



Influence of Physical Aspects and Throwing Velocity in Opposition Situations in Top-Elite and Elite Female Handball Players

by

Carmen Ferragut¹, Helena Vila², Jose Arturo Abraldes³, Carmen Manchado⁴

The relationship between anthropometric and physical characteristics of female handball players and throwing velocity is considered an important factor in handball performance. The aim of this study was to examine key differences in anthropometric and fitness characteristics between top elite and elite female players competing in the first Spanish handball league. A total of 89 players from the first Spanish handball league were divided into two groups, top elite (38) and elite (51) players, and assessed for anthropometric and fitness characteristics (throwing velocity, vertical jump and hand grip strength). A Student's t-test was used to determine whether a statistically significant difference between the two different levels of play occurred. Significant differences were found in age, body height, body mass, arm span, muscle mass, different girths (tensed and flexed arm, forearm, wrist, ankle), dominant hand width and length, different breadths (biacromial, bitrochanteric, bistyloid breadth and biepicondylar humerus) and fitness characteristics (hand grip strength and throwing velocity for different positions). Top elite players compared to elite players showed differences in anthropometric characteristics which were mainly located in the upper limbs and mostly were non-modifiable aspects by training. Furthermore, the best players were able to maintain a high throwing velocity in different tactical situations.

Key words: talent identification, jump shot, expertise level, throws with opposition.

Introduction

Handball has formed part of the Olympic programme since the 1972 Olympic Games in Munich. The best leagues in the world are from Europe, and the Spanish league is one of the most prestigious (fourth position in the European Handball Federation ranking for the 2012 season). One of the most vital elements in handball is throwing ability. Handball players improve their chances of scoring by throwing the ball as fast as possible and by accurately aiming at the goal (Gorostiaga et al., 2005). The faster the ball is thrown towards the goal, the less time the defenders and the goalkeeper have to save the

shot (Manchado et al., 2013). The velocity depends primarily on the player's ability to accelerate the ball with an overarm throw (Debanne and Laffaye, 2011). Handball coaches and scientists seem to agree that the main determinants of throwing velocity are throwing technique, timing of the consecutive actions of body segments, and upper and lower-extremity muscle strength and power (Gorostiaga et al., 2005).

To succeed in a sport, it is usually important to have specific body attributes (Malina et al., 1982). In previous studies, significant and positive correlations have been reported between ball velocity and general anthropometric

¹ - Faculty of Medicine and Health Sciences. University of Alcalá. Alcalá de Henares, Spain.

² - Department of Special Didactics. University of Vigo, Spain.

³ - Faculty of Sports Sciences. University of Murcia, Spain.

⁴ - Faculty of Education, University of Alicante, Spain.

characteristics ($r = 0.23-0.62$): body mass, lean body mass, body height, and body mass index (BMI) (Van den Tillaar and Ettema, 2004; Zapartidis et al., 2007). Further studies focused on anthropometric variables specific to handball (hand size and arm span) and even reported significant and positive correlations ($r = 0.29-0.37$) with ball velocity (Skoufas et al., 2003; Zapartidis et al., 2009). However, in all these studies, general anthropometric variables were better predictors than those specific to handball (Debanne and Laffaye, 2011).

To the best of our knowledge, only few studies clearly explain the importance of fitness and anthropometric characteristics and their relationship with throwing velocity in women's handball. It would be important to determine which factors have a greater influence on player's throwing velocity.

A number of previous studies have determined the anthropometrical profile of women's handball players on various national teams (Bayios et al., 2006; García et al., 2011; Gholami and Sabbaghian, 2010; Hasan et al., 2007). Some studies have also analysed physical characteristics of players at different competitive levels (Granados et al., 2007, 2008; Milanese et al., 2011) or with regard to their playing positions (Cizmek et al., 2010; Vila et al., 2012; Zapartidis et al., 2009). These studies have confirmed that there are differences in anthropometric and fitness characteristics between the different performance levels and playing positions.

Advancing in the analysis of team sports, Rampinini et al. (2009) reported that there were no studies exploring the relationship between physical performance and team's success in a homogeneous group of soccer players that played in the same league, yet some of these teams also participated in national and international championships. Furthermore, recent studies suggest that there are differences in anthropometric characteristics as well as physical and physiological demands between national and international competitions (Granados et al., 2013; Higham et al., 2014; Portillo et al., 2014; Suarez-Arrones et al., 2012). Currently there is no research in handball that compares a homogeneous group of players with different tasks and responsibilities within their teams (national and international level). Such data

would provide coaches with relevant information for assessing the optimum characteristics for peak performance.

