Original Article

Relation between general throwing tests with a medicine ball and specific tests to evaluate throwing velocity with and without opposition in handball

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ABSTRACT

Rivilla-García J, Martínez I, Grande I, Sampedro-Molinuevo J. Relation between general throwing tests with a medicine ball and specific tests to evaluate throwing velocity with and without opposition in handball. *J. Hum. Sport Exerc.* Vol. 6, No. 2, pp. 414-426, 2011. The aim of the present study was to analyze the relationship among general throwing tests, with a medicine ball, and throwing velocity tests with and without opposition in different groups of handball players, thus analyzing the influence of technique and decision making in specific throwing capacity. To do this, ninety-four handball players of different competitive levels, age groups and playing positions were tested in four throws of progressive specificity: a) throwing with a heavy medicine ball (THMB); b) throwing with a light medicine ball (TLMB); c) throwing velocity (VS); and d) throwing velocity with opposition (VO). The correlational study, using Pearson's correlation coefficient, was found to be significant ($p<0.01$) in the relations among the different tests in the whole sample and all groups. The data indicated not very high correlations between the THMB and the other tests, especially with the VO in the over 18 senior players ($r=0.404^{**}$). Correlation values for TLMB-VS were very high in general ($r=0.904^{**}$) and in all groups. By contrast, the correlation between the throwing tests was not high, especially in the under 18 players ($r=0.621^{**}$), backcourt players ($r=0.632^{**}$) and central players ($r=0.594^{**}$). The data lead to the conclusion that the general test has limited utility for assessing specific throwing capacity; that TLMB adequately predicts VS; and that opposition has a significant influence on specific throwing speed. **Key words**: TEST, SPECIFIC FITNESS, OPPOSITION, DECISION-MAKING.

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INTRODUCTION

Handball is an Olympic sport with a high demand for fitness which is revealed in the most important play actions which are throwing, feinting, sprinting, jumping and blocking. Perhaps this is why numerous studies have concentrated on analyzing players' fitness. The tests used have mostly been far from specific and unrelated to the precise characteristics of team players (Calleja et al., 2002; Vaquera, 2003).

The handball action which has been most studied is probably the throw as from an offensive point of view, it is the one which best predicts the team's performance (Román, 1997; Wit & Eliasz, 1998; Laguna, 2004), which is why its importance has been underlined by numerous authors (Eliasz, Janik & Wit, 1990; Sánchez, 1991; Fleck et al., 1992; Párraga, Sánchez & Oña, 2001; Gorostiaga et al., 2005; López, 2005; Granados et al., 2007).

There are many types of throw which can be classified according to the different analysis variables. Two of the most used classifications consider the trajectory of the ball and the motor performance of the throw. With regard to the former, throws can be divided into direct, bounce, rolling, or lob (adapted from Oliver & Sosa, 1996; Antúnez & Ureña, 2002) while with regard to motor performance the throws can be classified according to whether the player is standing or jumping and the latter further divided into suspended, forward and lateral jump shots. With regard to the specific throws used in the present study, they were direct standing throws. This type of throw is described below (Torrescusa, 1986):

The initial position of the players is to stand behind the throw line at a distance which permits them to take three preliminary stops before making a direct standing shot. The player's body should be facing the direction of the throw and the ball should be grasped in both hands. From this position the player should start to run forward towards the throw line with the ball held in both hands. The three steps which should be taken preliminary to the final throwing action are described below:

First step.
The player takes the first step with the opposite foot to the throwing arm and holds the ball in one hand. The throwing arm moves to a horizontal position by flexing the shoulder. Then the trunk begins to rotate in the direction of the throwing arm and the shoulder of the same arm begins an external rotation with the elbow bent at 90º which places the forearm in an almost vertical position with the hand at the highest point.

Second step.
When the player takes the second step (with the foot on the same side as the throwing arm) the torsion of the trunk increases towards the throwing arm and the throwing elbow is extended. These aspects are fundamental to achieve the longest trajectory and time during which force is applied to the ball thus giving it greater acceleration and take-off speed. At this moment the line of the shoulders can be seen to aim in the direction of the throw with the throwing shoulder behind the other one. Moments before taking the final step the trunk begins to twist in the opposite direction.

