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Polar Coordinate Analysis to Study Counterattacks in Senior and Under-16 Men's Handball

Análisis de Coordenadas Polares para estudiar el contraataque senior y sub´16 en balonmano masculino

Análise do contra-ataque sênior e sub 16 no handebol masculino usando coordenadas polares

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ABSTRACT

The aim of this study was to analyze counterattack actions by elite and under-16 players in men's handball using a methodologically validated taxonomic system. We analyzed counterattack actions in 17 games involving elite players as well as 10 games in Spanish championship of under-16 regional teams. We used the HOISAN software package and employed the polar coordinate analysis technique from the perspective of genuine retrospectivity. The taxonomy of the coding system was developed through a combination of a field format system and an exhaustive and mutually exclusive (E/ME) system of categories. The instrument includes 19 criteria and 148 categories. The focal categories used in this study were behaviors having to do with ball recovery, ball transport and counterattack completion. Differences between the studied populations were found for counterattack completion, deployment, transport and ball recovery. Technical errors were associated with the 6:0 defense in the elite categories and with the 5:1 defense in the under-16 category. In the senior categories, the number of players participating in counterattacks tended to be higher and a numerical advantage in the opponent's half of the court was associated with the team being ahead in the score; in the under-16 category, this behavior was associated with trailing in the score. We also observed that greater defender and goalkeeper effectiveness gives rise to more counterattack situations and under more favorable circumstances, and that this effectiveness is a determining factor in the success of a counterattack. The polar coordinate technique has estimated the technical-tactical relations in competition, which will allow to determine the psychological intervention strategies that improve performance.
Keywords: Systematic Observation, Game Analysis, Tactics, Handball, Polar Coordinate.

RESUMEN

El objetivo de este estudio fue analizar las acciones de contraataque de jugadores de élite y sub´16 en el balonmano masculino utilizando un sistema taxonómico validado metodológicamente. Analizamos las acciones en 17 partidos con jugadores de élite, así como 10 partidos en el campeonato de España de selecciones territoriales sub´16. Utilizamos el software HOISAN y empleamos la técnica de análisis de coordenadas polares desde la perspectiva de una retrospectividad genuina. La taxonomía del sistema de codificación se desarrolló mediante una combinación de un sistema de formato de campo y un sistema de categorías exhaustivo y mutuamente excluyente (E/ME). El instrumento incluye 19 criterios y 148 categorías. Las categorías focales utilizadas en este estudio fueron los comportamientos relacionados con la recuperación del balón, el transporte y la finalización del contraataque. Se

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encontraron diferencias entre las poblaciones estudiadas para la finalización del contraataque, el despliegue, el transporte y la recuperación. Los errores técnicos se asociaron con la defensa 6:0 en las categorías de élite y con la defensa 5:1 en la categoría de menores de 16 años. En las categorías senior, el número de jugadores que participaron en los contraataques tendió a ser mayor y una ventaja numérica en la mitad del campo se asoció con el equipo que estaba delante en el marcador; en la categoría sub´16, este comportamiento se asoció con el seguimiento en la puntuación. También se observa que una mayor efectividad del defensor y el portero da lugar a más situaciones de contraataque y en circunstancias más favorables, y que esta efectividad es un factor determinante en el éxito del contraataque. La técnica de coordenadas polares ha estimado las relaciones técnico-tácticas en competición, lo que permitirá determinar las estrategias de intervención psicológica que mejoren el rendimiento.
Palabras clave: Observación sistemática, Análisis del juego, Táctica, Balonmano, Coordenadas Polares.

RESUMO

O objetivo deste trabalho foi analisar as ações de contra-ataque no handebol masculino em dois grupos de jogadores de elite e um menor de 16 anos. Este trabalho tem como objetivo contribuir para a compreensão das ações no Handebol Masculino a partir de uma nova perspectiva. A partir de um sistema taxonômico validado metodologicamente, foram analisadas as ações de contra-ataque de 17 partidas de elite (10 da categoria espanhola mais alta de 2007-08 e 7 da equipe nacional no Campeonato Europeu de 2007) e 10 do campeonato de equipes regionais. sub 16 2006. Para isso, a técnica de coordenadas polares foi usada em sua versão genuína com o software Hoisan. As categorias focais têm sido utilizadas para recuperação de bola, transporte e comportamento de completação. Foram encontradas diferenças entre as terminações de contra-ataque nas três populações estudadas, bem como no modo de implantação, transporte e recuperação do celular. O erro técnico se manifesta desde a defesa 6: 0 nos seniores e 5: 1 no sub 16. Além disso, observouse que nas categorias seniores um número maior de jogadores participa e a superioridade numérica no centro do campo é alcançada com uma pontuação para por favor, estar no sub 16 com pontuação contra. Além disso, observouse que o aumento da eficiência defensiva e da meta traz mais situações de contra-ataque e em circunstâncias mais favoráveis, sendo decisivas para o sucesso do contra-ataque.
Palavras chave: Observação sistemática, Análise de jogos, Táticas, Handebol, Coordenadas polares.

