






## Score goal in handball matches and its relationship with throwing speed

### Lanzamientos que terminan en gol en partidos de balonmano y su relación con la velocidad de lanzamiento

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#### Abstract

Performance in handball comes from a complex combination of specific skills. Throwing speed is considered the most relevant action of a team's offensive game. The main objectives of this investigation were two, firstly, to determine if there are differences between the throwing speed in training and the throwing speed in competition, and secondly, to determine the anthropometric and conditional variables that have the greatest influence on the effective speed during a competition. The 14 junior players of the Portuguese national team who participated in the Junior World Championship were assessed through a countermovement jump test, their anthropometric variables were measured, they were assessed by dynamometry, and their maximum throwing speeds in training without a goalkeeper, with a goalkeeper. And during the eight games played in the championship were the maximum recorded speed of the throws that resulted in goals was selected for each player. One-way repeated-measures ANOVA was conducted to compare the effect of player interaction (no interaction, interaction with goalkeeper, interaction with all other players in competition) on ball velocity. Approximately 77% of the effective speed (the speed at which a player scores a goal during a match) was explained by the speed of throws in support from 9 metres, with no goalkeeper, and the circumference of the flexed arm. The players did not achieve their maximum throwing speed during the competition. The throwing speed during competition was strongly correlated with the flexed arm girth and throwing speed without the goalkeeper in training (factors that can be modified by training).

**Keywords:** Competition speed; performance; multiple linear regression; real game.

#### Resumen

El rendimiento en balonmano proviene de una combinación compleja de habilidades específicas. La velocidad de lanzamiento se considera la acción más relevante del juego ofensivo de un equipo. Los principales objetivos de esta investigación fueron dos, en primer lugar, determinar si existen diferencias entre la velocidad de lanzamiento en entrenamiento y la velocidad de lanzamiento en competición, y en segundo lugar, determinar las variables antropométricas y condicionales que más influyen en la velocidad efectiva durante una competición. Los 14 jugadores juveniles de la selección portuguesa que participaron en el Campeonato Mundial Junior fueron evaluados mediante un test de salto con contramovimiento, se midieron sus variables antropométricas, se evaluaron mediante dinamometría y sus velocidades máximas de lanzamiento en entrenamientos sin portero y con portero. Durante los ocho partidos disputados en el campeonato se seleccionó la velocidad máxima registrada de los lanzamientos que fueron gol para cada jugador. Se realizó un ANOVA unidireccional de medidas repetidas para comparar el efecto de la interacción del jugador (sin interacción, interacción con el portero, interacción con todos los demás jugadores en la competición) sobre la velocidad del balón. Aproximadamente el 77% de la velocidad efectiva (la velocidad a la que un jugador marca un gol durante un partido) se explicaba por la velocidad de los lanzamientos en apoyo desde los 9 metros, sin portero, y la circunferencia del brazo flexionado. Los jugadores no alcanzaron su máxima velocidad de lanzamiento durante la competición. La velocidad de lanzamiento durante la competición estuvo fuertemente correlacionada con la circunferencia del brazo flexionado y la velocidad de lanzamiento sin el portero en el entrenamiento (factores modificables por el entrenamiento).

**Palabras clave:** Gol; rendimiento; regresión lineal múltiple; juego real.

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## Introduction

Within the world of sports, both training and research scenarios need to approximate what happens in competition (Ribeiro et al., 2019). This is true for handball, but the vast majority of published studies are studies conducted during controlled training. These studies provide us with valuable information, but we must keep in mind that handball is a complex and multifactorial sport in which the player does not act alone but must coordinate his actions well with the rest of the team, an effort that is influenced in part by the behaviour of the opponent (Milanović et al., 2018; Wagner et al., 2012; Nebahat, 2024). This means that the best players are those who are highly capable of adapting to changes in the game to achieve greater performance.