Third step.
The last step in made with the opposite foot to the throwing arm. The last step is longer, an aspect which the technicians consider of key importance for suitably aiming the shot. Helped by the impulse offered by the back leg there is a rapid and explosive twist of the trunk in the opposite direction to the one indicated by the previous steps. The kinetic throwing chain begins in the legs, continues in the action of the hip which is in anteversion, continues with the twisting of the trunk and ends with the external rotation of the shoulder

and extension of the elbow and wrist. The player should look towards the goal until the last instant. Trunk torsion may often be accompanied by trunk flexion.

The success of the throw depends on two fundamental factors: velocity and accuracy (Van Muijen, Joris, Kemper & Van Ingen Schenau, 1991; Bayios & Boudolos, 1998; Wit & Eliasz, 1998; Párraga et al., 2001; van den Tillaar & Ettema, 2003). In turn, the velocity of the throw depends fundamentally on four factors: (a) throwing technique, (b) temporal coordination of the actions of the different body segments and (c) the muscle strength and (d) power of the arms and legs (Joris et al., 1985; Van Muijen et al., 1991). The importance of the last two factors mentioned explains the interest in evaluating them, although in many cases coaches have used throws with a medicine ball, which are very general and poorly validated tests (Mayo & Pardo, 2001; Moreno, 2004; Torres et al., 2004). Throws with a medicine ball have also been used as a training method for specifically improving throwing velocity in handball (DeRenne, Ho, & Blitzblau, 1990; Van Muijen et al., 1991; DeRenne et al., 1994; Cardoso & González-Badillo, 2006). The analysis of the relationship between this type of general throwing tests with a medicine ball and specific throwing tests in handball constitutes the starting point for the present study.

The analysis of throwing velocity and accuracy was carried out with the most modern, standardized and validated equipment and methods (Bretagne, 1980; Prokajac, 1980; Joris et al., 1985; Mikkelsen & Olensen, 1985). In these studies on throwing which were carried out in technical situations more similar to those of the actual game, the continued absence of opposition and therefore decision making is surprising. However, some authors have stated that cognitive factors and decision making influence throwing velocity (Fleck et al., 1992; Pardo, González & Mayo, 2007; Párraga et al., 2001) and some studies confirm this in handball (Rivilla et al., 2009) and water polo (Van der Wende, 2005; Vila et al., 2009). In this context the study by López (2005) which concludes that there is no difference in jump throwing velocity with and without opposition, is worthy of note (López, 2005). The velocities recorded in the different studies and the conditions under which the throws were performed are presented in Table 1.

It is surprising in this field of study that there is such a scarcity of research on the relationship among general tests, more precisely medicine ball throws, and specific tests; as well as between throwing velocity with and without opposition.

With regard to the relationship among general and specific throwing tests, several studies show a moderate correlation ($r>0.60$) between muscle strength and power and throwing velocity (Gorostiaga et al., 2005; Marques et al., 2007) in handball players, being greater ($r=0.80$) in women handball players (Granados et al., 2007). The relationship has also been demonstrated between throwing velocity and maximum strength in the bench press (Hoff & Almasbakk, 1995) and between throwing velocity and isokinetic strength in the upper body (Fleck et al., 1992). In contrast, some authors found an absence of relationship between throwing velocity and isokinetic muscle strength in the internal and external shoulder rotators (Bayios et al., 2001; Dauty et al., 2005).

In other sports like cricket, senior and junior players obtained strong correlations among peak throwing velocity and the chest pass and standing vertical jump (Pyne, Duthie, Saunders, Petersen & Portus, 2006). In the same way, in baseball a strong correlation has been found between throwing velocity and shoulder muscle strength in adduction and extension (Kane, 2003), although in this same sport some studies have found insufficient specificity of heavy medicine ball throws in relation to the movement patterns (Newton & McEvoy, 1994), putting into question the use of these general tests for talent spotting in this sport (Lidor et al., 2005).

