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Analysis of the Steps Cycle in the Action of Throwing in Competition in Men's Elite Handball

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Abstract: The aim of this article was to analyze the step cycle that precedes the throwing action in elite men's handball and its relationship with different factors, such as throwing distance, throwing technics, throw speed, whether it occurs in jump or standing, the last step, and efficiency. Twenty-four complete matches were analyzed, with a total of 1013 throws in three international elite men's handball championships. The results show that the most used step cycle is the one performed with two steps. There is a significant relationship between the step cycle and the throw distance, with two-step throws being the most used from outside 9 m (29.8%, $p < 0.001$), three-step throws at a distance between 6 and 9 m (35.9%, $p < 0.001$), and zero- and one-step throws from 6 m (30.5%, $p < 0.001$). Likewise, the last step with natural footing is the most used (93.7%, $p < 0.001$) with a complete cycle of steps, followed by false foot with more than three steps (27.3%, $p < 0.001$), and two feet with zero steps (12.6%, $p < 0.001$). In conclusion, the skill to take advantage of the dynamic improvement offered by the mastery of the step cycle, adapting to the different situations of the game, could be an essential characteristic of the player to effectively complete the throwing action.

Keywords: sport performance; throwing efficiency; technical; step cycle; team sport

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1. Introduction

Handball is an Olympic team sport with wide repercussions around the world. This sport is characterized by intermittent high-intensity actions, the speed of attack–defense changes during the game, and a great variety of offensive and defensive technical actions, as well as complex tactical schemes [1]. This sport is integrated within the cooperation teams sports with common space, understanding cooperation as the use of different technical and tactical means for the achievement of a common purpose, scoring a goal. On the other hand, opposition is the aim of the team in order to prevent the opponents from scoring a goal [2,3]. According to this approach, the observational methodology has been frequently used to analyze the most important performance factors in handball [4–6].

In this context, throwing a ball is defined as the most important action for the achievement of scoring a goal in handball, allowing a successful offensive phase [7–9]. Furthermore, throwing effectiveness is predetermined by other factors, such as throwing distance, which, in turn, is conditioned by other prior factor, such as the step cycle [6].

Handball-specific throws, in contrast to those from other sports, such as baseball or cricket, are characterized by a previous movement limited to a maximum of three steps, which actually are the most common throws in handball competitions [10–13]. For some authors, the three-step throwing cycle seems to be the most appropriate because of the high number of preparatory movements needed to coordinate the body segments and apply the most power to the end of the throwing chain. Moreover, these studies have proven better outcomes for the three-step cycle and good reliability over time [14,15].

The studies indicate that, at the professional national levels, the full-step cycle, with three previous steps, is the most used [16–18]. However, in the modern international game of handball, the mobility of the defense players is continuously increasing, leading to more open defensive systems, and positioning the attacking players further away from the goal area than in traditional handball defenses. Consequently, they do not give the thrower too much time to prepare the movement [16,19,20]. Therefore, some authors highlight the importance of mastering the technical–tactical resources of handball to succeed in competition [6,21–24].

Given the substantial changes in rules that enabled the simple practicality of playing with an extra player and an empty goal, the tactical systems have varied greatly in recent years, and offensive players have had to quickly adapt their technical–tactical background to maintain their levels of effectiveness in the game [22]. Therefore, our hypothesis is that the duration of the step cycle prior to the throw will be conditioned by the throwing distance. The aim of this study was to analyze the pre-throw step cycle in elite men's handball, as well as the relationship with criteria and categories such as efficiency, throw distance, throw type, throwing technics, last supporting foot, and final match result in elite men's handball competitions.

