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Throwing performance by playing positions of male handball players during the European Championship 2020

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The aim of this study was to analyze the throwing velocity and effectiveness of elite male handball players during the European Championship 2020. A local positioning system was used for the first time in a European Championship to collect 6568 throw events from 337 players of 24 national teams during 65 matches. ANOVA ($F = 80.8$, $p < 0.01$, $\eta^2 = 0.058$) revealed that back players throws were significantly faster (24.3–26.5 m/s) than the rest of the players (22.2–22.5 m/s). Similarly, throws made from the central zone showed the highest speed values of 28.0 m/s ($F = 43.2$, $p < 0.01$, $\eta^2 = 0.050$). In regard to the goal hit zone, higher speeds were shown for throws in side zones (24.9–26.8 m/s) compared to central zones (23.0–23.8 m/s) ($F = 49.0$, $p < 0.01$, $\eta^2 = 0.063$). Effectiveness was higher in wing players (62%–64%) than the rest (45%–56%) ($F = 30.9$, $p < 0.01$, $\eta^2 = 0.023$). Interestingly, the two higher velocity categories (>22 m/s) showed similar effectiveness (~60%), which were higher than the preceding slower category of 17–22 m/s (39.7%) ($F = 175.1$, $p < 0.01$, $\eta^2 = 0.074$). Regarding court zones, throws from first-line zones (48%–60%), were more effective than from second line (38%–43%) ($F = 13.1$, $p < 0.01$, $\eta^2 = 0.016$). With respect to the goal hit zone, effectiveness was higher in side (72%–77%) than in central zones (58%–64%) ($F = 523.2$, $p < 0.01$, $\eta^2 = 0.418$). Coaches should improve the throwing velocity of players but also train at submaximal velocities (effective velocity) to save energy and reduce the potential risk of injury. Finally, training should be specialized according to the performance shown by players from different throwing zones, rather than from playing positions.

KEYWORDS
court, effectiveness, elite, goal, LPS, velocity

1 | INTRODUCTION

Handball is an Olympic sport in which players are required to perform fast and intermittent actions of maximal or near maximal efforts of fundamental movement skills, such as running, blocking, jumping, and throwing,[1] interspersed with short recovery intervals.[2,3] Throwing is one of the most important actions in handball as being

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the precursor of most goal situations.[4,5] Therefore, throwing performance is considered a key factor for winning a match[6] as the team scoring more goals is the winning squad. The two main factors for a throw to be successful and score a goal are throwing velocity and accuracy.[7] Players with higher throwing velocity are more successful as the time available for goalkeepers and defenders to prevent the goal is reduced.[8] Similarly, if the ball is shot to the desired area of the goal, it will be harder for the goalkeeper to stop it.[4,9] Due to the importance of the throwing velocity and effectiveness in handball performance, many studies have been conducted to determine the factors that influence throwing performance, such as tactical (characteristics of the players involved in throwing action), technical (patterns of movement in the court), or physical (muscular strength).[1]

Most studies on throwing performance in handball have been conducted in controlled training conditions without goalkeeper under the perspective of biomechanics,[5] focusing on gender differences,[10] or performance levels.[11] Nevertheless, throwing in competitive contexts is influenced by the interaction between a team member, the opponent, and the goalkeeper.[7] Some studies have attempted to analyze the throwing performance of handball players during competitive matches, suggesting higher throwing velocities for specific playing positions (PP).[12,13]

However, the instruments used in the previous studies avoid a comprehensive analysis of both kinematic data of the throwing action and positional data of both players and the ball. For the first kind of data, existing methods for measuring the throwing velocity include human body tracking systems based on video cameras[14] and wearable devices,[15] recently validated in conjunction with machine learning algorithms.[16] For the second data type, positional information of players within a court is acquired using three methods: global positioning systems (GPS)[17] for outdoor venues, video-tracking systems,[18] and more recently, local positioning systems (LPS)[19] for both outdoor and indoor venues. LPS bring continuous positional tracking of the players and the balls in indoor settings with low position errors compared to error-free criterion,[20] allowing a multidimensional analysis of the throwing performance in real competitions.

In handball, the efficiency of a team in a match is a direct expression of the success in throwing actions over the rival goal and the degree of effectiveness demonstrated in defending the opposing team's offensive actions.[21] As the number of scored goal is the decisive factor to differentiate winner's from loser's,[22,23] a detailed quantitative analysis of throwing performance is necessary.