Table 1. *Throwing velocities in handball.*

Author/s	Sample	Throwing conditions	Velocities (m · s^{-1})
Mikkelsen & Olensen (1976)	Danish national team	*Standing without run up*	21.22
		Standing with run up	23.11
Bretagne (1980)		*Standing*	17.50 – 25.55
		Jumping	18.61 – 26.38
Prokrajac (1980)	Polish national team	*Standing without run up*	19.8
		Standing with run up	23.19
		Jumping	18.8
	Austrian national team	*Standing without run up*	27.7
		Standing with run up	19.4 – 22.2
		Jumping	18.05 – 25
	Rumanian national team	*Standing without run up*	23.3
		Standing with run up	25
	Israeli national team	*Standing without run up*	21.2
		Standing with run up	22.02
		Jumping	21.23
Kotzamani-dis (1987)	International players	*With vertical jump*	23.44
		With horizontal jump	25
Barata (1992)	n=23	*Standing without run up*	20
		Standing with run up	22.1
Hoff & Almasbakk (1996)	Norwegian players	*Standing without run up*	19.9 – 23.3
		Standing with run up	23.1 – 27
Baylos & Boudolos (1998)	Greek 1st Division	*Standing without run up*	23.51
		Standing with run up	26.27
Párraga et al. (2001)	ASOBAL players (n=16)	*Jumping with opposition*	17.21 – 20.53
Sibila et al. (2003)		*With classical jump*	24.14
		Jumping on wrong foot	22.32
Gorostiaga et al. (2005)	Professional players (n=15)	*Standing without run up*	23.8±1.9
		Standing with run up	25.3±2.2
	Amateur players (n=15)	*Standing without run up*	21.8±1.6
		Standing with run up	22.9±1.4
López (2005)	Honour Division B (n=11)	*Jumping without opposition*	25.03±1.50
		Jumping with opposition	24.36±1.48
Marques et al. (2007)	Elite players (n=14)	*Standing without opposition*	23.98±1.70
Pardo et al. (2007)	ASOBAL players (n=4)	*Standing without opposition*	26.09
		Jumping without	25.53

Bearing this background in mind we have found a specific lack of knowledge of the existence of a relationship among general throwing tests using a medicine ball and the specific tests used to assess throwing velocity.

The present study had as its first aim the analysis of the relationship which exists among general throwing tests using medicine balls of different weights and specific tests for assessing throwing velocity in handball. A second aim was to study the relationship between throwing velocity with and without opposition, about which no evidence was found in the literature studied.

MATERIAL AND METHODS

Sample

The sample was made up of a non random selection of 94 handball players, with the exclusion of the goalkeepers given that the action being analyzed (throwing) was of scant importance for them. The sample was divided according to the following criteria: age category (senior and under 18) and specific offensive position (backcourt, central, pivot and wing players). The general characteristics of the sample are shown in Table 2.

Table 2. *General characteristics of the sample.*

Total number of players	Age (years)	Height (cm)	Body Mass (kg)	Age Category	Specific position
94 players	23.16±5.1	183±5.01	85.4±8.32	Senior (n=43) Under-18 (n=51)	Backcourt (n=24) Central (n=25) Pivot (n=22) Wingman (n=23)

It was considered to be especially valuable to have a heterogeneous sample so that there were participants in all the groups which made up the classifications and, equally, to be able to count on teams from different competitive levels, including a team from the maximum world level like the Balonmano Ciudad Real team, which plays in the highest national (Asobal) and International (Champions) leagues.

Procedure

All the players who made up the sample performed four throwing tests of progressive specificity: 1) a throw with a heavy medicine ball (THMB), 2) a throw with a light medicine ball (TLMB), 3) throwing velocity without opposition (VS) and d) throwing velocity with opposition (VO).

Before performing the tests, the players were informed of the protocol, risks and benefits of the tests and gave their informed consent. The players from a same team were tested on the same day and in one session.

The preliminary warm up consisted of a general part, which included varied movements and exercises for muscle and joint mobility and flexibility, and a specific part made up of specific movements, specific flexibility exercises for the shoulder and varied throws with balls of different weights. Then in spite of the fact that all the players were familiar with the movements which made up the test, they were allowed to perform several throws before their first test throw, under identical conditions to those of the test, and were given technical corrections if needed.

