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Throwing speed in team handball: A systematic review

Running head: Throwing speed in handball

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THROWING SPEED IN TEAM HANDBALL: A SYSTEMATIC REVIEW

ABSTRACT

Its undeniable that throwing speed is one of the most important actions during handball match so it is really important for trainers improve their knowledge about it. Thus, the aim of the article is threefold: a) to review the scientific studies about the factors that determine throwing speed in team handball to be able to establish the importance of each one b) to summarize the scientific knowledge about throwing speed in handball including aspects that need more studies c) To suggest practical recommendations for handball coaches. Our review revealed that; a) Players with greater elbow angles and higher elbow displacement angles at the release of the ball throw faster b) Hand size, biacromial breadth and finger length are the main anthropometric factors related to throwing speed c) handball players are able to reach a high throwing speeds without lose accuracy, so they should carry out their throwing speed training sessions always at high speed d) There many different training proposals but with most of them throwing speed is improved. It is necessary to analyse the tactical-technical and conditional work related with throwing speed. e) There are very few studies made in real competition.

Keywords: Handball, throwing speed, kinetics, accuracy, body composition.

INTRODUCTION

Team handball is an Olympic sport characterized by fast and intermittent actions like running, jumping, blocking, and throwing (Hermassi, Chelly, et al., 2018). It is undeniable that throwing is one of the most important actions in handball game, since the main objective in this game is get the ball into the opponent's net, and this can only be achieved by throwing the ball.

A successful throw must meet two requirements: it must be fast, because the faster a player throws the ball the less time the goalkeeper has to stop it; and it must be accurate in order to place the ball in the desired area where it will be harder for the goalkeeper to stop (Rivilla-Garcia, Grande, Sampedro, & van den Tillaar, 2011; van den Tillaar and Ettema, 2003b, 2006).

For these reasons, throwing speed is one of the most studied handball skills by the scientific community. Many papers about throwing speed have been published where it is analysed from different point of view, in an attempt to determine the main factors that determine throwing skill in handball. Scientists agree that the main factors that determine throwing speed in team handball can be divided into three groups: motion technique, physical characteristics, and motor skill (van Muijen, Joris, Kemper, & van Ingen Schenau, 1991). Out of all the points, ball speed is the main factor for determining performance in handball overarm throwing (Fradet et al., 2004; van den Tillaar and Ettema, 2004, 2007; Wagner and Muller, 2008).

Thus, this article has three aims: a) to review the scientific studies on the factors that determine throwing speed in team handball so as to be able to establish the importance of each; b) to summarize the scientific knowledge about throwing speed in handball, including aspects that require further study, with the goal of promoting research on said aspects; and c) to propose practical recommendations for handball coaches.

LITERATURE SEARCH METHODOLOGY

The literature on throwing speed in handball was reviewed. All the articles were selected from an extensive search on major databases, including PubMed, Medline, Web of Science, Scopus, and EBSCO. The search language was limited to English. Various combinations of keywords were used, including handball, throwing, body composition, accuracy, and kinetics. Lastly, 64 articles were included in this review (Figure 1). Ethical approval was not required for this systematic review

[INSERT FIGURE 1]

1. MOTION TECHNIQUE

1.1. Overarm throw kinetics.

The overarm throw is a clear example of complex movement with a specific and clearly identifiable start and end. Werner, Fleisig, Dillman, & Andrews (1993) divide the movement into six phases: Wind up, stride, arm cocking, arm acceleration, arm deceleration and follow through. Although this classification was intended for baseball, the truth is that the kinetics of the overarm throw is common to several disciplines, including handball.

This type of throw seems to follow a specific movement pattern determined by a proximal to distal sequence of segments. This proximal to distal sequence has been identified in some sports like baseball as the one presented in faster throws (Putnam, 1993). Hence, proximal to distal sequence (PD) is defined as a temporal order of movements located in joints and body segments starting at the proximal side (trunk) and ending at the distal area (Marshall and Elliott, 2000).

Normally, in this type of movement, the joint and body segments must be synchronized to achieve maximum throwing speeds (Werner, et al., 1993). There are several arguments for the efficacy of this organization that includes mechanical (derived from Newton's Laws) and muscular aspects (a result of muscle pre-stretching or of optimal muscular coordination).