Performance in handball comes from a complex combination of specific skills that lead to a variety of actions to be taken that have many possible outcomes and that must be executed at high speed (Hatzimanouil et al., 2017; Mihaila et al., 2024). Throwing speed is considered the most relevant action of a team's offensive game (Granados et al., 2007) and an important factor in handball performance (Wagner et al., 2012). First line handball players vary their throwing zones and speeds in a balanced way, finding the greatest effectiveness at distances closer to the goal (Pueo et al., 2023). However, the throwing speed per se is not enough to score goals; it must be closely associated with throwing accuracy (van den Tillaar & Ettema, 2006; Vila et al., 2020). Numerous studies have analysed throwing speed from the perspective of the player as an individual and have obtained absolute velocity values in individual situations (Raeder et al., 2015, Hemnassi et al., 2015; García et al., 2013). However, the reality is that in handball, there are rare occasions when a player shoots at goal without the presence of a defender or at least a goalkeeper. To clarify this situation, some researchers (Gutierrez Davila et al., 2006; Rivilla-Garcia et al., 2011; Vila et al., 2012) evaluated throwing speed with opposition by adding a goalkeeper and found that the mere presence of the goalkeeper led to a decrease in throwing speeds. This indicates that the presence or opposition of an opponent forces the player to make adjustments while executing the throw. These results are reinforced by the conclusions reached in (Zapardiel et al., 2019), where the velocities were analysed during competition, and there were differences in velocity as a function of the degree of opposition and contact with the shooter.

Throwing effectiveness in top-level handball championships varies depending on the degree of interaction with others (goalkeeper and defenders), the distance from which the throw is made (six metres, penalty, nine metres...), the type of throw according to player position (wing, pivot, backcourt...), and the phase of play (attack, counterattack, penalty) (Hatzimanouil et al., 2017; Meletakos et al., 2011). The lowest percentage of effectiveness in shooting occurs in throws from nine metres made by the wings in the organized game phase (Hatzimanouil et al., 2017; Meletakos et al., 2011). The lowest percentage of effectiveness coincides with a greater degree of interaction between the players and a greater throwing distance. In these cases, the player's maximum throwing speed plays a greater role since the maximum interrelationship between speed and accuracy does not coincide with the player's maximum speed (Fitts, 1954). In short, throwing speed is a critical factor in competition but the question is how throwing speed and accuracy differ in stable and competition conditions (Petruzela et al., 2023).

Anthropometric factors are important for throwing velocity. Previous studies have reported significant and positive correlations between ball speed and general anthropometric characteristics such as body mass, lean body mass, body height, and body mass index (Van den Tillaar and Ettema, 2004; Zapartidis et al., 2007). Other studies have focused on anthropometric variables specific to handball, such as hand size and arm extension, and have even reported significant and positive correlations with ball speed (Skoufas et al., 2003; Zapartidis et al., 2009). However, in all of these studies, general anthropometric variables were better predictors than handball-specific ones (Debanne and Laffaye, 2011).

The object of our study was performance during competition rather than knowledge derived from individual reports or laboratory tests of athletes. This goal motivated us to undertake an applied ecological research study, where performance was analysed during competition. The specific objectives of this study were a) To determine if there are differences between throwing velocity in training and throwing velocity in competition; b) to determine the anthropometric and conditional variables that have the greatest influence on the effective speed during a competition.

## Material and Methods

### **Design**

A repeated-measures design was used to investigate the effects of player interaction on throwing speed in high-level male team handball players. Three levels of player interaction were defined: (a) no interaction (throwing at an empty goal), (b) interaction with a goalkeeper (throwing at a goal defended by a goalkeeper), and (c) interaction with all other players (throwing at goal in real game situations). The first two levels were tested in a training session; the third level was tested during competition.

One week before the start of the World Championship, the players underwent an anthropometric assessment and the throwing speed in training; and 4) the handgrip strength to assess the isometric strength of the forearm.

All tests were performed in a single session.

Later, during the championship, the throwing speeds during the competition were recorded.

### **Participants**

Fourteen elite junior handball players ( $20.61 \pm 0.60$  years) were selected from among the best players of the Portuguese Handball Federation to participate in the IHF Men's Junior U21 World Championship, held in Spain in July 2019. This team was ranked among the four best teams in the World Championship. All the athletes and coaching staff were informed of the tests to be performed, as well as the possible risks and benefits of the tests. Goalkeepers were not included in this study. The study was approved by the Ethics Committee of the School of Learning and Sports Sciences, under code 04-719, and met the criteria of the Declaration of Helsinki.

### **Instruments**

Anthropometric data were measured using a non-stretch Holtain fibreglass metric tape measure (Holtain Ltd, United Kingdom). Explosive upper body force production was assessed on the handball court using a radar device (StalkerPro Inc., Plano) with a recording frequency of 100 Hz and a sensitivity of 0.045 m-s<sup>-1</sup>. Hand grip strength was evaluated with a digital handgrip dynamometer (TKK 5401, Japan) with a sensitivity of 0.1 kg of force (kgf). The Ergo Jump Bosco System Byomedics, SCP, Barcelona, Spain was used to measure the squat jump and the countermovement jump.