2. Materials and Methods

The observational methodology allowed us to collect data directly from the participants in competition [25]. Participants were informed of the purpose of the study and signed an informed consent. These matches were videotaped at all times. The recordings and sequencing of shots from each match were analyzed (match analysis) [22]. Observational and descriptive studies (ODS) [22] validated the observational design that combines three dichotomous axes, namely nomothetic (plurality), single point of observation, and multidimensional, which help to separate the basic ways of analyzing observational data [26,27]. The guidelines on ethical issues in human-subject research in the Belmont Report [28], describing basic ethical principles and guidelines, were followed. According to the guidelines, images of public behavior can be used for research without the informed consent of the athletes. The ethical and deontological principles were complied in relation to the people participating in the study, and the handling of the data obtained was in accordance with the ethical principles of the Declaration of Helsinki. This study has the favorable opinion of the Research Ethics Committee of the Autonomous Community of Aragon in its act No. 10/2021.

2.1. Participants

The sample is composed of the men's national teams of the European Championship 2018, World Championship 2019, and European Championship 2020 that were ranked first-to-fourth finalists (Table 1). These championships were analyzed because they are fully representative of the elite teams in men's handball. We observed 12 matches, and 24 clashes were analyzed. A total of 174 players were analyzed (mean age, 26.98 ± 5.2 years; body weight, 89.9 ± 7.9 kg; height, 1.91 ± 0.84 m; training experience, 11.8 years; and training work, 20 h per week). All throws from all matches were analyzed.

Table 1. Participants.

Championship	Match		Phase
ECh2018	Denmark	Sweden	½ final
	France	Spain	½ final
	France	Denmark	3°–4°
	Spain	Sweden	Final
WCh2019	Germany	Norway	½ final
	Denmark	France	½ final
	Germany	France	3°–4°
	Norway	Denmark	Final

Table 1. *Cont.*

Championship	Match		Phase
ECh2020	Norway	Croatia	1/2 final
	Spain	Slovenia	1/2 final
	Slovenia	Norway	3°–4°
	Spain	Croatia	Final

WCh: World Championship; ECh: European Championship.

2.2. Instruments

An observational method was used to validate the study data [29], and a multidimensional ad hoc observation system [25] was created. The recording instrument was the free and versatile software Lince v.1.0. [30]. This program provides computerized observation procedures that speed up the recording process [31].

The independent variable was the cycle of steps used in each visualized throw, and the dependent variables were throw distance, throwing technics, throw height, throw speed, last foot, and throw result, as listed in Table 2.

Table 2. Definition of throw indicators used in the study [6].

Criteria Name	Category Definition
Distance	-6-m zone (6 m): Throw performed with the last contact of the player out of the 6 m zone (±45° angle to the goal posts with the base line) and falling inside and/or invading the air space of the 6 m area. -Middle zone (6–9 m): Throw performed with the last contact of the player that performs the action in the middle zone set between the 6 and 9 m area, without invading the air space of the 6 m area. -9 m zone (9 m): Throw performed with the last contact of the player out of the 9 m zone and falling inside or outside this area. -7 m zone (7 m): Throw performed in the regulatory action of 7 m. Middle-field zone (1/2): Throw performed with the last contact of the player in their own middle field.
Throwing technics	-Overarm throw: Throw performed with the arm above the head. -Hip throw: Throw performed with the arm at the height of the waist on the throwing arm side. -Rectified: Throw performed with the arm leaning to the opposite side of the throwing arm. -Back throw: Throw performed with his back towards the goal. -Low throw: Throw performed with the hand below the knee. -Front: Throw performed without overarm.
Throw height	-Jump throw: Throw performed in the air phase of the jump when the player is not in contact with the ground. -Stand throw: Throw performed when the player is in contact with the ground with one of his feet.
Throw speed	-Speed throw: Any other type of throwing that is not considered as skill throwing. -Skill throw: The player uses some sort of high-level technique such as a screw (throwing with effect), a topspin throw (a throw in which the ball in its air path changes its speed) and parabolic throwing.
Step cycle	-Zero step: A throw without using any step from the step cycle. -One step: Throw performed after taking a step. -Two steps: Throw performed after taking two steps. -Three steps: Throw performed after taking three steps. -Flying: Throw performed when the ball is caught in the air and thrown before it touches the ground. -More than three steps: Throw performed with more than three steps without being disciplined for this regulatory violation.