Therefore, considering that the relationship between anthropometric and physical characteristics of female handball players and throwing velocity is an important factor to determine handball performance, the aim of the present study was to investigate whether there were differences in anthropometric and fitness characteristics between top elite and elite players competing in the first Spanish handball league and the relationship with throwing velocity with and without opposition. Furthermore, thanks to the data reported in the present study in the international literature, talent identification and development could be enhanced.

Methods

Participants

Data were collected from 89 women's team handball players, all competing in the first Spanish handball league; goalkeepers were excluded. These players were divided into two groups: top elite (38) and elite players (51). Top elite players were considered those that also played in their respective national teams for two years prior to the study and elite players were those that played in the first Spanish handball league, but were not members of the national team for two years prior to the study. All the players and coaches received verbal and written information about the study and gave their informed written consent before anthropometric and fitness assessments. This study was approved by the Alicante University Committee for research involving human subjects and was carried out in accordance with the principles of the Declaration of Helsinki.

Measures and Procedures

Anthropometry: anthropometric measurements were taken according to standardised procedures by an International Society for the Advancement of Kinanthropometry (ISAK) certified anthropometrist (Stewart et al., 2011). Dimensions included body height, body mass, arm span, arm length and forearm length, three skinfolds (triceps, front thigh and medial calf), six breadths (biacromial, bipectoral, biacromial, bipectoral, bipectoral and bitrochanteric and

bistylloid) and ten girths (arm relaxed, arm flexed and tensed, forearm, wrist, chest, waist, gluteal, thigh, calf and ankle). The sum of four skinfolds was used as the main adiposity index. Measurement of the anthropometric variable of hand size was a new original method reported by Visnapuu and Jürimäe (2007). Body height and mass measurements were taken using a set of scales (Seca, Barcelona, Spain) with accuracy of 0.01 kg and 0.001 m; skinfolds were measured with a Harpenden Calliper, girths were estimated using a Lufkin metal tape (Lufkin Executive Thinline, W606PM, USA) and breadths and lengths' values were provided using an anthropometer (GPM, Siber Hegner, Zurich, Switzerland) with accuracy of 0.01 cm. Several variables were examined: a) body mass index (BMI), calculated as body mass (kg) divided by body height (m²), b) fat free mass (FFM) (kg), calculated using the method described by Lee et al. (2000), and c) selected anthropometric measures, used to determine a somatotype following methods described by Carter and Heath (1990).

Throwing velocity test: throwing velocity was assessed using a radar gun (StalkerPro Inc., Plano, TX, USA) with 100 Hz recording frequency and 0.045 m·s⁻¹ sensitivity, placed behind the goal post in front of the thrower. Prior to the throwing velocity assessment, participants performed a 15 min warm-up focused on overhead throwing. After applying resin as desired, participants performed two different throwing protocols, one with and one without a goalkeeper. For both protocols, participants threw an official handball as fast as possible towards a standard goal, using a single hand and their personal technique. The sequence of throwing was as follows: a throw from just behind the 7 m penalty mark, a throw from just behind the 9 m line, a three-step running 9 m throw and a three-step running 9 m throw with a jump. Three throws of each type were performed and the best trial was used for further analysis.

Maximal isometric hand grip strength test: grip strength of the dominant hand was measured using a standard adjustable digital hand-grip dynamometer (T.K.K. 5401, Tokyo, Japan) with sensitivity of 10 N. Both the anthropometric equipment and the hand-grip dynamometer were calibrated before each assessment. All subjects

were tested after 3 min of an independent warm-up and before the throwing velocity test, just after anthropometry assessment. The test was conducted with the arm extended parallel to the body. Movements of the arm or wrist were not allowed. Peak developed strength was recorded. The players performed 2 repetitions at maximum intensity with a three-minute rest between trials to minimise the effects of fatigue. The best trial was used for further analysis.