### **Measures**

The assessment included body dimensions (weight, height), lengths and diameters (upper and lower limbs), skinfolds (triceps, subscapular, biceps, supraspinal, abdominal, suprailiac, anterior thigh, medial calf), diameters (shoulder, wrist, humeral epicondylar, femoral bicondylar), and girth (relaxed and flexed arm, waist, hip, thigh, calf).

### **Procedure**

The anthropometric measurements followed the International Working Group of Kinanthropometry (ISAK) protocols (Ross & Marfell-Jones, 1995).

The body mass index (BMI) was calculated, as was the muscle percentage by the Martín formula (Martín et al., 1990). The percentage of fat mass was calculated by measuring skinfolds using the method described by (Jackson et al., 1980). Fat-free mass (kg) was calculated as the difference between weight and fat mass. Weight and height were measured using a SECA scale and stadiometer (Germany) with a 100-g accuracy for weight and 0.1-cm accuracy for height. The perimeters were measured in triplicate with a non-stretch Holtain fibreglass metric tape measure (Holtain Ltd, United Kingdom). The diameters (wrist and humeral epicondylar, femoral bicondylar, and shoulder) were determined with a 1-mm Holtain precision pachymeter (Holtain Ltd, UK). The margin of error was <2% for skinfolds and <1% for diameters and girths.

A 15-minute warm-up was performed, focussing on specific aspects of the throwing. Explosive upper body force production was evaluated on the handball court using a radar device placed behind the goal. Two different protocols were followed, one with a goalkeeper and the other without a goalkeeper. The throw was executed from the free-throw line (9 m) after taking three steps and in support. Only the throws on goal were recorded. To help motivate them, the players were immediately informed of their results. Three series of throws were executed, leaving an interval of three minutes of rest to avoid fatigue. All throws were made with regulation balls for men's senior players and always in a direction perpendicular to the goal. The players used resin.

Hand grip strength was evaluated with a digital handgrip dynamometer (TKK 5401, Japan) with a sensitivity of 0.1 kg of force (kgf). The study subjects became familiar with the dynamometer, and after three warm-up repetitions, the athletes performed two repetitions at maximum effort with their dominant and non-dominant hands while standing and with the dynamometer parallel to the body. The highest values for both hands were taken for analysis. The grip range of each subject was adjusted according to the medial phalanges of the hand. The dynamometer was squeezed as hard as possible in each case, without moving the arm or wrist.

#### Vertical jump

Each participant performed two kinds of maximal jumps, the squat jump and the countermovement jump, on a jump mat to measure flight and contact times. The jump height was determined from the flight time using standard calculations. The participants completed three attempts of each type of jump, and the best one was taken for statistical analysis. Between jumps, the participants were allowed to recover for three minutes to avoid fatigue.

During the World Championship, the throwing ending in goals speed was recorded with a radar gun placed behind the goal. The radar was placed at a distance of 3 metres and at a height of 1.20 metres (Zapardiel Cortés et al., 2017). Two observers carried out this task. One of them recorded the throw speed, and the other recorded the player who executed the throw ending in goals, the place from which he threw, and the degree of interaction with the opposing players. Once the championship ended, the analysed games were downloaded and reviewed to correct possible errors that may have occurred when recording the data in situ. The collected data were coded and recorded in an Excel spreadsheet. From the total of throws made during the eight games that were played, the maximum recorded speed of the throws that resulted in goals was selected for each player (Vila et al., 2020).

### **Statistical analysis**

Descriptive statistics (mean and standard deviation) were calculated for all variables. The normality of all data sets was verified by the Shapiro-Wilk test. The Levene test verified the homogeneity of the variance.