INTRODUCTION

Coaches have shown considerable interest in understanding the complexity of the sports played by their teams and applying this knowledge in their work. In particular, they have expressed interest in identifying indicators of effectiveness that can be incorporated into training sessions and integrated into their team's approach, thus improving their performance in competition and their chances of winning (Robles et al., 2014). Authors such as Prieto et al. (2015) have recently highlighted the growing trend of considering sporting competitions as complex dynamic systems, noting that the lack of research in this field makes it a fertile area for future work. The aforementioned authors have proposed a more dynamic research vision that takes into account the context and a temporal perspective on sports.

Over the past several years, observational methodology has contributed solutions based on a set of techniques that foster a better understanding of how sports are played (Anguera & Hernández-Mendo, 2014; Aragon et al., 2016; Castañer et al., 2016). Some of these observational studies have focused on various aspects of handball. For example, studies by González (2012) and Jiménez and Hernández-Mendo (2016) have examined the efficacy of counterattacks. Works by Prudente (2006) and Prudente et al. (2010) have analyzed goalkeeper interaction with defenders as well as the differences between winning and losing teams in the interruption of offensive sequences. Similarly, studies by Rogulj et al. (2004), and Lozano and Camerino (2013) have analyzed the offensive tactical systems used in positional attacks and counterattacks.

In the context of observational methodology, polar coordinate analysis, from the perspective of genuine retrospectivity (Anguera, 1997), is a technique shown to be useful for analyzing the complexity of behavior in natural settings. The power of polar coordinate analysis lies in its capacity for data reduction without information loss. This technique is therefore suitable for mapping the relationships between a particular category—known as a focal criterion or focal behavior—and the rest of the system. These

parameters, represented in the form of vector maps (Gorospe & Anguera, 2000), make it possible to combine the prospective and retrospective perspectives. The technique involves the use of adjusted residuals derived from sequential analysis (z scores) to calculate Zsum statistics ($Zsum = \sum z / \sqrt{n}$) (Cochran, 1954), where *z* corresponds to the values obtained at lags -5 to +5 and *n* is the number of lags (Castellano & Hernández-Mendo, 2003). Thus, it is possible to analyze the nature of relationships and the intensity between categories (Anguera et al., 1997). The use of a binomial test, which compares the probabilities of the observed conducts with the expected probabilities, ensures the independence of the z scores.

Polar coordinate analysis has been applied to the analysis of various sports, including tennis (Gorospe & Anguera, 2000), soccer (Castellano & Hernández-Mendo, 2003; Perea et al., 2012), basketball (Nunes et al., 2015), water polo (Menescardi, Estevan, & Hernández-Mendo, 2019) and taekwondo (López-López et al., 2015; Menescardi, Falco, Estevan, Morales-Sánchez, & Hernández-Mendo, 2019). In handball, polar coordinate analysis has been used by Prudente (2006) to examine ball recovery behaviors, defender-goalkeeper interaction and the influence of tactics that precede the completion of a play. Similarly, González et al. (2013) studied the effectiveness of attack completion in the final moments of tied games at the 2011 World Championship and at the 2012 Olympic Games. More recently, Sousa et al. (2015) used the technique to analyze 2-on-2 situations at the 2012 European Men's Handball Championship; Morillo-Baro, Reigal and Hernández-Mendo (2015) studied positional attacks in the men's and women's categories of beach handball; and Prudente et al. (2017) analyzed the influence of playing time and partial score on collective attack tactics.

Much of the research on handball has focused on offensive parameters or attacker-defender interaction (Prieto et al., 2015), while research on other phases of the game—such as defense and counterattacks—has been more scarce. The studies that have explored these other phases include those of González (2012), who analyzed the effectiveness of counterattacks, and Prudente (2006), who studied performance factors related to defense, development and completion. Similarly, Prudente et al. (2010) studied goalkeeper effectiveness by assessing goalkeeper-defender and defender-attacker interactions. Along similar lines, authors such as Oliver-Coronado and Sosa-González (2016) have proposed that the study of defensive systems in handball must be treated as complex, nonlinear, dynamic organizations.

The description of the patterns of play during the counterattack in handball of competition will allow to know the behavioral development that will determine the techniques or strategies of psychological intervention that optimize the performance (Hernández-Mendo & Anguera, 2001). So, the objective of this study was to use polar coordinate analysis to detect associations between behaviors that occur during counterattacks and their relationship with the defense in various categories of handball competition.

METHODS

Participants

A generalizability analysis (Jiménez & Hernández-Mendo, 2016) carried out before the study determined that a total of 25 games would need to be observed in order for the study to be valid, precise and generalizable. This analysis makes it possible to estimate the degree of generalization of the measurement design with respect to the particular conditions of a theoretical value. The resulting generalizability coefficient makes it possible to estimate how the observed mean compares with the mean of all possible observations (Blanco et al., 2000; Blanco-Villaseñor et al., 2014). The following games were observed:

1. 2006-2007 Asobal League (premier Spanish handball league). Games between the top five teams: FC Barcelona, Ademar León, Balonmano Valladolid, Portland San Antonio and Ciudad Real.
2. 2006 European Men's Handball Championship. Spain vs. Slovakia, Slovenia, Ukraine, Germany and France.
3. 2006 Spanish championship of under-16 regional teams. Valencia vs. Galicia; Castile-León vs. Basque Country; Castile-León vs. Navarre; Castile-León vs. Aragón; Basque Country vs. Andalusia; Catalonia vs. Cantabria; Galicia vs. Castile-León; Catalonia vs. Madrid; Valencia vs. Andalusia; Basque Country vs. Castile-León.