Vertical jump test: each participant performed two kinds of maximal jumps, the squat jump (SJ) and the countermovement jump (CMJ), on a jump mat (Ergo Jump Bosco System Byomedics, SCP, Barcelona, Spain) to measure flight and contact times. The jump height was determined from the flight time using standard calculation methods. In order to avoid unmeasurable work, horizontal and lateral displacements were minimized, and the hands were kept on the hips throughout the tests. The participants completed 3 attempts of each type of the jump with a three-minute rest in-between to avoid fatigue. The best result was used for the subsequent analysis

Statistical analysis

Standard statistical methods were used to calculate the mean and standard deviations. All data are expressed as mean ± standard deviation (all data were checked for distribution normality and homogeneity with the Kolmogorov-Smirnov, Lilliefors and Levene tests). A Student's t-test was used to determine whether a statistically significant difference between the two levels of play occurred. The reliability of throwing velocity, hand grip strength and vertical jump tests was assessed using ICC. An ICC value above 0.90 was considered high, values from 0.80-0.90 were considered moderate and values below 0.80 indicated that a field test was inadequate. The CVs for the field test were also calculated, and were below 5% in all tests. A 95% confidence interval was established. The $p \leq 0.05$ criterion was used for establishing statistical significance. The effect size was calculated using Cohen's d, by estimation of the mean difference between two groups, and then dividing the result by the pooled standard deviation; it was considered trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79) or large (0.80 and greater) (Cohen, 1992; Fritz et al., 2012; Maszczyk et al., 2014, 2016):

$$\text{Cohen's } d = (M_2 - M_1) / SD_{\text{pooled}}$$

$$SD_{\text{pooled}} = \sqrt{((SD_1^2 + SD_2^2) / 2)}$$

Results

Descriptive statistics of anthropometric characteristics and the somatotype of female handball players according to the two levels of play are shown in Table 1. Top elite female handball players obtained higher mean values in almost all the variables studied compared with elite players. The players presented an endomorphic-mesomorphic somatotype in both levels studied.

Top elite group was characterized by a higher value in body mass, body height, arm span, muscle mass (Body height: $p \leq 0.001$, $d = 1.10$; Arm span: $p \leq 0.001$, $d = 0.87$; Muscle Mass by Lee: $p \leq 0.001$, $d = 0.93$).

It is noticeable that top elite players showed greater values in the biepicondylar humerus breadth, hand length and hand width, with a large effect size (Biepicondylar humerus: $p \leq 0.001$, $d = 0.88$; Hand length: $p \leq 0.001$, $d = 0.78$; Hand width: $p \leq 0.001$, $d = 0.73$). Those traits are located in upper limbs and they are not modifiable by training.

Table 1
Mean and standard deviation values ($\bar{x} \pm sa$) corresponding to anthropometric characteristics of women's handball players according to two levels of play.