Therefore, the aim of this study was to investigate the throwing velocity and effectiveness in regard to PP, throwing zone and hit positions in the goal for top-level handball players. The LPS currently used in the first division of the German handball national league and the Velux EHF Final4 since the 2019/2020 season,[24] is employed in this study to retrieve continuous positional tracking of the players and the ball in the latest European Handball Federation EURO 2020. The introduction of a microsensor inside the ball itself allows analyzing, in an ecological way, variables related to the shots that had never been able to be studied directly before. Among the multiple possibilities of analysis, in addition to being able to quantify the total volume of shots per championship and match, it is possible to know with high precision the speed of the ball, its location in the goal, the place from where it has been shot and the player who performed it.

2 | MATERIALS AND METHODS

2.1 | Subjects

Data in this study was obtained from male players participating in the European Handball Federation (EHF) EURO 2020, held in Austria/Norway/Sweden. The sample consisted of 337 players distributed in the following PP: Left wing (LW), Left back (LB), Center back (CB),

TABLE 1 Physical characteristics of the players (mean ± standard deviation)

Playing position	*n*	Height (cm)	Body mass (kg)	BMI (kg/m^2)	Age (years)
Left wing	49	186.9 ± 5.6	84.5 ± 7.8	24.1 ± 1.5	28.3 ± 4.6
Left back	66	196.4 ± 4.2	97.4 ± 6.7	25.2 ± 1.4	26.8 ± 4.7
Center back	51	189.6 ± 5.7	90.2 ± 7.0	25.1 ± 1.5	27.5 ± 4.9
Right back	50	194.5 ± 5.9	95.8 ± 9.0	25.3 ± 1.5	27.9 ± 4.8
Right wing	44	184.7 ± 5.5	82.9 ± 6.3	24.3 ± 1.4	28.0 ± 4.4
Line player	77	196.7 ± 4.6	104.5 ± 13.2	26.9 ± 3.3	28.5 ± 4.7
Total	337	192.3 ± 6.7	93.9 ± 11.8	25.3 ± 2.2	27.8 ± 4.7

Abbreviation: BMI, body mass index.

Right back (RB), Right wing (RW) and Line players (LP). Goalkeepers were excluded from the analysis since their performance needs are not influenced by the throwing characteristics. As a result, 6568 throws were analyzed in this study. Anthropometric characteristics and age were collected from the official statistical data provided by the EHF (Table 1).

2.2 | Instrumentation

The position data of players and the ball were collected through a local positioning system (LPS) (Kinexon Precision Technologies). Recent studies have validated LPS against well-known systems such as GPS, showing proper between-device reliability (coefficient of variation around 5%).[19,20] A complete description of the system can be found elsewhere.[24,25] The LPS can determine the real-time position and motion data of the player and ball through lightweight position chips (tags). The player tag was positioned between shoulder blades using the manufacturer harness, whereas the ball tag was incorporated in the center of the ball. In both cases, the sensor calculates 3D data (x,y,z) with position accuracy <10 cm at sampling frequency of 20 Hz for players and 50 Hz for the ball, resulting in mean absolute errors of 0.04 ± 0.01 m/s and 0.86 ± 0.09 m/s, respectively.[20]

2.3 | Procedures

This was a descriptive observational cross-sectional study to examine the throwing performance according to PP and court throwing zones during competitive matches.

The study was approved by the EHF. The players were informed of the purposes, procedures, and risks of the study and provided informed consent before the beginning of the study in a contract with the EHF. Personal data were pseudonymized for the purpose of this study. All the procedures were conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University of Alicante (registration number UA-2020-09-10).

The following variables were retrieved from position and speed data from players and ball tags for each throw event. Concerning throwing velocities, there was no previous classification to use. This is because most of previous studies aimed to analyze the power and accuracy of throws under experimental/laboratory conditions and with a small sample. Our study is the first one analyzing throwing velocity in real competition and with a large sample using LPS. Nevertheless, in order to establish categories we analyzed the existing literature[4,5,7,9,12,13,26] on throwing velocity in handball and decided to include the following: C1 (<17 m/s), C2 (17–22 m/s), C3 (22–28 m/s), and C4 (>28 m/s). These categories correspond to approximately <60, 60–80, 80–100, and <100 km/h, respectively. In accordance with other studies,[12,13] the throwing position in the court was also categorized in nine zones within court, as depicted in Figure 1A.

Following previous studies,[12,13] the hit position in the goal was classified in nine equally sized zones, as shown in Figure 1B. The effectiveness was calculated in percent by the relation between the number of throws that scored a goal and the number of throws, in accordance with similar handball studies.[7,27]

2.4 | Statistical analyses

Descriptive data are presented as mean and standard deviation. The Kolmogorov-Smirnov test was used to check the normality distribution of the data in all subgroups under test. The differences between PP, throwing zones, goal hit positions, and velocity categories in regard to throwing velocity and effectiveness were determined using one-way ANOVA, followed by Games-Howell post hoc testing, appropriate when there is a lack of homogeneity of variances.