Means and standard deviations of ball-throwing velocity ( $m \cdot s^{-1}$ ) were calculated. A one-way with repeated measures ANOVA was conducted to compare the effect of player interaction (no interaction, interaction with goalkeeper, interaction with all other players in competition) on ball velocity. Because of the increasing degree of player interaction among the three conditions, repeated contrasts were conducted. The first contrast compared the condition without interaction to the interaction with a goalkeeper; the second contrast compared the interaction with a goalkeeper to the interaction with all other players in competition. Finally, effect sizes ( $\eta^2$ ) were calculated to assess the practical significance of the differences and interpreted as small ( $\eta^2 \geq .01$ ), medium ( $\eta^2 \geq .06$ ), and large ( $\eta^2 \geq .14$ ) (1). The level of significance was set at  $p \leq 0.05$ .

Given a set of independent variables with normal distribution and taking the competition speed as the dependent variable, multiple linear regression analysis was conducted to determine the relationships of the independent variables with the dependent variable (competition speed). The variable selection method used was stepwise inclusion. Multicollinearity was estimated using the variance inflation factor, which for all the variables did not exceed 10, and the average of their scores was close to 1 ( $= 1.024$ ), which indicates non-multicollinearity, and the scatter plots tested the assumption of linearity. The independence of the residues was verified with the Durbin-Watson test ( $= 1.664$ ).

## Results

The descriptive characteristics of the elite junior handball players who participated in the study are shown in Table 1.

**Table 1.** Physical characteristics of junior male handball players ( $\bar{x} \pm sd$ )

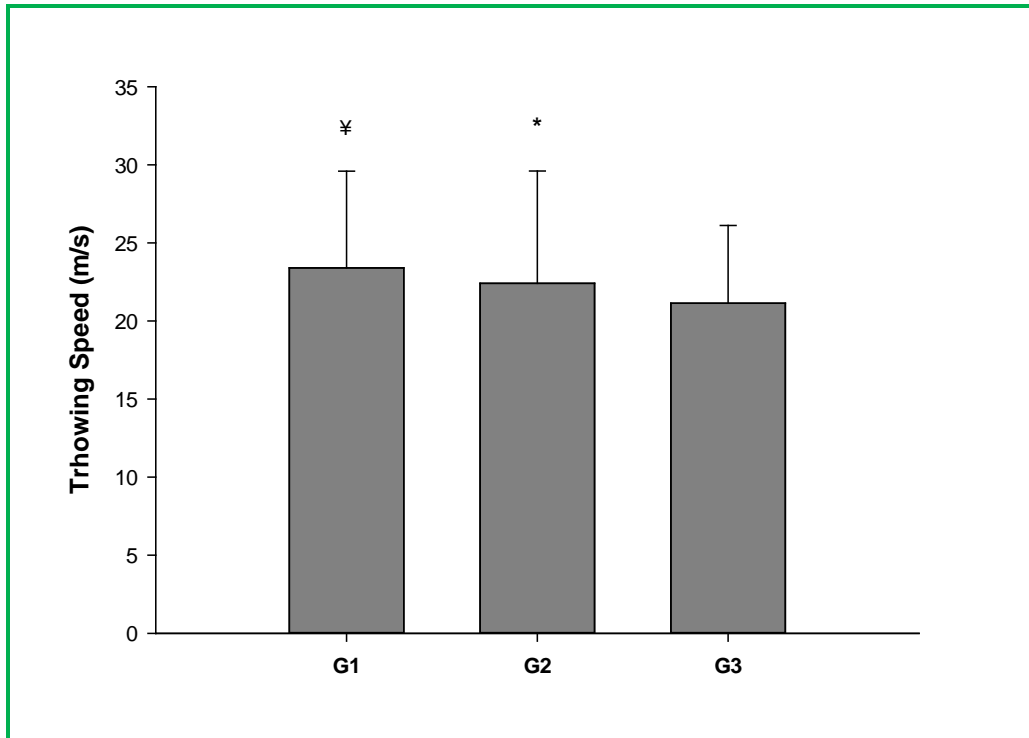
	Mean	SD	Lower	Upper
<b>High (cm)</b>	189.20	7.03	174.00	200.00
<b>Weight (Kg)</b>	92.59	15.99	69.90	123.50
<b>Age (years)</b>	20.61	0.60	19.45	21.52
<b>Experience (years)</b>	11.17	2.25	8.00	15.00
<b>Arm flexed girth (cm)</b>	36.70	4.04	32.50	45.00

The average throw speed of all the throws executed by the Portuguese junior handball team as a function of the degree of interaction with opponents is shown in Table 2. Statistically significant differences were found between the throws T1 and T2 in relation to T3.