Along those lines, there are some researchers (Fradet, et al., 2004; van den Tillaar and Ettema, 2003a, 2009) who have analysed the overarm throw in handball who have concluded that it was not of a P-D sequence. It seems that maximum linear velocity occurs later in the shoulder than the elbow (Fradet, et al., 2004). Moreover, maximum velocity of wrist flexion appears before the maximum speed of elbow extension, as well as before the internal shoulder rotation (van den Tillaar and Ettema, 2009).

In the case of joint movements, handball throws show a time sequence that is close to the so-called PD pattern. The only exception is the knee extension that occurs later. First, there is trunk movement, followed by shoulder movements (except horizontal adduction of the shoulder, which starts simultaneously with the trunk movements), then an internal rotation of the shoulder and elbow extension, followed by hand movements (Fradet, et al., 2004; van den Tillaar and Ettema, 2009).

In any case, the kinetic factors that are the most relevant or the ones which determine throwing speed has been a topic widely studied in handball. (Serrien, Clijsen, Blondeel, Goossens, & Baeyens, 2015; van den Tillaar and Cabri, 2012; Wagner, Buchecker, von Duvillard, & Muller, 2010a, 2010b; Wagner et al., 2014). Nowadays, it is known that shoulder internal rotation plays an important role in throwing speed (van den Tillaar and Ettema, 2004, 2007), as does elbow angle (van den Tillaar and Ettema, 2007). Thus, players with faster throws are those who display smaller elbow angles at the moment they release the ball. This is why they are able to accelerate the ball over a longer trajectory, which leads to the fact that there are positive relationships between throwing speed and total angle displacement of the elbow (van den Tillaar and Ettema, 2007) (Matsuo, Escamilla, Fleisig, Barrentine, & Andrews, 2001). It seems that the best throwers have greater shoulder internal rotation and elbow extension that allows them to throw faster. According to van den Tillaar and Ettema (2004), 73% of ball speed can be explained by the sum of the effects of elbow extension and internal shoulder rotation.

With regard to the pelvis, it would appear that the rotational angle correlates with maximum ball speed, indicating that better throwers start to rotate their pelvis forward earlier during the throw (van den Tillaar and Ettema, 2007). As for the trunk and lower limbs, van den Tillaar and Ettema, (2007) did not find any correlation between throwing speed and the trunk or lower limbs, but Wagner, et al., (2010a) reported that trunk flexion and rotation correlates with throwing speed.

1.2. Throwing techniques in team handball

The use of different throwing techniques results in different ball speeds (Fradet, et al., 2004; Gorostiaga, Granados, Ibanez, & Izquierdo, 2005; Vila et al., 2012). There are three common throwing techniques in handball: The standing throw, which involves keeping the lead foot on the floor and which is typically used in penalty throws; the standing throw with a run-up, where one foot is planted on the floor after the run-up; and the jump throw, which involves executing a vertical jump off one leg at take off after the run-up.

It is well known that these throwing techniques differ in the movements of the lower limbs and also achieve different ball speeds among them (Gorostiaga, et al., 2005; Granados, Izquierdo, Ibanez, Ruesta, & Gorostiaga, 2013; Rivilla-García, Grande, Chirosa, Gómez, & Sampedro, 2011; Vila, et al., 2012). Higher throwing speeds are obtained with the standing throw with a run-up, followed by the jump throw, and, lastly, the penalty throw (Vila, et al., 2012). It appears that the higher speeds obtained with the standing throw with a run-up are due to an enhanced acceleration of the pelvis and trunk due to the leg lift (Wagner, Finkenzeller, Wurth, & von Duvillard, 2014; Wagner, Pfusterschmied, Von Duvillard, & Muller, 2012).