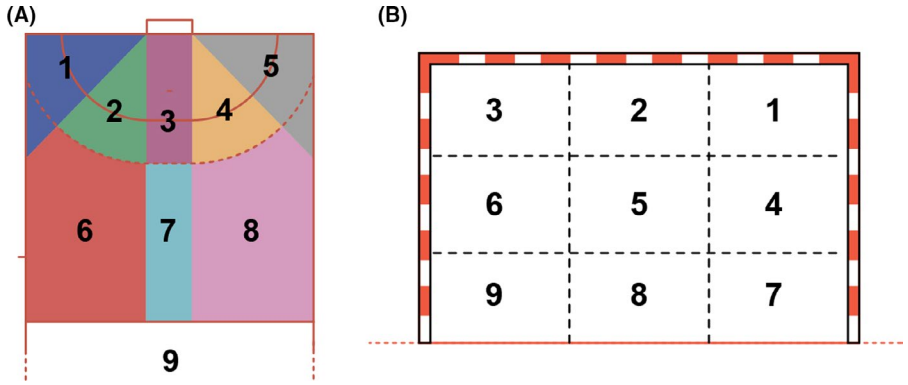

FIGURE 1 (A) Zones for throwing position in the court. (B) Zones for hit position in the goal

Spearman's correlation coefficient was computed to check association between effectiveness and throwing velocity in all subgroups. The alpha level of significance was set at $p < 0.05$. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS V22.0 for Windows, SPSS Inc).

3 | RESULTS

Throwing velocity by PP, throwing zones, and goal hit zones is presented in Figure 2. For each zone in the figure, the throwing velocity as mean ± SD is shown on top, statistical significance between this zone and the rest is displayed in the middle, and the total number of throws in this zone is depicted between brackets in the bottom. For example, for throwing zone 1 in shaded blue, the mean throwing velocity of the 464 throws was 21.5 ± 6.4 m/s which was significantivelly different to zones 2, 3, 4, 6, and 8. Results showed that the mean throwing velocity was 22.5 ± 5.9 m/s for LW, 26.5 ± 6.9 m/s for LB, 24.3 ± 7.5 m/s for CB, 25.9 ± 7.2 m/s for RB, 22.6 ± 6.0 m/s for RW, and 22.2 ± 6.7 m/s for LP. ANOVA ($F = 80.8$, $p<0.01$, $\eta^2 = 0.058$) revealed that Back players throws were faster than the rest of the players. Within back players, LB's and RB's showed higher values than the CB's. Regarding the position of throw in the court, the mean throwing velocity in the nine throwing zones is depicted in Figure 2B. Similarly, ANOVA ($F = 43.2$, $p < 0.01$, $\eta^2 = 0.050$) revealed that throws from side zones 1 and 5 were slower that from the rest of the court.

Concerning the goal, the mean velocity for each goal hit zone is displayed in Figure 2C, together with the number of throws. Differences between zones were shown in ANOVA ($F = 49.0$, $p < 0.01$, $\eta^2 = 0.063$), with post hoc indicating that throws in central zones (2, 5 and 7) are slower than in side zones. Throws in lower side zones (7 and 9) showed lower velocities than in upper side zones (1 and 3). Table 2 shows the throwing velocity for each position performed in the nine court zones. There were differences ($p < 0.01$) in LW ($F = 6.9$, $\eta^2 = 0.073$), LB ($F = 10.3$, $\eta^2 = 0.061$), CB ($F = 5.8$, $\eta^2 = 0.031$), RB ($F = 5.1$, $\eta^2 = 0.029$), and RW ($F = 4.3$, $\eta^2 = 0.044$) between throwing zones.

The effectiveness is presented in Figure 3 with the same data structure for zones than in Figure 2: effectiveness (mean ± SD), statistical significance between zones, and number of throws in the zone in top, middle, and bottom positions, respectively. Results showed that effectiveness by PP was 61.7 ± 48.6% for LW, 44.6 ± 49.7% for LB, 45.6 ± 49.8% for CB, 45.1 ± 49.8% for RB, 64.1 ± 48.0% for RW, and 56.0 ± 49.7% for LP,