**Table 2.** Mean and standard deviation values ( $\bar{x} \pm sd$ ) corresponding to throwing speed of men's handball players according to three levels of interaction

<b>(T1) Throwing without Goalkeeper</b>	<b>(T2) Throwing with Goalkeeper</b>	<b>(T3) Throwing with interaction in</b>
<b>interaction (m/s)</b>	<b>interaction (m/s)</b>	<b>real game (m/s)</b>
29.02±4.69	28.47±5.10	24.80±14.05

Our results show a significant and large main effect of player interaction on the ball-throwing velocity of the male handball players ( $F_{1,27, 16, 52} = 0.55, p \leq .001$ ). Because of the outcome of Mauchly's test of statistical significance ( $\chi^2_2 = 10.24, p \leq .006$ ), the degrees of freedom were corrected using Huynh-Feldt estimates of sphericity ( $\epsilon = .67$ ). Contrasts revealed a significant decrease in throwing speed with a medium effect when throwing at a goal defended by a goalkeeper in comparison to the non-interaction condition ( $F_{1, 13} = 5.41, p = .000, \eta^2 = 1.20$ ). Throwing velocities of the athletes were also affected by increasing player interaction to the highest degree. Compared to the goalkeeper interaction condition, the maximum-interaction condition decreased the throwing velocity significantly and with a large effect ( $F_{1, 13} = 3.47, p = .004, \eta^2 = 1.04$ ) (Figure 1).



**Figure 1.** Mean and standard deviation values ( $\bar{x} \pm sd$ ) corresponding to throwing velocity by groups of efficacy. ¥ Statistical differences with G3  $p > 0.001$ , \* Statistical differences with G3  $p > 0.05$

To score a goal, the players used an average of 85.46% of the maximum speed. If they were analysed individually (Table 3), the percentages were widely spread (66.33-106.19%). There was one player who had a faster throwing speed in competition than in training.

**Table 3.** Throwing speed in the different types of throw by each player

Player	T1 (m/s)	T3 (m/s)	T1-T3 (%)
1	28.33	23.61	83.33
2	27.78	20.56	74.00
3	28.61	27.22	95.15
4	28.61	24.44	85.44
5	30.00	27.78	92.59
6	30.28	28.89	95.41
7	28.61	23.06	80.58
8	27.22	18.06	66.33
9	28.33	26.11	92.16
10	28.89	23.06	79.81
11	28.61	24.17	84.47
12	31.94	26.39	82.61
13	27.78	20.56	74.00
14	31.39	33.33	106.19

**Legend:** T1: Throwing speed without Goalkeeper interaction; T3 Throwing speed with interaction in real game. T1-T3 Loss of speed between throwing speed without goalkeeper interaction and throwing speed in real game

The linear regression analysis showed the existence of a relationship between the variables:  $Y = -187.76 + 2.114X_1 + 1.554X_2$ , where Y is the competition throwing speed,  $X_1$  is the throwing speed without a goalkeeper, and  $X_2$  is the girth of the flexed arm. The positive or negative coefficient on the independent variables implies that they have a positive or negative influence, respectively, on the value of the dependent variable. The coefficient of determination was 0.77, and the mean squared error was -1.8475. Table 4 shows the standardized coefficients and their probability values.

**Table 4.** Unstandardized (B) and standardized (Beta) coefficients obtained through stepwise regression procedure in SPSS

	Unstandardized B	Coefficients Std Error	Standardized coefficients Beta
Constant	-187.76	48.57	
Throwing speed without goalkeeper	2.114	0.4	744*
Arm flexed girth (cm)	1.554	0.7	361*

## Discussion

The main finding of this work is that a significant reduction in throwing speed is observed as the degree of player interaction with the opponent's increases. This result has a medium effect size in training and a large one during competition. Some 77% of the effective speed (the speed that a player uses during the competition to score a goal) was explained by the speed of throws in support from 9 meters without a goalkeeper and the girth of the flexed arm.

Handball players achieve higher speeds during training than in competition. Here, when in training, throws were made with the goalkeeper present, the speed produced by the players decreased, agreeing with (Ferragut et al., 2018; Vila et al., 2012) in female handball players and (Rivilla-Garcia et al., 2011) with the presence of a defender in male handball players. This decrease in speed became significant when analysing the speed of the competition, which confirms that the degree of opposition influences the speed of the throw (Zapardiel et al., 2019). These results are in line with (Gutierrez Davila et al., 2006) and lead us to conclude that during the game, opposition by an opponent continuously forces players to adjust their movements during the execution of the throw, which could cause a decrease in speed (Fitts, 1954). In this sense, the repetition of actions and the knowledge of the result make the elite athlete self-regulate the "ideal" motion of a specific action (Toering et al., 2009).