2. PHYSICAL CHARACTERISTICS: INFLUENCE OF ANTHROPOMETRIC FACTORS ON THROWING SPEED

The relationship between throwing speed and anthropometric factors has not been studied in depth, but there are several studies suggesting that general anthropometric characteristics (height, weight, and arm span) are directly or indirectly related to throwing speed. (Debanne and Laffaye, 2011; Matthys et al., 2011; Skoufas, Kotzamanidis, Hatzikotoylas, Bebetsos, & Patikas, 2003; van den Tillaar and Ettema, 2004; Vila, et al., 2012; Wagner, et al., 2010b; Zapartidis, Gouvali, Bayios, & Boudolos, 2007; Zapartidis, Kororos, Christodoulidis, Skoufas, & Bayios, 2011). Ferragut, Vila, Abraldes, & Manchado, (2018), found a relationship between body breadth/body length and throwing speed. A longer lever arm could imply greater strength in throwing and, therefore, greater speed. (Skoufas, et al., 2003). These ideas are reinforced by recent research, (Schwesig et al., 2017), which found that there is a positive correlation for height and weight with throwing speed in jump throws in elite handball players. These findings are confirmed for height in “standing throw” and “jump throw without precision” speed for premiere league players (Fieseler et al., 2017). Higher body fat values show a negative correlation with throwing speed (Moss, McWhannell, Michalsik, & Twist, 2015), while increased fat-free mass (FFM) is related with greater strength and speed levels during the action of throwing the ball (Granados, Izquierdo, Ibanez, Bonnabau, & Gorostiaga, 2007; Granados, Izquierdo, Ibanez, Ruesta, & Gorostiaga, 2008; van den Tillaar and Ettema, 2004).

Specific anthropometric characteristics such as hand size (Ferragut, et al., 2018; Vila, et al., 2012) in female handball players (Zapartidis, et al., 2011; Zapartidis et al., 2009), and finger length in male and female U-16 (Visnapuu and Jurimae, 2007) have been identified as factors with a positive relationship with throwing speed and accuracy. A good grasp has a positive influence on ball speed. (Srhoj, Marinovic, & Rogulj, 2002; Visnapuu and Jurimae, 2007). Elisaz & Wit (1996) reported that finger length, biacromial breadth, and hand length are the most relevant anthropometric factors related to throwing speed. These aspects determine the quality of the grasp, which allows for better ball adjustment and handling. General anthropometric characteristics are better identifiers of ball speed than specific characteristics (Debanne and Laffaye, 2011). However, the influence of these factors on throwing speed is significantly less than that of motor skills (Eliasz and Wit, 1996; Skoufas, et al., 2003; Visnapuu and Jurimae, 2009).

These differences in anthropometrical aspects (also in throwing speed) are identified as significant when different competitive level players are compared (Gorostiaga, et al., 2005; Granados, et al., 2007) or between elite and non-elite players

(Ferragut, et al., 2018; Moss, et al., 2015). In the study presented by Vila et al. (2012), female handball players were analysed according to their positions on the court and they found differences in anthropometric aspects among them, but they did not find differences in throwing speed without a goalkeeper, and when the throw is with a goalkeeper, they only found differences at 9 m just behind the line, with a 3-step run. These results suggest that within the same competitive level, throwing speed training requirements are similar. More research on this issue is needed to reinforce these results.

There are few studies that analyse throwing speed according to sex. van den Tillaar and Ettema, (2004) reports that differences between male and female players were due to the differences in muscle mass and height, but these differences were significantly reduced when body size was expressed as fat free mass. In addition, body size should be an important factor in physical performance, also when the players are highly trained.

3. MOTOR SKILL: SPEED AND ACCURACY

As stated above, accuracy and speed are the most crucial aspects in handball throwing speed. In that regard, the relationship between accuracy and speed has been studied by several researchers (Etnyre, 1998; Garcia, Sabido, Barbado, & Moreno, 2013; Indermill and Husak, 1984; van den Tillaar and Ettema, 2003a, 2003b, 2006). There have been many theoretical principles used to explain the relationship between speed and accuracy in human movement studies: for example, Fitts's law (Fitts, 1954) states that the faster the movement the less accurate it is. In this line, Indermill & Husak (1984) (using tennis balls) and Etnyre (1998) (with darts) found that task achievement was inversely related to speed and accuracy.