The order of the test performance was from lesser to greater specificity. The throw with the heavy medicine ball (3 kg) consisted in throwing the ball the greatest distance possible with both hands from behind the head (throw-in), using an explosive forward movement (Figure 1).

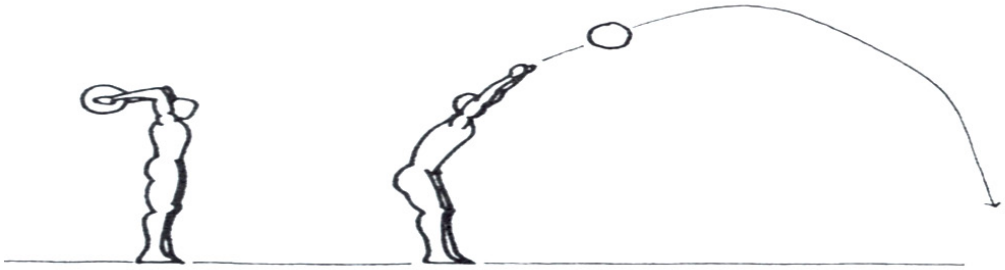

Figure 1. *Throwing test with the heavy medicine ball (Ortiz et al., 1999).*

The test with the light medicine ball (0.8 kg) consisted in throwing the ball, held in one hand, the greatest distance possible, using the correct handball throwing technique, and allowing a maximum of three preliminary steps but without permitting the thrower to cross the free throw line (9 metres) before or after the throw (Torrescusa, 1986).

The throwing velocity tests consisted in throwing at the goal (where a wooden panel had been placed) at the greatest velocity possible from a distance which was never less than 9 metres, with a maximum of three preliminary steps, and performing the technical gesture of a standing throw, and being allowed to use resin on the hands as in the actual game. With regard to accuracy, the players were instructed to make the throws accurate according to the criteria of difficulty for the goalkeeper's intervention as presented by Zeier (1987), that is, that independently of whether there was opposition or not from the goalkeeper, the throws should be aimed at the corners, the points farthest from the goalkeeper's position.

In the VO test the goalkeeper was situated on a line 0.5 m from the goal and was allowed to try to stop the ball only by movements in the frontal plane. For this an observer supervised the movements using a camera which was placed laterally to the prolongation of the line on which the goalkeeper was standing. The performance of the throwers was also supervised by an expert observer with a camera situated laterally and perpendicularly to the direction of the throw.

In all the tests a series of three throws was performed, with a pause between them of 10-15 seconds, until three values were obtained for each subject and test, of which the two best shots were recorded, and choosing for the study the one in which the highest velocity was achieved. A maximum of three series was allowed with a rest between them of 1 to 2 minutes (Gorostiaga et al., 2005; Granados et al., 2007). After each of the attempts in each test the players were informed of the value achieved with the purpose of motivating them with immediate feed-back.

Materials

The tests were performed in an indoor pavilion. The balls used were: "Salter" medicine balls of 3 kg mass and 72.22 cm circumference (THMB) and 0.8 kg and 58 cm circumference (TLMB) and official handball balls for the throwing velocity tests (VS and VO).

The distance corresponding to the medicine ball throw was calculated using a black canvas sheet (20 x 2 m) where the ball left a mark on the exact spot where it landed. The velocity of the throw was estimated by calculating the flight time using a chronometric system (Sportmetrics, Valencia, Spain), with an accuracy of 0.001 s. This system was composed of a sensor which detected the passing of the ball, which had 8 photocells distributed vertically and evenly (in a range from 1.40 – 2.50 m from the ground), situated on the goal perimeter (6m from the goal) and by a sound sensor, with adjustable intensity, situated at the bottom central part of the goal. The sound sensor detected both the contact of the ball with the goal (goal) and with the goalkeeper (save).

As indicated previously, the goalkeeper and the throwers were supervised with two digital cameras situated on the side of the court.

Statistical analysis

A descriptive statistical analysis was performed using standard statistical methods. Then a correlational study was performed with the data obtained from the four tests by the different groups into which the sample had been divided using the Pearson correlation coefficient. The statistics were calculated using the SPSS 10.0 software programme.