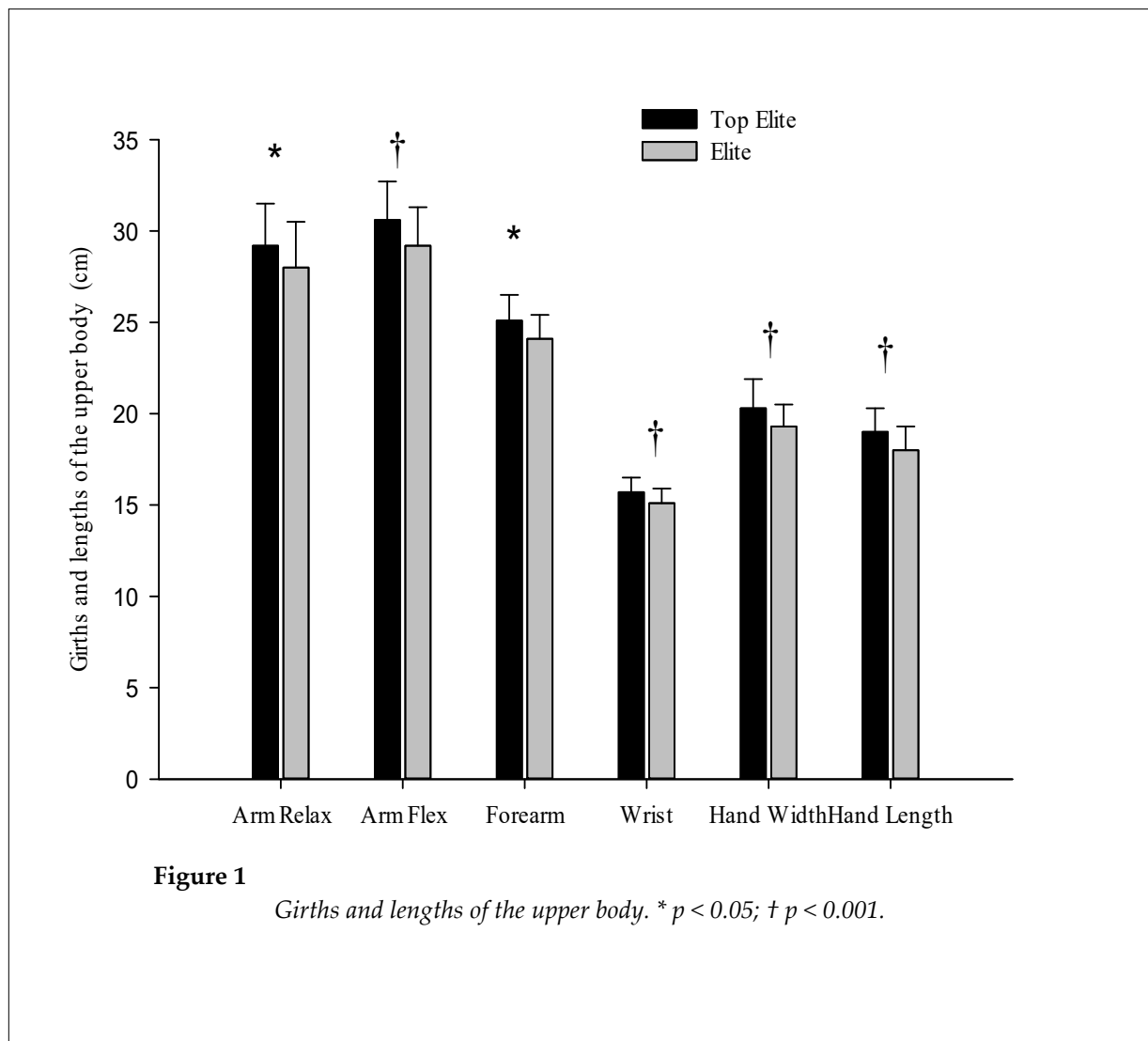
Variables	Top Elite players (38)	CI. ₉₅ for \bar{x}	Elite players (51)	CI. ₉₅ for \bar{x}	ES
Age (years)	26.4 ± 4.5*	25.1 - 27.7	24.0 ± 4.4	22.8 - 25.2	0.55
Experience (years)	15.1 ± 4.2	14.3 - 15.9	15.1 ± 4.8	14.3 - 15.9	0
Body height (cm)	174.3 ± 7.7†	167.6 - 182.0	166.7 ± 5.6	165.2 - 168.3	1.10
Body mass (kg)	70.6 ± 7.8†	66.6 - 73.8	64.1 ± 7.6	61.9 - 66.2	0.85
Arm span (cm)	174.3 ± 9.9†	168.7 - 180.0	167.0 ± 7.2	164.6 - 169.4	0.87
Body composition					
BMI (kg/m ²)	23.2 ± 1.5	22.5 - 23.7	23.0 ± 2.2	22.4 - 23.7	0.10
Muscle Mass Lee (kg)	26.2 ± 2.6†	24.9 - 27.1	23.9 ± 2.4	23.1 - 24.9	0.93
Girth (cm)					
Waist (minimum)	76.1 ± 5.0	73.3 - 78.9	74.8 ± 5.5	73.9 - 75.8	0.24
Gluteal (hips)	101.0 ± 5.8	97.0 - 104.6	98.2 ± 6.4	95.8 - 100.7	0.47
Thigh (1 cm gluteal)	60.7 ± 4.7	57.6 - 63.8	59.5 ± 6.2	57.1 - 61.9	0.22
Thigh (mid-troch-tib. lat)	53.7 ± 4.4	51.6 - 56.8	53.6 ± 4.6	52.3 - 54.9	0.02
Calf (maximum)	36.8 ± 2.3	36.1 - 38.4	36.1 ± 1.9	35.5 - 36.6	0.34
Ankle (minimum)	22.9 ± 1.5†	21.6 - 24.1	21.9 ± 1.3	21.5 - 22.5	0.73
Length (cm)					
Arm	32.5 ± 2.4	31.3 - 33.6	31.0 ± 3.2	30.0 - 32.0	0.52
Forearm	23.9 ± 2.0	22.8 - 24.9	23.7 ± 1.3	23.3 - 24.1	0.12
Breadth (cm)					
Biacromial	37.7 ± 1.6†	37.2 - 38.1	36.6 ± 1.5	36.1 - 37.0	0.72
Biiliocrystal	27.2 ± 2.1	26.3 - 28.6	26.4 ± 1.8	25.8 - 27.0	0.41
Bitrochanteric	32.6 ± 2.3†	31.6 - 33.5	31.4 ± 1.7	30.6 - 32.2	0.61
Bistyloid	5.3 ± 0.3†	5.1 - 5.5	5.1 ± 0.3	5.0 - 5.1	0.67
Biepicondylar humerus	6.6 ± 0.4†	6.4 - 6.8	6.3 ± 0.3	6.2 - 6.4	0.88
Biepicondylar femur	9.6 ± 0.8	9.2 - 10.0	9.4 ± 0.5	9.3 - 9.6	0.31
Somatotype					
Endomorphic	3.8 ± 1.0	3.3 - 4.2	3.8 ± 1.0	3.5 - 4.1	0
Mesomorphic	4.2 ± 1.1	3.7 - 4.7	4.4 ± 1.0	4.1 - 4.7	0.2
Ectomorphic	2.3 ± 0.8	2.0 - 2.6	2.3 ± 0.7	2.1 - 2.5	0