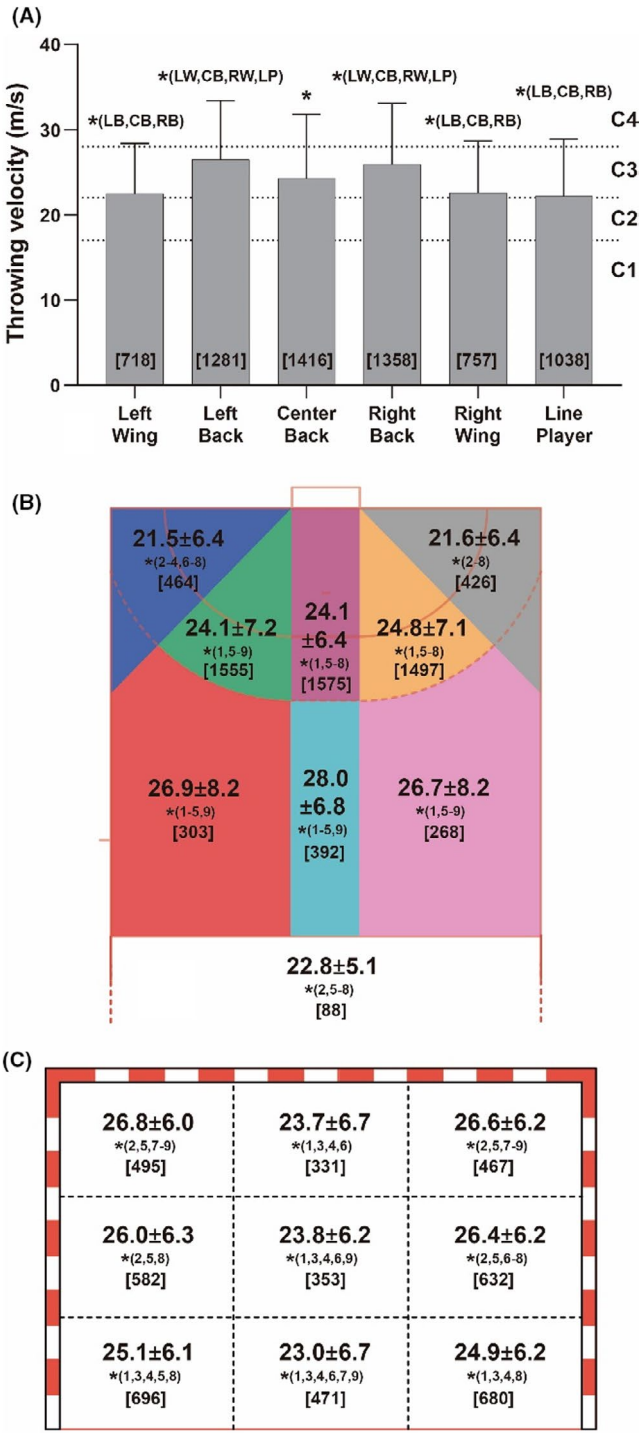

FIGURE 2 Throwing velocity by (A) playing positions, (B) throwing zones, and (C) goal hit zones. Whiskers indicate SD. Velocity zones: C1 (<17 m/s), C2 (17–22 m/s), C3 (22–28 m/s), and C4 (>28 m/s). *Significance between playing positions (A), playing zones (B) and goal hit zones (C) indicated in parenthesis. Single asterisk means difference between all playing groups. Number of throws indicated between brackets for each group

as presented in Figure 3A. As with throwing velocity, ANOVA ($F = 30.9$, $p < 0.01$, $\eta^2 = 0.023$) revealed that wings and LP effectiveness was higher than the back

TABLE 2 Throwing velocity (m/s) by playing positions and court throwing zones. *Significance between zones for each position indicated by zone numbers in parenthesis. Number of throws indicated between brackets for each group