Table 2. *Cont.*

Criteria Name	Category Definition
Foot	-Natural: Throw performed with the last contact of the player with the floor being with the opposite foot beside the executing arm. -Changed: Throw performed with the last contact of the player with the ground being with the foot of the same side of the executing arm. -Two feet: Throw performed with the last contact of the player with the ground being with both feet simultaneously.
Results	-Goal: A throw that is granted as a goal by the referees due to exceeding the net line. -Out: A throw that is not touched by any player of the rival team and ends out of the net or hits the bars without being a goal. -Blocked: A throw where the goalkeeper prevents the throw from ending up in the goal. -Defense: Contact/action of the defender on the ball throw.

2.3. Procedure

The observation instrument was validated by a panel of experts composed of 3 graduates in physical activity and sport sciences and national coaches with research experience in observational methodology [32].

Two observers were trained thanks to the construction of an observation manual in which the criteria, category, and codes of the observational process were defined [25]. All analyses were carried out over a period of 30 days, using the same tool and in the same space. Data validity was achieved by calculating the degree of concordance or reliability of the observers' record, using Cohen's Kappa index [33], which obtained a value of 0.80 for interobserver reliability and 0.89 for intraobserver reliability.

2.4. Statistical Analysis

Data were processed and presented by using the IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive analysis was used to calculate the distribution of frequencies and percentages of the different criteria and category. The normality of the distribution of the data was checked by using the Shapiro–Wilk test. Differences between groups (winners and losers) were examined by using the analysis of variance (one-factor ANOVA). To explore these correlations further, the adjusted residuals or z-score test [34] was used with a significance level of $p < 0.05$ ($z \geq \pm 3.29$).

3. Results

The analysis of variance (one-factor ANOVA) of the normally distributed interval criteria found no significant differences (Table 3) between the means of the different championships with respect to the number of throws (1.890 f; 0.176 sig) and their effectiveness (0.542 f; 0.590 sig).

Table 3. ANOVA and number of throws, with results per team and match.

Competition	Match/Team	Score	Throw	Effectiveness
European Championship 2018	Spain Sweden	29	46	63.04%
		23	39	58.97%
	France Denmark	32	45	71.11%
		29	45	64.44%
	France Spain	23	38	60.53%
		27	41	65.85%

Table 3. *Cont.*

Competition	Match/Team	Score	Throw	Effectiveness
	Denmark Sweden	34	45	75.56%
		35	56	62.50%
World Championship 2019	Norway Denmark	22	42	52.38%
		31	43	72.09%
	Germany France	25	40	62.50%
		26	44	59.09%
	Denmark France	38	48	79.17%
		30	41	73.17%
	Germany Norway	25	43	58.14%
		31	37	83.78%
European Championship 2020	Spain Croatia	22	30	73.33%
		20	29	68.97%
	Slovenia Norway	20	38	52.63%
		28	45	62.22%
	Norway Croatia	28	47	59.57%
		29	47	61.70%
	Spain Slovenia	34	43	79.07%
		32	41	78.05%
ANOVA			1.890 f 0.176 sig	0.590 > 0.05

In our analysis of the step cycle and all study variables with frequency and percentage correlations (Table 4), there was a statistically significant correlation between throws from 7 m with the fly step cycle (90%, $p < 0.01$), zero step (30.5%, $p < 0.001$), and one step (54.8%, $p < 0.01$). Throws from a distance between 6 and 9 m have a statistically significant relationship with cycles of three steps (35.9%, $p < 0.001$) and more than three steps (54%, $p < 0.01$). It should be noted that the 9 m throws are correlated with the two-step throws (29.8%, $p < 0.001$). In the analysis of the correlations of the cycle of steps prior to the throw and the last foot of support, the statistically significant correlation between the throws made from a changed foot and the use of more than three steps (27.3%, $p < 0.001$) stands out. Equally, correlations were found between throws made with three steps and a natural-foot last support (93.7%, $p < 0.001$), whereas zero-step throws correlated with shooting with a two-foot throw at the same level (12.6%, $p < 0.001$).

