer and handball, respectively, have more difficulties identifying the height of trajectory than the side of the throw.

The individual results can describe certain changes in the movement patterns for the five analyzed throwers, in function with the direction of the throw. Therefore, with respect to the side of the throw, it confirms that when the throw is from the left side, the markers from the elbow and the ball maintain a position farther position from the right side of the body, between the times t=-150 and t=-100 ms, changing the tendency from t=-50 ms, until the final throw (t=0), where finally the throw finishes at the farthest forward point from the body. The described changes for the directed throws from the left side, present a higher amplitude of movement in the transversal plane (defined by the x and axises), that justify the longer amount of time (T_{THROW}) recorded for the directed throws from the left side (table 1). In relation to the height of the throw, it can be confirmed that, between the time t=-100 and t=-50, the ball tends to be higher when the throw is directed to lower zones.

These findings are consistent with those described by Abernethy and Russell (1987), Goulet, Bard, and Fleury (1989), Abernethy (1990) and Cañal-Bruland, van Ginneken, van der Meer, and Williams (2011) in demonstrating that expert badminton, tennis or squash players are capable of collecting information in a period of between167-83 ms before the ball's contact with the racket, with the racquet and the player's arm being the most sensitive areas to extract the necessary information. In this sense, our previous studies have shown that expert goalkeepers initiate their movement -193 ± 67 ms before ball release, although the goalkeeper's movement begins with a relatively low velocity of movement of the CG, reaching only 0.09 ± 0.119 ms -1 in the -100 ms before release, a rate that increases as the moment of release approaches

(Gutierrez-Davila et al., 2011). This behaviour by the goalkeeper has been justified as not giving cues or direction indicators to the thrower while being able to rectify his movements in case of error, a very effective strategy by expert goalkeepers in the interaction of strategies between thrower and goalkeeper. The results of this research reinforce this idea, showing that the differences between the averages of attempts at the different throwing directions increase as the moment of release approaches.

Finally, the results suggests that the players less specialized in distance throwing utilize different patterns to throw to different sides, while the specialized throwers utilize the same movement pattern to throw to both sides of the goal, modifying the said pattern only at the final moment of the throw. This data confirms and summarizes the contributions of Schorer et al. (2007) to consider the strategy to delay changes in the pattern movements, with the purpose to delay the information of the direction that the goalkeeper perceives, constituting a complex skill that only can be done by the most experienced throwers.

Conclusions

The most experienced players in exterior throwing perform less changes in the movement pattern which results in less time from the point of the release of the ball, appearing in the markers more distal (elbow and ball) the causes of the said changes. These results suggest that the throwers with experience and specialization in exterior throwing utilize the same movement pattern to throw to both sides of the goal, although modifying this pattern at the end of the throw.

Although the movement patterns utilized in the throws were different for each thrower, it was confirmed that certain common changes exist when throwing to the four directions: a) when the throw is directed to the left side (the non-dominant side of the thrower), the markers of the elbow and the ball maintain a greater trajectory in the transversal plane and b) between the times t=-100 and t=-50, the ball tends to be higher when thrown to lower zones. The common changes describes in the movement patterns for the five analyzed throwers, could constitute stable cues of direction that the goalkeepers should consider to predict the direction of the throw.

Referencias

Abdel-Aziz, YI, and Karara, HM. (1971). *Direct linear transformation from comparator coordinates into object space coordinates in close-range photogrammetry*. ASP Symposium on Close-Range Photogrammetry. Falls Church, VA: American Society of Photogrammetry.

Abernethy, B., and Russell, DG. (1987).The relationship between expertise and visual search strategy in a racquet sport. *Human Movement Science*, 6, 283-319.

Abernethy, B. (1990). Anticipation in squash: Differences in advance cue utilization between expert and novice players. *Journal of Sports Sciences*, 8, 17-34.

Bartlett, R., Bussey, M. and Flyger, N. (2006). Movement variability can not be determined reliably from no-marker conditions. *Journal of Biomechanics*, 39, 3076-3079.

Bartlett, R., Wheat, J. and Robins, M. (2007). Is movement variability important for sports biomechanics? *Sports Biomechanics*, 6 (2), 224-243.

Button, C., Davids, K., and Schöllhorn, WI. (2006). *Coordination profiling of movement system*. In K. Davis, S. Bennett and K. M. Newell (eds), Movements system variability. Champaign, I. L: Human Kinetics.

Cañal-Bruland, R., van Ginneken, W.F., van der Meer, B.R. and Williams, A.M. (2011). The effect of local kinematic changes on anticipation judgments. *Human Movement Science*, 30, 495-503.

Goulet, C., Bard, C. and Fleury, M. (1989). Expertise differences in preparing to return a tennis serve: a visual information processing approach. *Journal of Sport and Exercise Psychology*, 11 (4), 382-398.

Gutiérrez-Dávila, M., Rojas, F.J., Ortega, M., Campos, J. and Parraga, J. (2011). Anticipatory strategies of handball goalkeepers. *Journal of Sports Sciences*, 29 (12), 1321-1328.

Herring, R.M and Chapman, A.E. (1992). Effects of changes in segmental values and timing of both torque and torque reversal in simulated throws. *Journal of Biomechanics*, 25, 1173-1184.

Lidor, R., Argov E., and Daniel, S. (1998). An exploratory study of perceptual-motor abilities of women: Novice and skilled players of team handball. *Perceptual and motor skills*, 86, 1, 279-288.

Putnam, C. (1993). Sequential motion of body segments in striking and throwing skills: description and explanation. *Journal of Biomechanics*, 26, 125-135.

Savelsbergh, G.J.P., Williams, M., Van der Kamp, J. and Ward, P. (2002). Visual search, anticipation and expertise in soccer goalkeepers. *Journal of Sports Sciences*, 20, 279-287.

Schmidt, R.A. (1985). The search for invariance in skilled movement behavior. *Research Quarterly for Exercise and Sport*, 56, 188-200.

Schorer, J. Baker, J., Fath, F. and Jaitner, T. (2007). Identification of interindividual and intraindividual movement patterns in handball players of varying expertise levels, *Journal of Motor Behavior*, 39, 5, 409-421.

Vignais, N., Bideau, B., Craig, C., Brault, S., Multon, F., Delamarche, P. and Kulpa, R. (2009). Does the level of graphical detail of a virtual handball thrower influence a goalkeeper's motor response? *Journal of Sports Science and Medicine*, 8, 501-508

Wood, J.A and Jennings, L.S. (1979). On the use of spline functions for data smoothing. *Journal of Biomechanics*, 12, 477-479.

Referencia del artículo:

Marcos Gutiérrez-Dávila, M., Ortega-Becerra, M. Párraga, J., Campos, J., Rojas-Ruiz, F.J. (2013). Influencia de la dirección de lanzamiento en la biomecánica de los patrones de movimiento en el lanzamiento en balonmano. . *E-balonmano.com: Revista de Ciencias del Deporte 9*(2), 59-70.
http://www.e-balonmano.com/ojs/index.php/revista/index