Zone	LW	LB	CB	RB	RW	LP
1	20.7 ± 5.7*(2,3) [266]	23.3 ± 7.3*(4,6–8) [81]	21.5 ± 6.9*(3,4,7,8) [95]	22.9 ± 6.2 [8]	23.6 ± 2.9 [2]	24.6 ± 6.2 [12]
2	23.0 ± 5.7*(1) [190]	26.0 ± 7.1*(6,7,9) [413]	23.6 ± 7.3*(7) [401]	25.9 ± 7.9*(5) [192]	23.0 ± 7.5 [45]	21.9 ± 6.7 [314]
3	24.1 ± 4.7*(1) [177]	26.0 ± 6.3*(6,7,9) [211]	24.2 ± 6.9*(1,7,9) [345]	25.2 ± 6.3*(5,7) [216]	23.9 ± 5.6*(5) [226]	22.5 ± 6.7 [400]
4	22.6 ± 6.8 [41]	26.6 ± 7.1*(1,7,9) [198]	24.6 ± 7.1*(1,9) [303]	26.3 ± 6.8*(5) [520]	23.1 ± 5.7*(5) [156]	21.9 ± 7.0 [279]
5	24.2 ± 1.4 [3]	17.3 ± 9.1*(7) [10]	22.8 ± 7.8 [23]	22.8 ± 6.4*(2,4,7,8) [98]	21.2 ± 6.1*(3,4,9) [285]	22.2 ± 3.0 [7]
6	22.4 ± 10.1 [12]	28.5 ± 6.5*(1–3,9) [156]	25.1 ± 10.0*(9) [91]	27.5 ± 8.3 [39]	15.4 ± 0.0 [1]	21.2 ± 5.0 [4]
7	28.41 ± 5.9 [9]	28.8 ± 5.8*(1–5,9) [142]	27.3 ± 7.9*(1–3,9) [107]	28.2 ± 6.6*(3,5) [125]	17.7 ± 9.4 [4]	23.6 ± 8.5 [5]
8	27.4 ± 10.7 [5]	28.6 ± 7.1*(1,9) [54]	27.2 ± 8.6*(1,9) [42]	26.1 ± 8.4*(5) [148]	23.9 ± 8.6 [16]	27.3 ± 7.3 [3]
9	21.8 ± 5.9 [15]	22.2 ± 3.5*(2–4,6–9) [16]	20.9 ± 2.0*(3,4,6–8) [9]	23.0 ± 5.8 [12]	23.9 ± 3.6*(5) [22]	23.6 ± 7.9 [14]

Note: Post hoc tests are not performed for RW in zone 6 because only one throw was collected.

players. Within first-line players, LP's showed lower effectiveness than the RW's and LW's. Similarly, Figure 3B shows that the effectivity by velocity category ranges from 23.9 ± 42.6% for C1, 39.7 ± 48.9% ($n = 1156$) for C2, 58.7 ± 49.2% for C3, and 60.8 ± 48.8% for C4. ANOVA ($F = 175.1$, $p < 0.01$, $\eta^2 = 0.074$) showed that C3 and C4 throws were more effective that C1 and C2 throws.

Regarding the position of throw in the court, the mean effectiveness in the nine throwing zones is depicted in Figure 3C. As with the rest of variables, ANOVA ($F = 13.1$, $p < 0.01$, $\eta^2 = 0.016$) revealed that throws from first-line zones (1–5) were more effective than from second line (6–8). Within first-line zones, throws from zone 3 showed the highest effectiveness, being 7-m throws that mostly contributed (72.8%). With respect to the goal hit zone, the number of goals from total throws and the corresponding effectiveness is shown in Figure 3D. ANOVA ($F = 523.2$, $p < 0.01$, $\eta^2 = 0.418$). Throws in side zones (1, 3, 4, 6, 7, and 9) are more effective than in central zones (2, 5, and 8), whereas throws in zone 8 were the least effective.

The effectiveness of each position within each court zone is displayed in Table 3. Significant differences ($p < 0.01$) were observed with ANOVA for LW ($F = 3.1$, $\eta^2 = 0.034$), CB ($F = 3.8$, $\eta^2 = 0.021$), RB ($F = 3.5$, $\eta^2 = 0.021$), and RW ($F = 3.0$, $\eta^2 = 0.031$), and LP ($F = 2.3$, $\eta^2 = 0.018$) between throwing zones.

Finally, Spearman's correlation coefficient indicated no association between effectiveness and throwing velocity, both globally and analyzed by PP, velocity category, or throwing zones.

4 | DISCUSSION

The aim of this study was to analyze throwing performance based on PP, throwing zone on the court and hit positions in the goal in the matches played during the Men's EHF EURO 2020. In general, the results highlighted that, in high competition handball, the player's throws are mediatized by the position where they play and the area where they make the shot.

During the EURO a total of 6568 shots were made, with 28.33% (1861) located outside the limits of the goal. This means an average of 50.52 throws per team and game. These data are slightly higher than those shown in the study carried out by Alexandru et al.[28] during the World Championship Croatia 2009 (42.75 throws), and the study by Hatzimanouil[29] which reported 40.49 throws in the Greek league.