In handball, the relationship between speed and accuracy has been study by several researchers (Garcia, et al., 2013; Nuno et al., 2016; van den Tillaar and Ettema, 2003a, 2003b). Based on these studies, several explanations have been developed about this relationship. van den Tillaar and Ettema, (2003b) conducted a study with expert handball players who were asked to throw and emphasize speed, accuracy, or both. These researchers found that the type of instruction influenced throwing speed but not the accuracy; therefore, an increase or a decrease in speed is not necessarily followed by an increase or decrease of accuracy. Accuracy was not reduced at the highest speeds, but it did not improve when speeds decreased significantly. Thus, this inverse relationship is not applicable to this complex movement.

Similar results to those found in expert players were obtained with novice players in a later study (van den Tillaar and Ettema, 2006), which revealed that expert and novice players use the same coordination pattern in throwing, although expert players have optimized their throwing technique and do not exhibit a speed/accuracy trade-off, but novice players do not display an optimized technique, so they can show a speed/accuracy trade-off.

It would appear that handball players are able to keep high throwing speeds near to maximum (80-90%) without decreasing their accuracy (Garcia, et al., 2013; van den Tillaar and Ettema, 2006), so it would be desirable to train at high speeds, since deceasing it will not improve its accuracy.

4. THROWING SPEED TRAINING

Several studies had been published about the use of different training methods to enhance throwing speed in handball players. The studies were conducted using different approaches: analytical strength training (Cherif, Chtourou, Souissi, Aouidet, & Chamari, 2016; Hermassi, Chelly, Fathloun, & Shephard, 2010; Marques and Gonzalez-Badillo, 2006) (Hermassi, et al., 2010; Sabido, Hernandez-Davo, Botella, Navarro, & Tous-Fajardo, 2017) and functional training (Andersen, Fimland, Cumming, Vraalsen, & Saeterbakken, 2018; Kuhn, Weberruss, & Horstmann, 2018; Manchado, Garcia-Ruiz, Cortell-Tormo, & Tortosa-Martinez, 2017; Saeterbakken, van den Tillaar, & Seiler, 2011). In recent years, several studies have emerged using core training in order to improve throwing speed, but the quantity of research available is quite scarce, the samples are different, and the results reported do not match up. In the study reported by Manchado, et al., (2017) on male handball players and in the study presented by Saeterbakken, et al., (2011) on young female players, significant differences were found in throwing speed between the control and the experimental group. However, Kuhn et al. (2018) did not find differences between the control and the experimental group in senior female handball players.

As for functional training (Andersen, et al., 2018), youth handball players performed explosive exercises with bands for nine weeks with the objective of improve throwing speed; however, significant differences in throwing speed were not found. These results are not in line with those reported by Mascarin, et al. (2017).

In the same vein, different strength training methodologies are also being used to improve throwing speed, such as plyometric training (Spieszny and Zubik, 2018), heavy and medium load combination (Hermassi, et al., 2010), use of eccentric loads (Sabido, et al., 2017), small games and sprints (Iacono, Eliakim, & Meckel, 2015), resistance training (Cherif, et al., 2016; Hermassi, van den Tillaar, Khlifa, Chelly, & Chamari, 2015; M.Marques and Gonzalez-Badillo, 2006), and also the use of strength exercises with unknown and known loads (Sabido, Hernandez-Davo, Botella, & Moya, 2016).

Nearly all trainings have shown higher throwing speed values when the upper body was included in the routines. The published studies reflect that there are certain strength-training protocols that achieve improvements in throwing speed range (medicine ball, bench press with high, medium and resistance loads, small games), which may suggest that with very little time investment, coaches can incorporate these protocols into their training routines to improve players' throwing speed. It could be assumed that the upper body is a poorly trained aspect in handball.

Some studies show higher performance levels in certain types of throws depending on the training routine used. In the study presented by Iacono et al. (2015), the group that performed small game routines improved it throwing speed in standing throws with a run-up, while those who performed sprint training improved their throwing speed in the jump throw. Hermassi, Ingebrigtsen, et al., (2018) showed significant speed gains in both the standing throw with a run-up and the jump throw after ten weeks of heavy load training, but the moderate load group only improved in the jump throw. Moreover, Hermassi, et al., (2015) reported better throwing speeds after eight weeks of heavy loads training in elite handball players.