The development of the present study, conducted in compliance with the ethical principles exposed by the Declaration of Helsinki (World Medical Association,

2013) entitles us to establish that: (a) the subjects of observation in this study are placed in a stadium, i.e., a public setting; (b) this setting cannot be entitled with the sufficent expectation of privacy; and (c) neither intervention nor direct interaction on the part of the observed individuals was required (https://student.societyforscience.org/human-participants). Thus, according to the rules of competitions and the guidelines and basic ethical principles described in the Belmont Report, which supports the convenience of using images of public behaviour for the sake of research on human subjects, neither ethics committee review nor written informed consent from the participants has been needed to enable the use of the analized video recordings, as these are in the public domain.

Being so, we find ourselves in the position of pointing out that ethical requirements for observational methodology have been completely met throught the whole study.

Instruments

The instrument used in this study (Table 1) was created by Jiménez and Hernández-Mendo (2016). The taxonomy of the coding system was developed through a combination of a field format system and an exhaustive and mutually exclusive (E/ME) system of categories (Anguera, 1979; Anguera & Hernández-Mendo, 2013). The instrument includes 19 criteria (type of counterattack, score, numerical balance, cause of recovery, zone of recovery, type of defense, reception area, number of passes in own field, number of passes in the opposite field, players who participate, number of boats, numerical imbalance in the opposite field, resignation zone, end zone, player who attends, player that finishes, ending, minute strip and duration) and a total of 148 categories. All criteria and categories were defined to reflect the categorical nucleus and degree of plasticity (Anguera, 1990). The instrument was validated and the results of the data quality analysis were optimal (Jiménez & Hernández-Mendo, 2016).

Table 1. Criteria and categories included in the observation instrument.

CRIT	CAT	CRIT	CAT
1. Type of counterattack	**CONTRA**: counterattack **COGOL**: quick throw-off after goal **POSIC**: positional attack **INICIO**: positional attack after start of game	**2. Score**	**MPATE**: tie **12FAV**: ahead by 1-2 goals **M2FAV**: ahead by >2 goals **12CON**: trailing by 1-2 goals **M2CON**: trailing by >2 goals
3. Numerical balance	**IGUAL**: equality **1SUP**: advantage of 1 **M1SUP**: advantage of >1 **1INF**: disadvantage of 1 **M1INF**: disadvantage of >1	**4. Cause of recovery**	**ERLANZ**: missed shot **REB**: rebound **INTER**: interception **ERTEC**: technical error **GOLCTR**: goal by opposing team
5. Zone of recovery	**Z1**: recovery in zone 1 **Z2**: recovery in zone 2 **Z3**: recovery in zone 3 **Z4**: recovery in zone 4 **Z5**: recovery in zone 5 **Z6**: recovery in zone 6 **Z7**: recovery in zone 7 **Z8**: recovery in zone 8 **Z9**: recovery in zone 9 **Z10**: recovery in zone 10 **L11**: recovery in zone 11	**6. Type of defense**	**321**: 3:2:1 defense **60**: 6:0 defense **51**: 5:1 defense **42**: 4:2 defense **33**: 3:3 defense **5M1**: 5+1 defense **4M2**: 4+2 defense **50**: 5:0 or 4:0 defense (with numerical disadvantage) **41**: 4:1 defense **REPLI**: defensive regrouping
7. Zone of reception	**ZR1**: reception in zone 1 **ZR2**: reception in zone 2 **ZR3**: reception in zone 3	**8. Passes in own half of the court**	**PP0**: 0 passes in own half **PP1**: 1 pass in own half **PP2**: 2 passes in own half **PP3**: 3 passes in own half **PP4**: 4 passes