Backs were the players who made the most shots (61.74%), significantly more than wings (22.46%) and LPs (15.80%). These percentages are in line with those

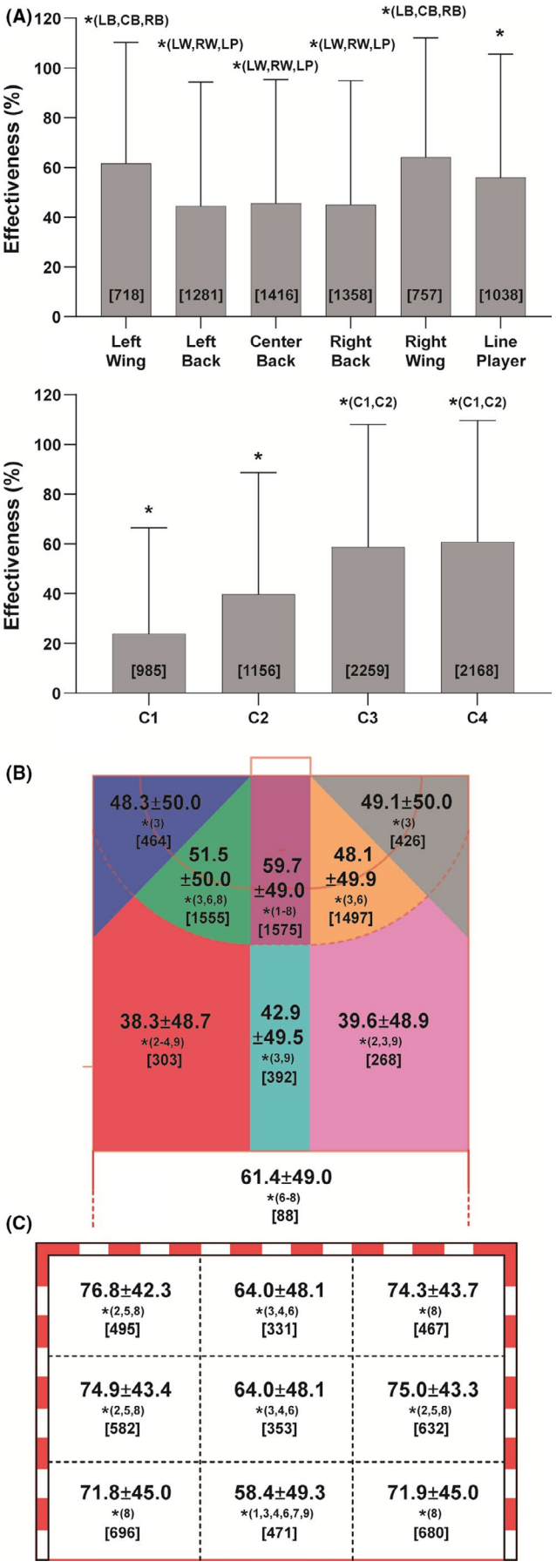

FIGURE 3 Effectiveness by (A) playing positions, (B) velocity categories, (C) throwing zones, and (D) goal hit zones. Whiskers indicate SD. Velocity zones: C1 (<17 m/s), C2 (17–22 m/s), C3 (22–28 m/s), and C4 (>28 m/s). *Significance between playing positions (A), velocity zones (B), playing zones (C) and goal hit zones (D) indicated in parenthesis. Single asterisk means difference between all groups. Number of throws indicated between brackets for each group

obtained by Montoya et al.[30] during the Beijing Olympic Games 2008, where they tried to relate the result of the match with the number of times that the wings ended an offense phase. In this study, the backs ended 64% of the attacks in the lost matches and 57% of the won; the wings 21% and 28%, respectively, and the LPs 15% in both cases.

4.1 | Throwing velocity according to throwing zones, goal hit zones and PP

One of the main variables of a throw is velocity. The data from the present study showed that during the male EURO 2020, ball throwing velocity varied across the court throwing zone, the goal hit zone, and PP.

To the best of our knowledge, this is the first research that analyzed throws according to the court zone where they have been performed, regardless of PP. One of the main findings of our research is that throws made from the central zone (7) were those that showed higher speed values (28.0 m/s), while those made from the most outside zones presented significantly lower values with respect to the rest of the areas (~21.5 m/s). This circumstance clearly indicates that players carry out long trajectories toward the central zone to gain in displacement speed and transfer it into throwing velocity. However, in the most outside zones, skill prevails over power. These data are similar to those found in the study of Zapardiel et al.,[12] where the authors established a close relationship between the type of defense and the throwing zone. Throws carried out by the backs are usually with opposition and no contact, a situation where higher throwing velocity is expected.[26] In contrast, the outside zones throws that were with contact and no opposition, often from shorter distances, with a whip-like wind-up and with more focus on accuracy are generally performed at lower velocities.[26] In their study, the best teams obtained higher values in central zones, although the differences shown in their study were smaller (zone 8: 26.7 ± 8.2 vs. 22.44 ± 4.25; zone 7: 28.0 ± 6.8 vs. 23.93 ± 3.76; zone 6: 26.9 ± 8.2 vs. 21.86 ± 4.01, all m/s). The improvement in the player's physical fitness or/and the instrumentation used for the throwing recording (Microsensor vs. Radar gun) can justify these differences between studies.