[INSERT TABLE 1]

5. THROWING SPEED IN COMPETITION

Performance analysis studies aim to come as close to real competition as possible. Extensive research has been conducted on throwing speed in controlled situations, but it would appear that there are only two studies that analyse throwing speed in real competition (Zapardiel Cortés, Ferragut, Manchado, Abraldes, & Vila, 2017; Zapardiel

Cortés, Vila, Abraldes, Manchado, & Ferragut, 2017). In the first study, throwing speed and accuracy were analysed during the XXIII Men's Handball Championship. This study revealed interesting data on throwing speed, reporting that the average throwing speed during the championship was 22.23 m/s in the first half and 22.30 m/s in the second half, of a total of 3214 registered throws from the area in front of the goal. Although it is difficult to compare these speeds with those already published on training, some similarities can be observed in the data obtained from competitions by these researchers and those already published on training. Depending on the type of throwing, published speeds are around 19.3 m/s and 20.00 m/s for throws from 7 meters, 230.8 m/s and 26.06 m/s for throws from 9 meters with a run-up, and 23.0 m/s and 23.1 m/s for jump throws (Gorostiaga, et al., 2005; Hermassi, et al., 2015; Marques, van den Tillaar, Vescovi, & Gonzalez-Badillo, 2007; Rivilla-Garcia, et al., 2011). Zapardiel Cortés, Ferragut, et al., (2017) reported that the average throwing speed did not change during the entire match and no differences in speed were established between those that led to a goal and those that did not. Furthermore, they could not find any differences in accuracy between the first and second half of the match. They concluded that in real matches, handball players exhibit very high speed values in spite of the real opposition during the throw and that the speed is not decreased during the match. Likewise, throws that lead to a goal and those that did not were thrown at the same speed, so there is no difference in terms of the speed between successful throws and unsuccessful ones. It is important to bear in mind that this is only one study, so further studies on real matches would be needed to corroborate these results.

In the second study (Zapardiel Cortés, Vila, et al., 2017), throwing speeds were analysed by zones (left side, center and right side). It is in the central part of the court from which the greatest number of throws are made (56.8%) and the highest speeds are recorded (23.93 m/s), showing significant differences with speeds recorded in lateral zones. These differences are maintained when the throws lead to a goal (24.04 m/s) and when they do not (23.84 m/s). When the speeds of the top eight and last eight teams in the rankings are analysed, differences arise in the central zone.

As for throwing speed with opposition, research shows a negative correlation between opposition and throwing speed (Rivilla-García, et al., 2011; Rivilla-Garcia, et al., 2011). Rivilla García et al (2011). suggest that cognitive workload has a negative influence on speed. However, this theory is not reflected in the Zapardiel et al. (2017) study, since the greater speeds are recorded in successful throws (24.04 m/s), so the speed pattern must be analysed during a real competition. Zapardiel et al. (2017) report that it is in central zone where the greatest number of defenders are located, so players usually throw with a defender closer to them and farther from the goal (8 meters). This causes the offense to throw faster to score a goal.

PRACTICAL APPLICATIONS

It has been established that the players with the fastest throws are those with narrower elbow angles at the moment they release the ball and greater internal shoulder internal rotation and elbow extension, so it could be helpful to work on joint mobility in the preliminary stages of handball learning.

Biacromial width, hand size, and finger length are the most relevant anthropometric aspects related to throwing speed, and considering that these parameters cannot be modified through training, talent scouting programs should take them into account.

Since it is clear that handball players are able to maintain high levels of accuracy at high speeds, training should always be performed at high speeds. Regardless of the training routine used, most of them successfully improve throwing speed in training situations, so greater physical planning is needed in order to develop throwing speed. If it is such a relevant action (to score a goal) physical, technical and tactical work related to throwing speed should logically be analysed.

There are few studies that analyse throwing speed in real competition, even though it is quite possible to do so in handball, so it would be helpful to expand the research on throwing speed, but only if this enhanced speed is employed during the match, and currently this is an unknown aspect.

In that regard, and also from an ecological perspective, there are several types of throws used during a match: throws with a run-up, jump throws, with or without contact, but these characteristics are not addressed by most of the research.