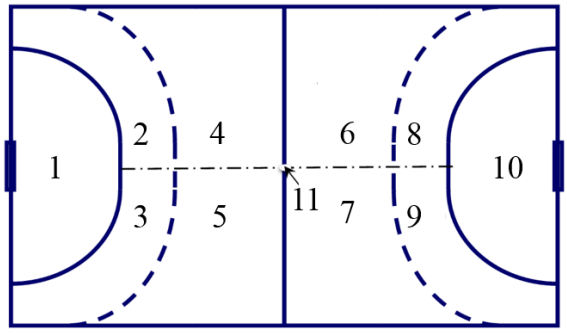
CRIT	CAT	CRIT	CAT
	ZR4: reception in zone 4 **ZR5**: reception in zone 5 **ZR6**: reception in zone 6 **ZR7**: reception in zone 7 **ZR8**: reception in zone 8 **ZR9**: reception in zone 9 **ZR10**: reception in zone 10 **NZR**: no zone		in own half **PP5**: 5 passes in own half **MPP5**: >5 passes in own half
9. Number of passes in opponent's half of the court	**PC0**: 0 passes **PC1**: 1 pass **PC2**: 2 passes **PC3**: 3 passes **PC4**: 4 passes **PC5**: 5 passes **MPC5**: more than 5 passes	**10. Number of participating players**	**1JUG**: 1 player **2JUG**: 2 players **3JUG**: 3 players **4JUG**: 4 players **5JUG**: 5 players **M5JUG**: >5 players
11. Number of bounces	**0BOTE**: 0 bounces **1BOTE**: 1 bounce **2BOTE**: 2 bounces **3BOTE**: 3 bounces **4BOTE**: 4 bounces **5BOTE**: 5 bounces **M5BOT**: >5 bounces	**12. (Im)balance in opponent's half of the court**	**ALSUP**: large advantage **SUP**: advantage **NOSUP**: equality **INF**: disadvantage **ALINF**: large disadvantage
13. Zone of relinquishment	**Z15**: zones 1-5 **Z610**: zones 6-10 **NOR**: no relinquishment	**14. Zone of completion**	**ZF1**: zone 1 **ZF2**: zone 2 **ZF3**: zone 3 **ZF4**: zone 4 **ZF5**: zone 5 **ZF6**: zone 6 **ZF7**: zone 7 **ZF8**: zone 8 **ZF9**: zone 9 **ZF10**: zone 10

CRIT	CAT	CRIT	CAT
15. Assisting player	**NASIS**: no assisting player **PASIS**: goalkeeper **AASIS**: left back **BASIS**: center **CASIS**: right back **DASIS**: right wing **EASIS**: pivot **FASIS**: left wing	**16. Completing player**	**AFIN**: left back **BFIN**: center **CFIN**: right back **DFIN**: right wing **EFIN**: pivot **FFIN**: left wing **PFIN**: goalkeeper
17. Completion	**GOLSA**: goal and sanction **GOL**: goal **PFASA**: missed penalty throw and sanction **PENFA**: missed penalty throw **SANC**: sanction **REBGOL**: rebound goal **PENGOL**: goal by penalty throw **ERRPR**: passing or catching error **ERLAN**: missed shot **FALTEC**: technical foul **PGOSA**: goal by penalty throw and sanction **NOREN**: neutral because of relinquishment **NOREB**: neutral because of rebound **NOARB**: neutral because referee stops play	**18. Time range**	**D05**: minutes 0-5 **D610**: minutes 6-10 **D1115**: minutes 11-15 **D1620**: minutes 16-20 **D2125**: minutes 21-25 **D2630**: minutes 26-30 **D3135**: minutes 31-35 **D3640**: minutes 36-40 **D4145**: minutes 41-45 **D4650**: minutes 46-50 **D5155**: minutes 51-55 **D5660**: minutes 56-60 **P105**: minutes 0-5 of 1st overtime period **P1610**: minutes 6-10 of 1st overtime period **P205**: minutes 0-5 of 2nd overtime period **P2610**: minutes 6-10 of 2nd overtime period

CRIT	CAT	CRIT	CAT
19. Duration	**2SEG**: 1-2 seconds **4SEG**: 3-4 seconds **6SEG**: 5-6 seconds **8SEG**: 7-8 seconds **10SEG**: 9-10 seconds **12SEG**: 11-12 seconds **M12SG**: >12 seconds		

To divide the playing court, we used the six-meter line, the nine-meter line, the goal area and center line as points of reference. The numbering is related to both fields, as shown in Figure 1.

Figure 1. Playing court zones.



To code the data, we used HOISAN (Hernández-Mendo, López-López, Castellano, Morales-Sánchez, & Pastrana, 2012; Hernández-Mendo et al., 2014), a software package that performs polar coordinate analysis and presents the output as vector maps.

Procedure

As a first step, a quantitative data-quality assessment was conducted with HOISAN v.1.6.3. (Hernández-Mendo et al., 2012). The use of Cohen's Kappa concordance index, as well as the Kendall tau-b, Pearson and Spearman correlation coefficients determined both intra- and interobserver agreement (Hernández-Mendo et al., 2012).

The next step had its foundations of generalizability theory, by which it would be able to optimize measurement errors in a priori studies and complement the data-quality analysis (Blanco-Villaseñor, Castellano, Hernández-Mendo, Sánchez-López, & Usabiaga, 2014; Reina-Gómez, Hernández-Mendo, & Fernández-García, 2009). This analysis was carried out by using SAGT v.1.0 (Hernández-Mendo, Blanco-Villaseñor, Pastrana, Morales-Sánchez, & Ramos-Pérez, 2016) on the application of a two-facet design (category/observer= C/O) used to calculate the reliability of observers who code the matches in an accurate way. Moreover, the same analysis, with the same design was used for the intraobserver case as well. Afterwards, the analysis was inverted (i.e. C/O) with the aim of checking the homogeneity of the different categories being used. These analyses were performed using the dataset from the observation of the men's Spain-France match at the 2006 European Handball Championship. Previously, an observational protocol and meticulous training of observers was prepared. The matches were analyzed during the months of March, April and May 2006.