Note: (*) $p \leq 0.05$; (†) $p \leq 0.001$; CI = Confidence intervals. ES = Effect Size

Table 2
Mean and standard deviation values ($\bar{x} \pm sa$) corresponding to fitness characteristics of female handball players according to three levels of competition

Variables	Top Elite players	Elite		ES	
	(22)	CI ₉₅ for \bar{x}	players (51)		CI ₉₅ for \bar{x}
Hand grip strength (N)	355.9 ± 5.5*	330.3 – 374.7	335.1 ± 4.6	322.2 – 348.0	4.20
SJ (m)	0.28 ± 0.1	0.27 – 0.31	0.28 ± 0.04	0.27 – 0.29	0
CMJ (m)	0.29 ± 0.1	0.27 – 0.32	0.29 ± 0.04	0.28 – 0.31	0
7 m (m·s ⁻¹)	21.3 ± 5.7*	20.4 – 22.0	20.4 ± 1.6	19.8 – 21.0	0.16
9 m standing (m·s ⁻¹)	21.3 ± 5.7*	20.3 – 31.7	20.3 ± 1.6	19.7 – 21.0	0.18
9 m + 3 steps (m·s ⁻¹)	22.8 ± 5.4	21.8 – 23.2	22.2 ± 1.7	21.6 – 22.8	0.10
9 m + jump (m·s ⁻¹)	22.6 ± 5.4*	21.9 – 22.9	21.6 ± 1.5	21.1 – 22.1	0.19
7 m + GK (m·s ⁻¹)	20.68 ± 6.1*	20.1 – 21.8	20.0 ± 1.4	19.6 – 20.4	0.12
9 m standing+ GK (m·s ⁻¹)	21.3 ± 5.5†	21.0 – 22.0	20.3 ± 1.4	19.9 – 20.7	0.19
9 m + 3 steps + GK (m·s ⁻¹)	22.9 ± 5.6†	22.4 – 23.9	21.9 ± 1.6	21.4 – 22.3	0.18
9 m + jump + GK (m·s ⁻¹)	22.5 ± 5.2†	20.0 – 23.0	21.4 ± 1.3	20.9 – 21.9	0.22

Note: (*) $p \leq 0.05$; (†) $p \leq 0.001$. CI = Confidence intervals. ES = Effect Size, GK: Goalkeeper
SJ = squat jump; CMJ = countermovement jump



Top elite players attained the highest values for forearm isometric strength ($p \leq 0.05$, $d = 4.20$), but surprisingly, no statistically significant differences were observed between the two levels of play for vertical jumps. In addition, top elite players achieved higher significant throwing velocities compared to elite players ($p \leq 0.05$, $d < 0.20$). These differences were significant ($p \leq 0.001$) in throws with the presence of a goalkeeper, with a small effect size ($d \leq 0.20$).