ANALYSIS LIMITATIONS

Following a review of the bibliography on this topic, some limitations were found that require further studies in order to gain a better understanding of the matter.

1. Different methodologies have been used to assess throwing speed, which complicates the analysis of the data.

2. No studies were found on the real impact in competitions of enhanced speed.

3. There is not enough research (only two papers were found) on throwing speed analysis in real competition with tactical situations.

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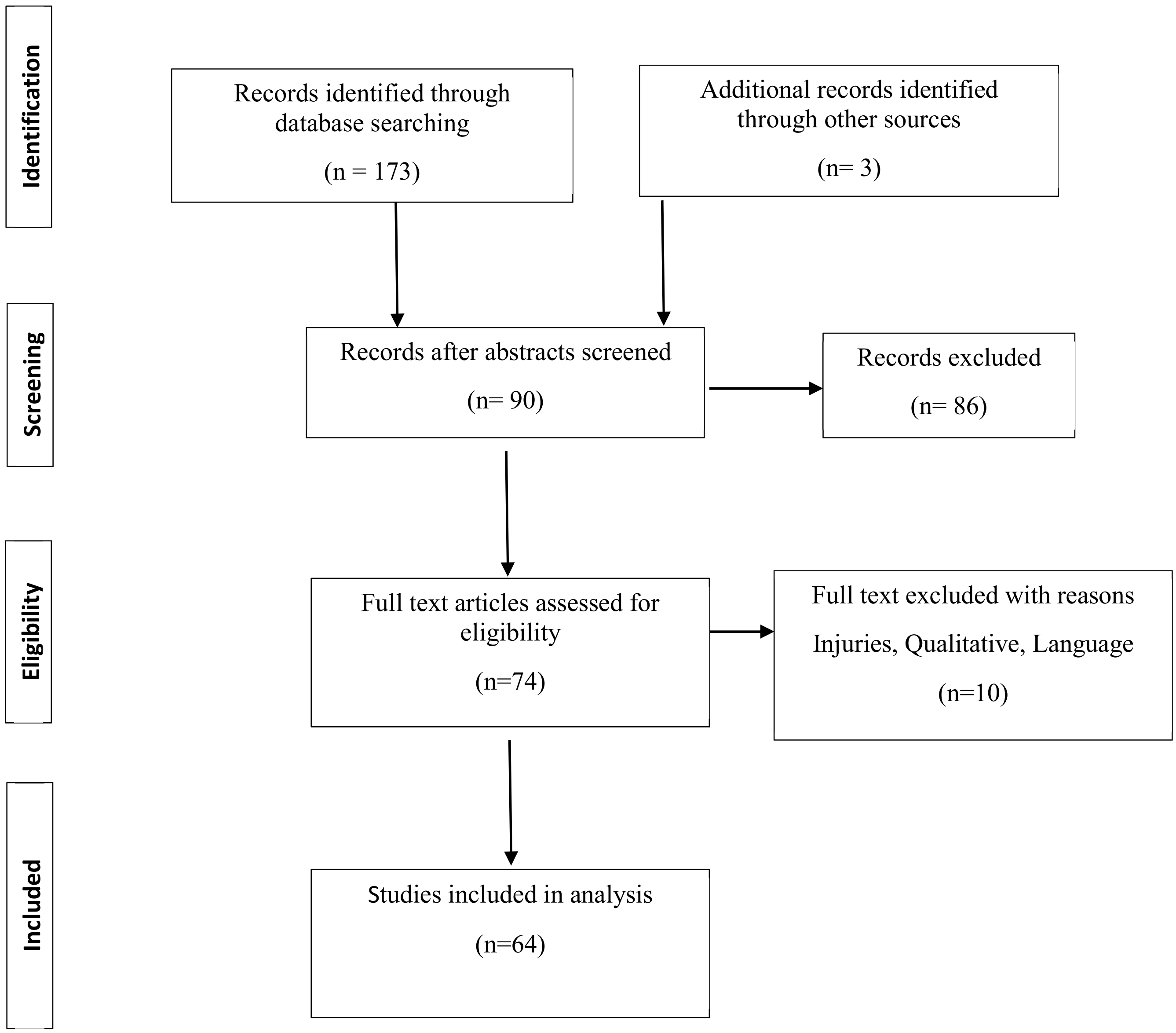

Figure 1. Flow chart of study selection.