RESULTS

Firstly to verify the reliability of the tests performed, the Intraclass Correlation Coefficient (ICC) was calculated as well as the coefficient of variation (Table 3). The results obtained show the high reliability among the four tests performed.

Table 3*. Reliability among attempts.*

TEST	N	RELIABILITY AMONG ATTEMPTS (Intraclass Correlation Coefficient)	Coefficient of Variation (%)
THMB	94	0.9926	3.5
TLMB	94	0.9882	6.3
VS	94	0.9798	3.6
VO	94	0.9779	4.6

The values found in the throwing tests were very disparate with regard to the groups studied according to each of the criteria used to divide the sample. They are shown in the Table 4:

***Table 4**. Mean ± Standard Deviation (X±DT) of the distance (m) and velocity (m·s^{-1}) of the throwing tests performed. Results in total, by categories and by positions.*

	THMB (m)	TLMB (m)	VS (m · s^{-1})	VO (m·s^{-1})
Total (n=94)	10.61 ± 1.58	33.19 ± 6.89	23.58 ± 2.64	22.05 ± 2.55
Senior (n=43)	11.53 ± 1.43	37.68 ± 4.35	25.35 ± 2.2	23.53 ± 2.59
Under 18 (n=51)	9.84 ± 1.26	29.41 ± 6.37	22.09 ± 1.99	20.8 ± 2.01
Backcourt (n=24)	10.89 ± 2.1	36.63 ± 6.08	25.27 ± 2.09	23.43 ± 2.28
Central (n=25)	10.4 ± 1.65	35.98 ± 5.31	24.57 ± 2.36	22.85 ± 2.43
Pivot (n=22)	10.58 ± 1.69	32.39 ± 2.46	22.69 ± 2.46	20.6 ± 2.4
Wing (n=23)	9.7 ± 1.33	30.73 ± 7.36	22.41 ± 2.3	20.27 ± 1.68

Below are the correlations among the four throwing tests, both with regard to the total number of subjects who made up the sample and the different groups into which it was divided (Table 5).

***Table 5.** Relationship among the values for the different throwing tests.*

	THMB-TLMB (*r*)	THMB- VS (*r*)	THMB-VO (*r*)	TLMB- VS (*r*)	TLMB-VO (*r*)	VS-VO (*r*)
Total	0.761**	0.781**	0.647**	0.904**	0.743**	0.776**
Senior	0.544**	0.629**	0.406**	0.837**	0.713**	0.785**
Under 18	0.753**	0.729**	0.657**	0.912**	0.755**	0.621**
Backcourt	0.530**	0.667**	0.608**	0.923**	0.664**	0.632**
Central	0.756**	0.798**	0.690**	0.941**	0.506**	0.594**
Pivot	0.791**	0.792**	0.758**	0.946**	0.641**	0.752**
Wing	0.706**	0.740**	0.770**	0.840**	0.691**	0.773**

*** The correlation is significant with p<0.01.*

The data revealed significant correlations in all cases. The values obtained by the senior group were lower than those for the under 18 group except in VS-VO. The highest correlations, independently of the group analyzed, were found between the TLMB and VS, with very high values in the under 18 group and in the backcourt, centre and pivot players, both tests involving a similar technique and absence of opposition. However, this was not true for the THMB and VO where values decreased substantially, especially in the backcourt and central players. Equally the correlation between the throwing velocity tests (VS and VO) was much lower, and did not reach a high value in any of the groups especially the under 18s, backcourt and central players.

The relations obtained between the more general test (THMB) and the rest of the tests were moderate or low depending on the group and decreased as the test with which it was correlated became more specific.

DISCUSSION AND CONCLUSIONS

The starting point for this study was the finding that two aspects had not been analyzed previously in the collection of studies which assessed throwing in handball with general tests using a medicine ball or specific tests of throwing velocity. After conducting a thorough bibliographic review of studies using general and specific tests in handball, no research was found which analyzed the relationship between them. Equally in the analysis of the studies which included throwing tests with and without opposition it was observed that there was no comparison of the velocity achieved in each of the situations.