In regards to the goal hit zone, higher speeds were shown for throws in side zones compared to central zones.

TABLE 3 Effectiveness (%) by playing positions and court throwing zones. *Significance between zones for each position indicated by zone numbers in parenthesis. Number of throws indicated between brackets for each group in Table 1

Zone	LW	LB	CB	RB	RW	LP
1	57.1 ± 49.6*(3)	42.0 ± 49.7	30.5 ± 46.3*(2,3)	50.0 ± 53.5	50.0 ± 70.7	33.3 ± 49.2
2	65.3 ± 47.7	45.3 ± 49.8	50.4 ± 50.1*(1)	43.2 ± 49.7	60.0 ± 49.5	56.7 ± 49.6*(5)
3	71.8 ± 45.1*(1,4)	48.8 ± 50.1	52.8 ± 50.0*(1)	56.5 ± 49.7*(6,8)	75.2 ± 43.3	59.3 ± 49.2*(5)
4	39.0 ± 49.4*(3)	44.4 ± 49.8	43.2 ± 49.6	46.0 ± 49.9	63.5 ± 48.3	52.7 ± 50.0*(5)
5	66.7 ± 57.7	20.0 ± 42.2	26.1 ± 44.9	37.8 ± 48.7	56.8 ± 49.6	0.0 ± 0.0*(2−4,9)
6	50.0 ± 52.2	40.4 ± 49.2	37.4 ± 48.6	25.6 ± 44.2*(3)	—	75.0 ± 50.0
7	66.7 ± 50.0	45.8 ± 50.0	40.2 ± 49.3	41.6 ± 49.5	25.0 ± 50.0	20.0 ± 44.7
8	20.0 ± 44.7	42.6 ± 49.9	33.3 ± 47.7	37.8 ± 48.7*(3)	62.5 ± 50.0	66.7 ± 57.7
9	60.0 ± 50.7	43.8 ± 51.2	55.6 ± 52.7	75.0 ± 45.2	68.2 ± 47.7	64.3 ± 49.7*(5)

Note: Post hoc tests are not performed for RW in zone 6 because only one throw was collected.

Within side zones, throws to high zones presented higher speeds. The central zone is where the goalkeeper is usually positioned and, thus, the players likely chose to perform a skill throw here. In regards to high or low throws in the sides, the projection angle is probably influencing performance,[31] as it happens in other throw-based sports.[32]

When analyzing the differences by PP, the RB's and LB's throwing velocity was higher compared to the other positions (7.3%, 14.1% and 15.3% with respect to CB's, Wings and LP's, respectively). CB's showed also higher throwing velocity than wings (7.4%) and LP's (8.6%). In the same line are the results shown by Shalfawi[33] for male Norwegian players in a non-competitive context, who reported 24.11 m/s for Backs, 23.53 m/s for LPs and 22.89 m/s for Wings.

Since no other studies have investigated the subject, we speculate that the rank of ball speed patterns across positions could be explained by training adaptation,[33] anthropometric characteristics of the players,[34–36] and the adjustment of the throw to the opposition of the goalkeeper and defenders that may change the throwing kinematic pattern and could consequently change throwing velocity.[9]

4.2 | Effectiveness

From a tactical point of view, throws have to maintain a balance between accuracy and velocity.[7] The player must adapt the power depending on the zone and defense opposition at the moment of throwing. In this line, Zapardiel[26] showed that first-line players are more effective when they throw with opposition and contact than when they do it with opposition and without contact. On the contrary, second-line players were more effective when they threw with opposition and without contact than when they did it with opposition and with contact. Although previous research in handball suggested that there is an inverse relationship between speed and accuracy,[34,37–39] in our study, higher velocity throws (C4 and C3) were more effective than slower ones, performed in C1 and C2 (40% and 20% respectively). This is in contradiction with the study of Vila et al.[7] that showed an inverse relationship between effectiveness and throwing velocity whereby faster throws reduced players' effectiveness in competitive scenarios. Perhaps the important thing is that C3 throws showed to be as effective as C4 throws, which suggests that this could be the range where players better combine effectiveness and velocity (which could be termed as "effective velocity") and subsequently, coaches via training, should improve this range in competitive play.[7] It would probably be preferable to carry out throws with submaximal velocity so we could save energy and reduce the potential risk of injury.[13]

The results are logically consistent in terms of distance and throwing angle. Throws carried out close to the 6-m line showed greater effectiveness. The same happens with the angulation, where more centered throws were the most effective ones. Therefore, court zone 3 showed the highest effectiveness values. We should keep in mind that 7-m throws are included in this area, and these throws have an efficiency of 72.81% (434 shots, 316 goals, and 118 failures).