Table 4. Frequency and percentage of the use of the step cycle and adjusted residuals or z-score between all study criteria.

		Steps Cycle						
		Fly	Zero	One	Two	Three	More	Total
Distance	6 m	9 (90%) **	53 (30.5%) ***	149 (54.8%) **	138 (44.2%)	86 (38.6%)	9 (40.9%)	444 (43.83%)
	7 m	-	93 (53.4)	-	-	-	-	93 (9.18%)
	6–9 m	1 (10%)	11 (6.3%)	53 (19.5%)	73 (23.4%)	80 (35.9%) ***	12 (54%) ***	229 (22.61%)
	9 m	-	11 (6.3%)	64 (23.5%)	93 (29.8%) ***	53 (23.8%)	1 (4.5%)	223 (22.01%)
	½		6 (3.4%)	6 (2.2%)	8 (2.6)	4 (1.8%)	-	24 (2.37%)
Throwing technics	Hip	-	4 (2.3%)	16 (5.9%)	16 (5.1%)	13 (5.8%)	1 (4.5%)	50 (4.94%)
	Normal	10 (100%)	166 (95%)	254 (93.4%)	291 (93.3%)	207 (92.8%)	21 (95.5%)	949 (93.68%)
	Front	-	1 (0.6%)	-	-	-	-	1 (0.1%)

Table 4. *Cont.*

		Steps Cycle						
		Fly	**Zero**	**One**	**Two**	**Three**	**More**	**Total**
	Back	-	1 (0.6%)	-	1 (0.3)	1 (0.4%)	-	3 (0.3%)
	Torsion	-	2 (1.1%)	2 (0.7%)	4 (1.3%)	2 (0.9%)	-	10 (0.99%)
Throw height	Jump	10 (100%)	111 (63.8%)	230 (84.6%)	46 (14.7%)	190 (85.2%)	4 (18.2%)	591 (58.34%)
	Step	-	63 (36.2)	42 (15.4%)	266 (85.3%)	33 (14.8%)	18 (81.8%)	422 (41.66%)
Throw speed	Fast	9 (90%)	165 (94.8)	257 (94.5%)	300 (96.2%)	219 (98.3%)	22 (100%)	972 (95.95%)
	Slow	1 (10%)	9 (5.2%)	15 (5.5%)	12 (3.8%)	4 (1.8%)	-	41 (4.05%)
Foot	False	-	7 (4%)	20 (7.4%)	35 (11.2%)	10 (4.5%)	6 (27.3%) ***	78 (7.7)
	Two feet	2 (20%)	22 (12.6%) ***	20 (7.4%)	17 (5.4%)	4 (1.85)	-	65 (6.42%)
	Natural	8 (80%)	145 (83.3%)	232 (85.3%)	260 (83.3%)	209 (93.7%) ***	16 (72.7%)	870 (85.88%)
Result	Block	-	2 (1.1%)	12 (4.4%)	19 (6.1%)	10 (4.5%)	1 (9.1%)	44 (4.34%)
	Out	-	11 (6.3%)	22 (8.1%)	34 (10.9%)	21 (9.4%)	4 (18.2%)	92 (9.08%)
	Goal	9 (90%)	126 (72.4%)	166 (61%)	176 (56.4%)	141(63.2%)	13 (59.1%)	504 (49.75%)
	Save	1 (10%)	35 (20.1%)	72 (26.5%)	83 (26.6%)	51 (22.9%)	3 (13.6%)	245 (24.19%)
Total		10 (0.99%)	174 (17.18%)	272 (26.85%)	312 (30.8%)	223 (22.01)	22 (2.17%)	1013 (100%)

m: metros; ** $p < 0.01$. *** $p < 0.001$.