From the analysis of the relationship among the general and specific tests used, it can be deduced that the test which reveals the lowest correlations with the others is the general throwing test using a heavy medicine ball (THMB). The correlation of the THMB is lower with the more specific tests with the lowest (r: 0.647; $p<0.01$) corresponding to THMB with VO. The reason for this low correlation could be the great difference in coordination, with regard to the technique performed, and in cognitive aspects, with regard to decision making. Given the low correlation revealed between THMB and the more specific tests, its use in predicting the performance of a player in the more specific tests, VS and VO should be questioned, especially in senior players (over 18). The applicability of the THMB should also be put into doubt to assess specific throwing capacity in handball. This statement coincides with that of several authors who insist on the necessity of using specific tests to assess the throwing capacity of handball players as the general tests can generate assessment errors (Calleja et al., 2002; Vaquera, 2003; Lidor et al., 2005). Newron & McEvoy (1994) ratify in their study the insufficient information which THMB contributes when applied to baseball throws.

The correlation values among throwing tests in the present study coincide with those found in other studies (Gorostiaga et al., 2005; Marques et al., 2007), being lower than those found by Granados et al. (2007) in women handball players. The correlation values between throwing velocity and maximum strength (Hoff y Almasbakk, 1995), as well as between throwing velocity and isokinetic strength in the lower body (Fleck et al., 1992) were not high.

With regard to the elite group, some studies coincide in commenting on the absence of significant correlations between the isokinetic muscle strength in the shoulder rotators (Bayios et al., 2001; Dauty et al., 2005) and throwing velocity. In contrast some studies of other sports, obtained strong correlations between peak throwing velocity and the chest pass and standing vertical jump (Pyne et al., 2006) and muscle strength in the shoulder (Anthrakidis et al., 2008; Kane, 2003).

In contrast the correlation between TLMB and VS was high and significant in all groups, especially in young players in their training phase (under 18) (r: 0.912, p<0.01). This strong correlation between the tests may be due to the similarity in coordination, technical performance and the fact that there is no cognitive involvement being carried out without opposition. It can therefore be stated that TLMB is more suitable for predicting VS (r: 0.904; p<0.01) than VO where the values obtained were lower (r: 0.743, p<0.01). This could be important as a large number of teams in their training phase and amateur players do not have adequate means to assess throwing velocity but do possess light medicine balls with which to administer TLMB. No studies were found on this topic, although a substantial increase in throwing velocity after using a light medicine ball has been confirmed (Barata, 1992).

Lastly the relatively low but significant correlation between VS and VO is surprising (r: 0.776, p<0.01), with the lowest value corresponding to the under 18 players (r: 0.621, p<0.01). This result, and above all the difference in the velocity attained in both types of throw (VS: 23.58±2.64 $m \cdot s^{-1}$; VO: 22.05±2.55 $m \cdot s^{-1}$) in spite of involving the same performance technique, showed the direct influence exerted by the opposition of the goalkeeper on the velocity reached by the player. This response in throwing velocity is interesting bearing in mind that the decision making complexity is not high as there is only opposition from the goalkeeper. These results lead to the initial deduction that cognitive factors, which are involved to a greater extent in throws with opposition, have a significant effect on the decrease in velocity in handball goal shots. These values coincide with the opinion of those authors who state that throwing velocity does not only depend on technique, coordination, explosive strength and accuracy, but also tactical and cognitive factors (Fleck et al., 1992; Párraga et al., 2001; Pardo et al., 2007), as well as with studies which have found differences in throwing velocity with and without opposition in handball (Rivilla et al., 2009) and water polo (Van der Wende, 2005; Vila et al., 2009). However, they contradict the small differences found between these two throwing situations but when performed with a jump (López, 2005).

In conclusion, it can be stated that the general throwing test with a heavy medicine ball (THMB) does not have a strong correlation with specific throwing capacity. However, the throwing test with the light medicine ball (TLMB) may be useful to assess the capacity for specific throws without opposition, although not so useful for those with opposition.

Finally the present study shows that cognitive factors, more involved in throws with opposition may be determinant in the lower velocity that the player reaches in goal shots compared with situations in which the throws are without opposition.

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