In other studies conducted in junior players, the speeds recorded were lower than those recorded in this study, being between 24.05 and 25.6 m/s (Hermassi et al., 2015; Rousanoglou et al., 2014; Sabido et al., 2016; Sabido et al., 2017). However, these comparisons should be interpreted carefully because few studies have been published and the methods (radar gun, digital video camera), the types of throw, and the samples have been very different.

In turn, it is clear that in tactical-strategic training, it is also necessary to make the throws in a specific way, that is, they must be executed under the influence of the same interactions that arise during competition, since any other type of throw will not specifically help improve the in-game throwing speed (Zapardiel et al., 2019). This is in line with other studies (Karcher & Buchheit, 2014; Wagner et al., 2012), which pointed out the need for training and evaluations to more closely resemble the realities of competition. Reinforcing this idea, if we analyse the difference between the maximum speed that the players could produce and the one they attained during the competition to score a goal, we found that on average, the players used 85.46% of their maximum speed. One study (van den Tillaar & Ettema, 2006) suggests that handball players can keep their throw speeds near the maximum (80-90%) without decreasing their accuracy, so it would be desirable to train at high speeds, since decreasing it will not improve their accuracy. Importantly, there was a significant percentage of improvement in the speed used during the competition (14.54% on average). We should not forget that this is a percentage of the average speed; if the percentages are observed individually (Table 3), there was high inter-subject variability (66.33-106.19 m/s), so it is necessary, as far as possible, to individualize the training session

for each player on each team. These results reinforce the findings of (Vila et al., 2020), which indicate that it would be important for the coach to identify the range in which each player combines efficiency and speed ("effective speed") and, through training, improve the effective speed the player achieves in real games.

The regression equation of this study shows the importance of having a high maximum speed, since the speeds used in the game depend on it. The girth of the flexed arm is related to strength and reinforces the importance of strength on speed with a high degree of interaction. Both variables can be modified by training, and they explain 77% of the throwing speed during competition, which can be considered an important percentage for which the coaching staff can intervene from two perspectives (physical conditioning and technical-tactical training). In the case of this sample, we understand that there is homogeneity in anthropometric criteria (participants belong to a national team). Comparisons are difficult because to our knowledge, there are no similar studies.

In recent years, numerous studies have proposed different strength training regimens to increase throwing speed (Hermassi et al., 2011; Hermassi et al., 2015; Ignjatovic et al., 2012; Marques & Gonzalez-Badillo, 2006; Sabido et al., 2016) by different methods, with heterogeneous samples but with similar results (gain or improvement in throwing speed). Other studies have explored the effects of core training (Manchado et al., 2017; Saeterbakken et al., 2011) and resistance band training (Mascarin et al., 2017) on throwing speed. All these proposals have been done in training situations, but in no case has it been shown that this improvement in speed has been accompanied by an improvement of speed during an actual game.

One study (Raeder et al., 2015) in female handball players observed improvements in throw strength, power, and speed, but not in accuracy. Since the intervention did not improve accuracy, those authors considered it necessary to propose a second approach to guide strength training in handball. Their results reinforce the conclusions of this study. This leads us to think that, on the one hand, it is necessary to train to improve the maximum throw speed by focussing primarily on conditioning (physical trainers), but that, on the other hand, the coach should plan training actions in the presence of opposition to specifically improve competition speed. It would be appropriate to explore specific throwing training activities with different interactions designed to simulate different attention-grabbing aspects of competition, as already mentioned above.

## Practical Applications

The present results indicate the need to train for high velocities (effective velocity), but not maximum velocities, since the player's effectiveness will be impaired.

It is necessary to maintain a high percentage of effectiveness in the throws executed during training, but under conditions that replicate as closely as possible those of competitive scenarios. Consequently, coaches must devise situations (visual, auditory and kinaesthetic) that stimulate players' capacity to perceive movement, anticipate and make decisions, and design and implement tasks that include multiple degrees of freedom within a dynamic context, since variable, random practice helps increase learning and improve skill transfer in the medium and long term.

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