4. Discussion

This research focused on the context of the game process and specifically analyzed the actions that can lead to success in team sports [22,35–37]. The aim of this study was to analyze the influence of the cycle of steps prior to throwing a ball in handball and its effectiveness, as well as the relationship between the variables that characterize the action, in elite men's handball competitions.

The results show that the use of different step cycles prior to the throwing of the ball is conditioned by the distance of this throwing and the last support foot used. This is due to the wide variety of situations that can occur during the game (fast break shots, outside shots, pivot shots, and winger shots) [6].

Firstly, we found a relationship between the throwing distance and the results. Some studies found that throws from 6 m were in a positive relationship in the success of scoring a goal [38,39]. On the contrary, Antúnez et al. observed a negative relationship from 9 throwing meters [40].

Our results show that the throwing distance determines the use of different step cycles. This may be due to the in-game difficulty of effectively throwing the ball beyond the 9 m line. Interestingly, in this kind of throwing, a technical execution with three steps appears to be too slow, and defenders could easily defend and intercept the opponent's shots. On the contrary, throwing the ball with zero or one step gives less time for the goalkeepers and defenders to react; this would allow attackers to anticipate their movements and gain an advantage during the game [41]. However, this tactical approach usually results in longer shooting distances. It is worth noting that these results are in agreement with other studies, confirming that, when the distance increases, effectiveness and precision decrease [9,24,42]. Furthermore, the players who most commonly use a single step to throw the ball are those who throw from short distances, where impairments in the neuromuscular throwing chain are less damaging to the performance and the little time to execute the throw seems to be the key factor.

Interestingly, the most common throwing step cycle when shooting between the lines (6–9 m) was with a complete cycle of steps (three steps). This strategy seems to respond to the player's intention to get as close as possible to the opposing goal, rushing to score a goal and trying to avoid the goalkeeper's anticipated actions. This result is in accordance with the studies of Gutiérrez-Dávila et al. [43] and Carbonell et al. [41]. These results highlight important aspects to be considered by coaches: (i) throws between lines (6–9 m) are mostly made with a complete cycle of steps (three steps), (ii) throws from beyond the 9 m line are mostly made with two steps, and (iii) throws from the 6 m line are mostly made with zero or one step.

As for limitations of the study, we can conclude that it is necessary to increase the sample size to have greater relevance in the factors analyzed. Moreover, the analysis of contextual variables (championship phase, partial score, match result) could improve the consistency of the analysis model. Moreover, the type of competition includes matches in the final phase and matches in the group phase, in addition others based on the knockout stage that may have influenced the behavior of the teams analyzed.

Finally, there is a lack of studies that analyze the last support performed within the technical execution of the throwing of the ball. Our findings highlight the greater use of the natural foot support for the last step of the throwing, that is, the opposite foot to the throwing arm. The explanation may be twofold, due to the laws of the game that only allow three steps before the throwing of the ball and in order to adopt an optimal throwing position [23]. In this direction, the natural foot support showed to be more effective than the non-natural one in each type of shooting analyzed. Furthermore, in the present study, the relationship between the two-feet throw and the zero-step throw appears to be a consequence of the greater influence of the game with the pivot player in the current handball game [44].

5. Conclusions

The conclusions derived from this study are that the highest percentage of shots in handball are made with two steps prior to the shot, throws from beyond the 9 m line are mostly made with two steps, throws between 6 and 9 m are executed to a greater extent with a previous cycle of three steps, and throws from the 6 m line are mostly made with zero or one step. Moreover, most throws were executed with the full cycle of steps, three steps. It is performed with the last natural support foot.

For all of this, it is important to propose a correct training process for the formation of the handball player, where the dynamic richness offered by mastery of the steps cycle is taken advantage of. The control of the step cycle is an essential characteristic to carry out the throwing action effectively. Coaches should propose exercises that modify the step cycle at all ages. Training throws from 9 m with two steps is the optimal way to increase performance in handball.

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