Discussion

In the present study, profiles for anthropometric and fitness characteristics were compared across two categories of Spanish women's team handball players competing in the first Spanish handball league. Greater results were observed among top elite players compared to elite players regarding several of the anthropometric characteristics and throwing velocity. These findings confirm the importance of anthropometric characteristics, mainly with reference to upper limbs (lengths and breadths) and throwing velocity performance for elite women's team handball players. The main novelty of the study is that when assessing a sample of high level players, there were key differences in terms of anthropometric characteristics and throwing velocity between players belonging to the national team and players who played in Spain at the highest level. To our knowledge, studies distinguishing between those levels have not been carried out. Another study (Granados et al., 2013) compared the same team before and after becoming an international member, but no comparison between national team players and players competing in the same league, yet not from the national team, was performed. We refer to players that have already undergone a prior selection process in their own countries, thus, we can conclude that top elite players compared with elite players have more advantageous anthropometric characteristics when analyzing variables important for handball (body height, body mass, dominant hand, arm span, hand width, biacromial, bistyloid, bitrochanteric and biepicondylar breadth). These variables are related to advantages in handball, field of vision, occupation of space, one-on-one situations, and benefits in the struggle for space and for ball

handling (Vila et al., 2012; Zapartidis et al., 2009).

Top elite players showed higher body mass and greater muscle mass than elite players. These results confirm the importance of power in handball, which is required in such actions as sprinting, jumping, blocking, pushing and rapid changes of direction. The present study also confirms the importance of muscular and skeletal strength in handball (García et al., 2011; Vila et al., 2002). However, no differences in fat content and BMI values were observed among the two levels. These results lead us to reinforce the idea that the BMI is not a relevant index to evaluate athletes.

Moreover, top elite handball players showed significantly higher upper body girths (arm flexed and tensed, forearm and wrist girths), but not in the lower limbs. Taking into account that muscle mass of the arm is related with the arm girth and greater muscles generate greater force (Always et al., 1992; Schantz et al., 1983), our results suggest that top elite handball players had been subjected to more handball-specific training. These findings are in agreement with those reported by Milanese et al. (2011). No doubt, a structured strength and fitness programme should be implemented to improve performance of elite female handball players, because team handball involves both, close body contact and a high amount of direct physical impact (Bayios et al., 2006; Srhoj et al., 2002).

The present study found no significant differences between the two groups of players in the vertical jumps (SJ and CMJ). This could be due to the importance of this skill at all handball levels. Since no statistically significant differences were observed in explosive power, it should be highlighted that top elite players showed significant differences in body mass, body height and muscle mass compared with elite players, which may indicate that absolute power was greater among international players (Granados et al., 2013).

Hand grip strength is essential in order to place and throw the ball in different sports, but is especially important considering the dominant hand of a handball player (Koley and Singh, 2009). Similarly, our results show that hand grip strength was also significantly different in top elite players compared with elite ones. It is noticeable that hand width and length cannot be modified by training. Nevertheless, top elite

players showed greater hand length and hand width than the elite ones, and, logically, it was not due to training. Thus, hand size seems to be a discriminatory aspect for high performance in female handball. The ability to grasp the ball is essential in handball, and it is associated with hand size. A good grasp has a positive influence on the ball's throwing velocity (Srhoj et al., 2002; Visnapuu and Jurimae, 2007), a relationship that has been confirmed in this study. It has been hypothesized that in women's handball ball size is not proportional to the size of the player's hand, which could affect the quality of their game (Oliver and Sosa, 2013). This could explain our results. Accordingly, the size, length and width of the hand are undoubtedly crucial to become a top elite player, because a greater value of hand length and hand width provides a greater hand surface in order to grasp the ball. This could improve handling of the ball and thereby enhance the speed and precision of the ball throw during the game.