The last step consisted of the use of the HOISAN software to perform a polar coordinate analysis in a way that enabled us to establish the existence of excitatory or inhibitory relationships between focal behaviors and conditional behaviors (in accordance to the quadrant where the vectors locate themselves). Only statistically significant relationships ($p<0.05$), i.e. relationships with a vector radius of ≥ 1.96, have been considered here. The characterization of the four quadrants is as follows (Anguera, Blanco, & Losada, 1997):

- Quadrant I [+,+]: Prospective and retrospective activation. Focal behavior and conditional behavior are mutually excitatory.
- Quadrant II [-,+]: Prospective inhibition and retrospective activation. Focal behavior is inhibitory and conditional behavior is excitatory.
- Quadrant III [-,-]: Prospective and retrospective inhibition. Focal behavior and conditional behavior are mutually inhibitory.
- Quadrant IV [+,-]: Prospective activation and retrospective inhibition. Focal behavior is excitatory and conditional behavior is inhibitory.

The focal behaviors—selected in order to establish their association with the conditional behaviors—are associated with various dimensions of the game. Specifically, the 5:1 defense (51) and the 6:0 defense (61) belong to the "type of defense" dimension, i.e. the defense used to recover the ball; missed shot (ERLANZ), technical error (ERTEC) and interception (INTER) belong to the "mode of

recovery" dimension, i.e. the way in which the ball is recovered; advantage (SUP) belongs to the "(im)balance in opponent's half of the court" dimension; and passing or catching error (ERRPR), goal (GOL) and assist by the center (BASIS) belong to the "mode of completion" dimension, i.e. the result of the counterattack.

RESULTS

A data-quality assessment of the ad hoc instrument (Jiménez & Hernández-Mendo, 2016) was carried out and the instrument was found to be reliable and valid from a quantitative point of view. The Pearson, Spearman and Kendall tau-b correlation coefficients were between 0.987 and 0.999, values understood to be excellent for research purposes. The values of Cohen's kappa were between 0.935 and 1 for 18 of the criteria studied and 0.70 for the 19th criterion. The criteria can therefore be considered optimal. From a qualitative point of view, the use of the consensus agreement method (Anguera, 1990) allowed us to improve intraobserver agreement a priori.

Next, we present the results obtained using a two-facet design (category/observer = C/O) to determine intraobserver reliability. With this design structure, analysis of the generalizability coefficients indicated an excellent level of generalization reliability (0.992). An excellent level of interobserver reliability (0.999) was also found using the same two-facet design (C/O).

To determine to the homogeneity of the categories, we once again used a two-facet design (observer/category = O/C). With this design structure, the generalizability coefficients had a value of 0.000. Therefore, the categories are adequate and meet the requirement of being exhaustive and mutually exclusive.

Next, we present the behavioral maps obtained in the polar coordinate analysis. Polar coordinate analysis allowed us to determine the types of relationships that exist between the focal and conditional behaviors included in the category system. Table 2 shows that a large number of significant relationships were identified in our analysis.

Table 2. Number of significant relationships identified between focal and conditional behaviors in the three populations studied.

	Focal behavior	C	QI	QII	QIII	QIV	Total
Type of defense	51	ASO	19	9	21	8	**57**
		U16	33	10	24	8	**75**
		EUR	39	4	37	6	**86**
	60	ASO	20	5	4	6	**35**
		U16	29	4	5	4	**42**
		EUR	37	3	17	4	**61**
Cause of recovery	ERLANZ	ASO	13	9	9	8	**39**
		U16	12	6	21	2	**41**
		EUR	9	8	11	2	**30**
	ERTEC	ASO	4	8	10	7	**29**
		U16	6	12	8	8	**34**
		EUR	13	6	10	8	**37**
	INTER	ASO	12	5	15	9	**41**
		U16	12	2	6	2	**22**
		EUR	11	8	4	7	**30**
(Im) balance in opponent's half of the court	SUP	ASO	14	7	8	15	**44**
		U16	7	1	7	2	**17**
		EUR	13	3	8	2	**26**
Completion	ERRPR	ASO	7	7	8	4	**26**
		U16	13	7	6	5	**31**
		EUR	10	2	14	6	**32**
	GOL	ASO	12	3	8	4	**27**
		U16	5	7	2	7	**21**
		EUR	14	2	2	8	**26**
	BASIS	ASO	2	1	3	1	**7**
		U16	0	1	0	2	**3**
		EUR	4	0	5	1	**10**

Table 3 shows the significant relationships identified between focal and conditional behaviors in criteria belonging to the "type of defense" dimension. The table specifies the quadrants in which the relationships are located and the populations in which they were detected.