It is difficult to compare this research with other studies, not only because of the use of different instruments or the number of throws analyzed, but also because the studies that analyzed major championships, such as the WCh in Portugal 2003, did not include all the positions and did not analyze the throwing zones.[40] Nevertheless, the effectiveness showed in this research is similar to ours in relation to the wings and backs (around 60% and 40% respectively). There is a 10% difference with respect to the LPs.

In the same line as previous results, in our study throws located in goal hit zones 1 and 3 and therefore carried out at the highest velocity (26.6 ± 6.2 and 26.8 ± 6 m/s, respectively) showed also the highest effectiveness. Central zones, where the goalkeeper is supposed to be placed, showed the lowest effectiveness.

Another important contribution of this study is that effectiveness, such as throwing velocity, was different depending on the PP and the zone where the throw was made. In this regard, Wings and LPs were about 20% more effective than backs (LB, CB, and RB), and this remains true when considering their zone of influence.

Players are very specialized in their zone of influence, where they are clearly more effective. This is especially the case of LPs (over 56%), who make virtually no distance throws (approximately 1% in zones 6 to 8) or from extreme positions (approximately 2% in zones 1 and 5), where their effectiveness decrease. Wings also showed high effectiveness in their zone of influence (between 57% and 75%), greater as the angle increases, being significantly higher in the throws near to the center zone (zone 3), although this data can be influenced because wings are usually responsible for the 7 m. Wings are not lavished much outside their zone, with just 4% of the throws carried out in zones 6 to 8 and 6% far away from their natural playing zone although they maintain acceptable effectiveness in these areas. LPs, despite their high specialization and greater centrality, have lower effectiveness percentages than the wings, probably due to the high degree of defensive opposition.

Among back players, the differences in effectiveness between zones are smaller, with greater differences of the RB with respect to the LB, although they were only significant between zones 3 and 8. This means that the right side was more effective when throwing between lines through the central zone. These data, as it happened with the wings, may be influenced by 7-m throws. Our research is in line with Ferrari et al.[41] who observed, that in the EHF Champions League (EHFCL), more goals were scored in the central zones. Backs do not usually throw in zones far from their natural position, although when they do, the effectiveness is not reduced much.

Despite the great advance involved in the use of microsensors inside the ball for the control of throwing performance, this research has not been conducted without limitations. It would be desirable that for future work the situation/context in which the throw occurs (positional play, fastbreak, breakthroughs or 7 m) could be included.

5 | PERSPECTIVE

The ecological throwing performance evaluation in a high-level championship will be useful for coaches to make more accurate training proposals. Our data suggest that players should improve the throwing velocity but also train at submaximal velocities (effective velocity) to save energy and reduce the potential risk of injury.

It is also important to specialize training according to the performance shown by players from different zones of throwing. When Back players throw from outside zones they do with greater velocity than wings but with less effectiveness. The same is valid for line players when they leave their comfort zone and throw from more outside zones; they throw with higher velocity but with less effectiveness. This suggests that Back and LP should work more on skill throws when working in zones far from their natural position. Coaches should then design throwing drills by throwing zones more than by PP. Wings may be a different case, perhaps because of their technical quality, especially related to the manipulation of the ball. When they leave their zone, they are able to maintain an acceptable efficiency, with throwing velocities from distanced zones similar to the Back players.

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AUTHOR CONTRIBUTIONS

Basilio Pueo, Juan Tortosa-Martínez, Luis J. Chirosa-Rios, and Carmen Manchado involved in research concept and study design. Juan Tortosa-Martínez, Luis J. Chirosa-Rios, and Carmen Manchado involved in literature review. Basilio Pueo involved in data collection. Basilio Pueo, Juan Tortosa-Martínez, Luis J. Chirosa-Rios, and Carmen Manchado involved in data analysis and interpretation. Basilio Pueo involved in statistical analyses. Basilio Pueo, Juan Tortosa-Martínez, Luis J. Chirosa-Rios, and Carmen Manchado involved in writing of the manuscript. Basilio Pueo, Juan Tortosa-Martínez, Luis J. Chirosa-Rios, and Carmen Manchado involved in reviewing/editing a draft of the manuscript.

DATA AVAILABILITY STATEMENT

Restrictions apply to the availability of these data, as they are property of the European Handball Federation (EHF) and only accessible for the participating members.

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