Table 1. Studies of the different training programs on throwing speed in handball.

Author	Participants	Intervention	Results
Sabido et al, 2016	28 m; 17.2 ± 0.6 y; KL= Unknown loads; UL= Known loads	[4 s*6 r de press bench (30, 50 and 70% of 1RM)] *2S weekly*4 weeks	UL group improved the performance variables to a greater extent than the KL group
Dello Iacono et al, 2015	18 m; 24.8 ± 4.4 y; SSGs = Small-sided games; RSS = Repeated shuffle sprint	Twice a week for 8 weeks; SSG: 5 small-sided handball games with 3 a-side teams; RSS: 2 sets of 14-17 of 20-m shuttle sprints; 9-m jump shots interspersed by 20-second recoveries	SSG seems to be more effective in improving agility and standing throw, whereas RSS seems preferable in improving 10-m sprint, CMJ, and jump shot
Marques and González-Badillo, 2006	16 m; 23.1 ± 4.7 y; RT= Resistance training; DT= Detraining	Apart from normal practice sessions + 12 weeks RT; 7-week DT maintained normal practices; T1 = before the experimental period, T2 = after 6 weeks, T3 = after the 12-week experimental period T4 = 7 week DT period	The throwing velocity (a 3-step run) improved significantly only between T1-T2 and T1-T3
Sabido, Hernández-Davo, et al, 2017	18 m; 23.9 ± 3.8 y; EOT = Eccentric-overload training; CG	Habitual strength training + EOT one session/week during a 7-week 4 sets*8 r for the bilateral half-squat and unilateral lunge exercises	No group showed changes in handball throwing velocity
Cherif, Chtourou, et al 2016	22 m; 22.1 ± 3.0 y; EG = Strength training; CG	Usual routine handball training sessions + 3-5 sets of 3-8 repetitions with 3 min of rest in between (85-95% of the 1RM)*2 sessions/week	Both groups improve throwing speed but EG presents higher values (5)
Spieszny and Zubik, 2018	28 m; G1 = Strength training; G2 = Plyometric training; G3 = CG	G1 = 2 sessions/week* 45 min; S1= máximum strength; S2= 3 to 6 r * 3-4 s (individualized) G2 = 2 sessions/week* 30-40 min; 5-10 exercises * 3-4 s	Different results were obtained when studying changes in the flight speed of the thrown ball
Hermassi, Ingebrigtsen, et al 2018	22 m; EG = Resistance; CG	(30-35 minutes * 2 sessions/week) * 10 weeks	The throwing velocities showed significant interaction effects.
Hermassi, S. Chelly, M. S. Fathloun, M. Shephard, 2010	26 m; 20.0 ± 0.6 y; HR = Heavy load resistance group; MR = Moderate load resistance group; CG	HR: 1–3 repetitions per set * 3–6 sets of each exercise with 3- to 4-minute rest between sets (80–95% of their personal 1RM) MR: 3–6 repetitions per set * 2–4 sets of each exercise with 1-to 1.30-minute rest between sets (55–75% of their personal 1RM)	Resistance training improves throwing velocity, whether a heavy or moderate load was used.
Ettema, Glosen, van den Tillaar, 2008	13 f; 18.1 ± 2.1 y; RG = specific resistance training program; TG = Regular training	3 times per week for 8 weeks + regular training RG: throwing movement with a pulley device of 85% of their personal 1RM TG: 81 Fast throws	An increase in throwing velocity with normal balls after the training period was observed for both groups. This difference was not statistically significant.

Raeder, Fernandez-Fernandez, Ferrauti, 2015	28 f; 20.8 ± 3.3 y; MBT = Medicine ball training; CG	3 sets a week * 6 weeks (2 r more every 2 weeks). Different throwing exercises using 2 different ball weights (2 and 1 kg), followed by a throwing protocol using a regular handball	Throwing speed improves in MBT, whereas throwing precision remained unaffected

Legend: m= male; f= female; y= years; CG= Group control; *s=sets; r= repetitions; S=Session;*