As for the type of defense used in recovery, there is a mutually excitatory relationship (Quadrant I) between the 5:1 defense and (im)balance in the opponent's half of the court, which manifests in the under-16 category as equality (NOSUP), in the European championship as a large disadvantage (ALINF) and in the Asobal League as a simple advantage (SUP). In the case of the 6:0 defense, however, the same

result (ALINF) was obtained for the national teams at the European championship, equality (NOSUP) for the Asobal League and a large advantage in the opponent's half of the court (ALSUP) for the under-16 category. In addition, for all three groups, a significant link between the 6:0 defense and ball recovery in zone 1 (Z1), the goal area.

In the "mode of recovery" dimension, when a missed shot occurs, the zone of reception of the first pass—in this case by the goalkeeper—indicates the upcourt distance traveled by the ball in this first pass and thus the possibility of a first- or second-wave counterattack.

Table 3. Dimension: Type of defense used in recovery. Relationships identified between focal and conditional behaviors.

			Asobal			Under-16			European championship		
	Focal behavior	Q	Cond. behavior	R	Angle	Cond. behavior	R	Angle	Cond. behavior	R	Angle
51	Zone of recovery	I	Z3	4.81	10.82	Z4	2.77	86.93	Z1	5.39	44.02
		I				Z5	4.74	35.05	Z3	5.01	38.18
		II	Z4	2.24	134.97	Z3	3.15	100.25			
		III	Z1	3.73	227.28	Z1	6.28	227.11	Z2	4.68	236.33
		III							Z4	2.82	191.88
		III							Z5	3.37	210.42
		IV				Z2	2.32	341.75			
		IV				L11	3.3	319.42			
	Cause of recovery	I				ERTEC	3.33	41.56	ERLANZ	2.88	60.72
		I				REB	2.75	71.51	REB	3.67	26.77
		I							INTER	4.15	23.56
		II	ERLANZ	2.73	95.74						
		III	ERTEC	4.08	255.37	ERLANZ	8.14	224.71			
		III				INTER	2.13	225			
		IV				GOLCTR	3.3	319.42			
	(Im)balance in opponent's half of court	I	SUP	2.21	17.6	NOSUP	5.37	67.99	ALINF	2.28	21.52
		II							INF	4.42	95.47
		III	NOSUP	2.25	207.51	ALSUP	5.28	231.57	NOSUP	5.99	250.4
		III				ALINF	4.34	247.44			
60	Zone of recovery	I	Z1	2.05	20.29	Z1	9.68	37.58	Z1	2.01	67.25
		I				Z6	2.85	45	Z2	4.11	40.3
		I							Z5	3.75	59.57
		I							Z7	2.16	46.58
		II				L11	2.27	127.75			
		III	Z3	3.38	189.01	Z3	5.06	241.16	Z3	6.32	219.1
		III				Z4	4.92	214.47	Z4	3.04	265.64
		III				Z5	4.35	218.64	Z9	2.31	224.4
		III							L11	2.84	233.81
	Cause of	I	REB	4.67	66.44	ERLANZ	9.88	47.68	ERTEC	2.7	68.19
		I	ERTEC	4.34	56.81						

		Asobal			Under-16			European championship		
Focal behavior	**Q**	**Cond. behavior**	**R**	**Angle**	**Cond. behavior**	**R**	**Angle**	**Cond. behavior**	**R**	**Angle**
recover y	II				GOLCTR	2.27	127.75			
	III	ERLANZ	4.76	245.38	REB	3.36	239.61	REB	2.6	191.29
	III	INTER	3.11	248.84	ERTEC	5.53	231.64	INTER	2.31	224.4
	III							GOLCTR	2.84	233.81
(Im)bal ance in oppone nt's half of court	I	NOSUP	2.18	41.24	ALSUP	6.89	35.86	ALINF	10.17	55.65
	I				ALINF	7.49	58.06			
	II							ALSUP	3.91	120.14
	III	SUP	2.32	240.83	NOSUP	7.33	233.58	NOSUP	5.44	230.88
	III	INF	2.02	195.76				INF	5.48	265.28

As Figure 2 shows, the passing distance is longer in the Asobal League (ZR6 and ZR9, zones located beyond the center line) than in the under-16 group (ZR5) or in the national teams, which tend to catch the first pass in their own half of the court (ZR2).

Figure 2. Quadrants I and III vector map for focal behaviors ERLANZ (missed shot), ERTEC (technical error) and INTER (interception) in the three populations

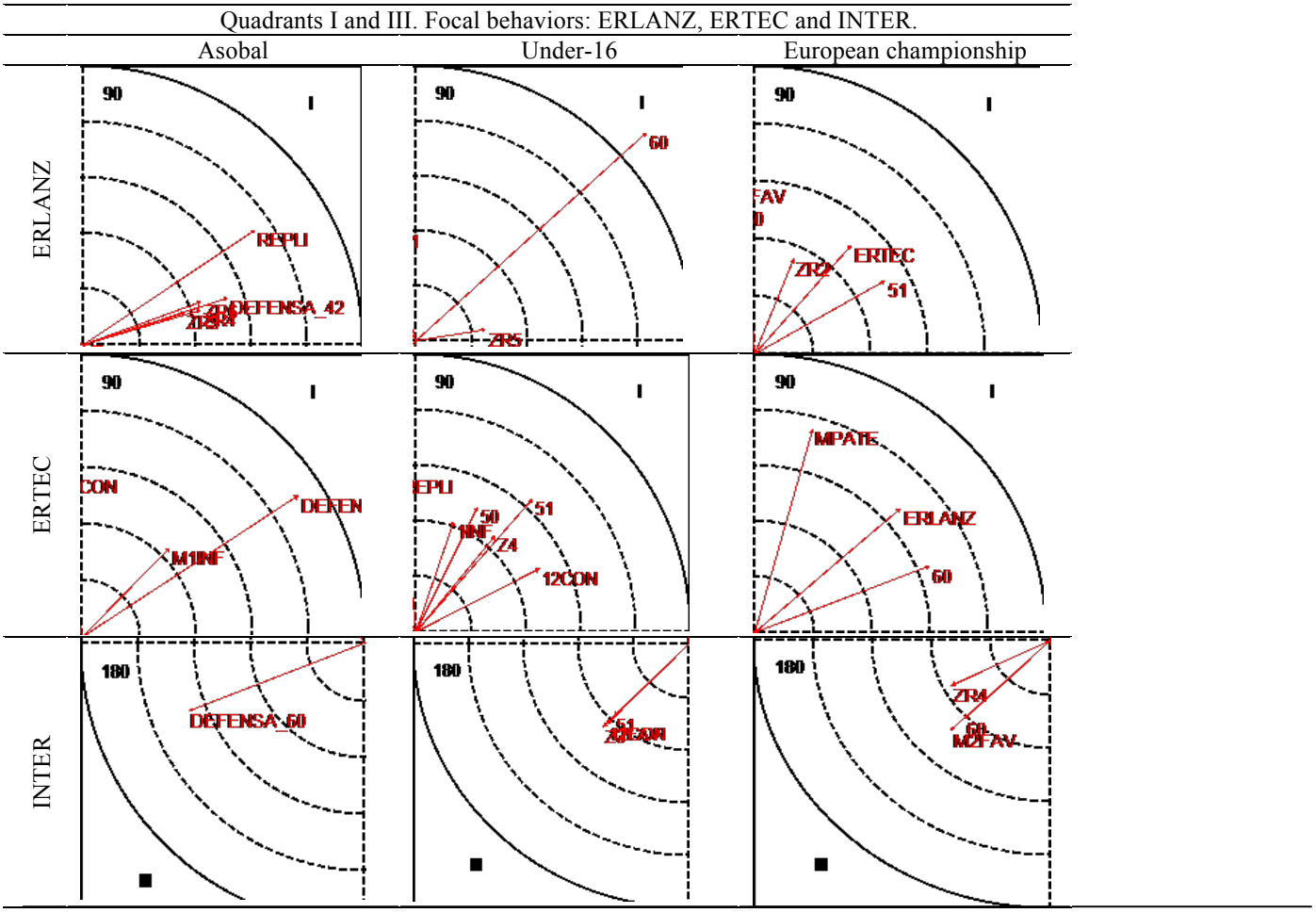


Figure 2 also shows, in Quadrant I, a significant relationship between type of defense and ball recovery with the forcing of a technical error. This relationship was identified for closed defense (60) in the senior categories and for open defense (51) in the under-16 group.

The relationships found for interception varied between the groups. Interception was associated with closed defense (60) in the men's categories and with open defense (51) in the under-16 group. As Figure 2 shows, these relationships are found in Quadrant III, where relationships between focal and conditional behaviors are mutually inhibitory.

In "(im)balance in the opponent's half of the court" dimension, the results provide information about the type of deployment and the use of wave-based play. Of particular note is the Quadrant I relationship between numerical advantage in the opponent's half of the court (SUP) and score. In the under-16 category, SUP was associated with the team being behind in the score (12CON). In the senior categories, however, it was associated with the team being ahead (M2FAV in the Asobal League and 12FAV in the national teams).

In the dimension "mode of completion", which provide information about the way in which counterattacks are completed, there is a mutually excitatory relationship between the scoring of a goal and the number of players participating in the counterattack. Specifically, GOL is associated with the participation of three players (3JUG) in the under-16 category, four players (4JUG) at the European championship and more than five players (M5JUG) in the Asobal League.

DISCUSSION

The main aim of this study was to describe the relationships identified between behaviors that favor the start and development of the counterattack phase of handball in various groups of players. We also analyzed the differences between the defense system used and the mode of ball recovery, ball transport and play completion. Our data have allowed us to identify significant relationships between focal and conditional behaviors. We have also been able to extract some data that could help to improve the understanding of the game and provide useful information that could be applied in training sessions and competitions.

The results indicate that defensive regrouping is the game phase least used for ball recovery and that, as in previous studies (Prudente, Garganta, & Anguera, 2004; Prudente, 2006; González, 2012), ball recovery and deployment were associated with closed defensive systems—basically the 6:0 defense—and with the 5:1 open defense. The 5:1 defense was associated with players on the national teams recovering the ball via interception, with Asobal League teams achieving a numerical advantage in the opponent's half of the court, and with under-16 teams recovering the ball in zones far away from their own goal. These results could be explained by younger, non-professional players having less mastery of ball handling and players in higher categories being less inclined to assume risks.

In contrast, the 6:0 defense was associated in all three categories with ball recovery taking place in ZR1, the goal area. The causes of recovery were missed shot in the men's categories—consistent with the results of González (2012)—and technical error in the under-16 category. When the 6:0 defense was used, counterattack deployment after ball recovery did not tend to achieve a numerical advantage in the opponent's half of the court in the two elite categories. This result can be interpreted as indicative of the professional players' greater skill in defensive regrouping. Under-16 is the only category in which the 6:0 defense was associated with a high numerical advantage in the opponent's half of the court. As for mode of recovery, the forcing of technical errors was associated with the 6:0 defense in the senior categories and with the 5:1 defense in the under-16 category.

Not all differences in behavioral flow entailed excitatory relationships. Interception was found to have a mutually inhibitory relationship with the 6:0 defense in the elite categories and with the 5:1 defense in the under-16 category. This finding seems to show that interceptions do not tend to take place when these defenses are used in these categories.

The incidence of ball recovery following a conceded goal or quick throw-off after a goal was very low, especially in the national teams at the European championship. In the Asobal League and under-16 category, there were excitatory relationships involving being both ahead and behind in the score. In both categories, counterattack completion was found to be associated with the left wing. In the senior categories, an association with the open 5:1

defense was found in the Asobal League and with the 3:3 defense in the national teams. In all cases, these behaviors were associated with the first quarter of the second half of the game. The data on ball recovery indicate that players in different categories act differently. For professional players, ball recovery is associated with technical error or missed shot and players tend to take risks such as stealing, interception, quick throw-off after a goal and attempting to achieve numerical asymmetry during counterattack deployment under conditions that are theoretically advantageous (being ahead in the score, proximity to the center of the court, unguarded player). In contrast, under-16 players tend to take more risks in the final moments of the game or when their team is losing.

As for counterattack deployment, the reception zone of the first pass after a missed shot indicates the distance of the goalkeeper's throw and thus indicates whether or not a first-wave attempt is being made. In the Asobal League, these passes tended to be longer and more ambitious than in the under-16 category and, especially, in the national teams. Again, this difference could be explained by a preference for having the outfield players transport the ball upcourt, i.e. relying on the third wave or the expansion of a sustained counterattack (Román, 2015) as a means of continuing to attack after the defense has regrouped.

As for numerical balance in the opponent's half of the court, an advantage in this regard was associated in senior teams with being ahead in the score and in under-16 teams with trailing in the score. This numerical advantage was associated in senior teams with recovery caused by technical error or rebound and in under-16 teams with recovery caused by interception, possibly due to the younger players exhibiting riskier decision-making in unfavorable situations and lower skill level during defensive regrouping. Strikingly, the only relationship identified for the national teams was high numerical disadvantage in the opponent's half of the court, illustrating the importance that these teams place on the second and third waves as well as the relinquishment of counterattacks. In the European championship, the center and the left wing were the positions associated with assists.

As for goal-scoring, excitatory relationships were found for the participation of three players in the under-16 category, four players in the national teams, and more than five players in the Asobal League. This could be attributed to successful counterattacks being more elaborate in the senior categories, with greater emphasis on transporting the ball with short passes (Prudente, 2006; González et al., 2013). There were differences between the studied populations in terms of assists by the center (or playmaker): plays tended to be completed by the left back in the under-16 category and by the pivot on the national teams. The national teams' goalkeepers had a low rate of attempted assists but were highly effective at play completion.

Overall, and consistent with the findings of other studies (González, 2012), we identified an increase in defensive activity and its impact on counterattacks, especially among winning teams. However, González (2012) identified no relationship between the initial cause of a counterattack and its ultimate effectiveness, finding instead that the (unspecified) circumstances under which the counterattack took place were the determining factor.

In our study, however, we found that defender and goalkeeper efficiency gave rise to more counterattack situations, and under more favorable circumstances. We found that behaviors related to counterattack development and completion did not give rise to as many counterattack situations.

The present study had various limitations. We did not take into account changes in handball regulations—such as the "empty goal" rule that allows seven players to attack while leaving the goal unattended—that were introduced after the study was carried out. Nor did we take into account any differences derived from the fact that two of the studied populations were participating in elimination-style championships while the third was playing in regular league games. It would be interesting to compare our findings with data from women's populations, to study the impact of changes in handball regulations, and to take into account other variables such as type of game (closely matched, balanced, lopsided score, etc.), pace of play (number of ball possessions per team), influence of the opposing team, and phase of competition.

PRACTICAL APPLICATIONS

Our analysis allowed us to describe the existing influence between actions prior to the counterattack phase in handball—such as mode of recovery and type of defense—and the development and

completion of the counterattack phase. We also identified behavioral differences between the populations studied. Polar coordinate analysis was shown to be a useful technique for this sort of analysis. The conclusions obtained can be extrapolated for the purposes of athletic training and for improving efficiency in competition.

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