Most of the studies on throwing velocity have been conducted under conditions relatively unlike those which occur in a real game. Consequently, there is a need for further research on throwing velocity in situations that more closely resemble game conditions, with different degrees of opposition (with/without a goalkeeper) (Rivilla-García and Sampedro-Molinuevo, 2010; Wagner et al., 2011) and different execution variables (a standing throw, a three-step run and standing throw, a jumping throw). The highest velocities were obtained in the absence of a goalkeeper, a finding which coincides with the results reported in a study by Rivilla et al. (2011). Top elite players' performance in handball throwing was better than that of elite players in situations of opposition (accuracy requirement). These findings are in agreement with the results reported by Etnyre (1998), van den Tillaar and Ettema (2006) and Sherwood and Schmidt (1980). These differences are important as they indicate that throwing velocity under conditions that more closely resemble the real game (i.e. with a tactical component) differentiates between players within the same level. These results are not in line with those reported for male handball players (Gutiérrez et al., 2006). Possible explanations for these discrepancies may be the low number of participants (11) and the level of play studied

(sub-elite).

Several studies have shown that the majority of female handball players present throwing velocity values between 13.33 and 27.0 m·s⁻¹ (Granados et al., 2007; Hoff and Almasbakk, 1995; Vila et al., 2012), even when using different measurement methods (photoelectric cells, radar, cinematography), protocols and equipment. It is difficult to compare the results of the present study with those reported in other available studies; however, the measurements obtained in the present study fall within the range reported in the literature for female handball players.

Conclusions

On equal terms of training, top elite players showed differences in anthropometric characteristics compared to elite players. These differences were mainly located in the upper limbs and mostly were non-modifiable by training, leading to the conclusion that anthropometric characteristics were discriminating factors of performance at the highest level.

Lower limb explosive strength is important not only to perform jumps or accelerations, but also in throwing velocity. Explosive strength of the upper and lower extremity muscles should be emphasised to improve throwing velocity.

The best players are able to maintain a high throwing velocity in tactical situations. Thus, anthropometric characteristics and throwing velocity in tactical situations (with goalkeepers) should be considered in the selection of young female handball players in order to develop future elite players.

References

- Alway SE, Grumbt WH, Straygundersen J, Gonyea WJ. Effects of Resistance Training on Elbow Flexors of Highly Competitive Bodybuilders. *J Appl Physiol*, 1992; 72(4): 1512-1521
- Bayios IA, Bergeles NK, Apostolidis NG, Noutsos KS, Koskolou MD. Anthropometric, body composition and somatotype differences of Greek elite female basketball, volleyball and handball players. *J Sports Med Phys Fitness*, 2006; 46(2): 271-280
- Carter J, Heath B. *Somatotyping: development and applications*. (Vol. I). New York: Cambridge University Press; 1990
- Cizmek A, Ohnjec K, Vucetic V, Gruic I. Morphological differences of elite Croatian women's handball players according to their game position. *Hrvat Sportskomed Vjesn*, 2010; 25: 122-127
- Cohen J. A power primer. *Psychol Bull*, 1992; 112(1): 155-159
- Debanne T, Laffaye G. Predicting the throwing velocity of the ball in handball with anthropometric variables and isotonic tests. *J Sports Sci*, 2011; 29(7): 705-713
- Etnyre BR. Accuracy characteristics of throwing as a result of maximum force effort. *Percept Mot Skills*, 1998; 86(3 Pt 2): 1211-1217
- Fritz CO, Morris PE, Richler JJ. Effect size estimates: Current use, calculations, and interpretation. *J Exper Psycho: General*, 2012; 141: 2-18.
- García M, Alcaraz PE, Ferragut C, Manchado C, Abalde LA, Rodríguez N, Vila MH. Body Composition and Throwing Velocity in Elite Women's Team Handball. *CCD*, 2011; 17(6): 129-135
- Gholami M, Sabbaghian L. Anthropometric, body composition and somatotype differences of Iranian elite female basketball and handball players. *Br J Sports Med*, 2010; 44(14): i19-i20
- Gorostiaga EM, Granados C, Ibanez J, Izquierdo M. Differences in physical fitness and throwing velocity among elite and amateur male handball players. *Int J Sports Med*, 2005; 26(3): 225-232
- Granados C, Izquierdo M, Ibanez J, Bonnabau H, Gorostiaga EM. Differences in physical fitness and throwing velocity among elite and amateur female handball players. *Int J Sports Med*, 2007; 28(10): 860-867
- Granados C, Izquierdo M, Ibanez J, Ruesta M, Gorostiaga EM. Effects of an entire season on physical fitness in elite female handball players. *Med Sci Sports Exerc*, 2008; 40(2): 351-361
- Granados C, Izquierdo M, Ibáñez J, Ruesta M, Gorostiaga EM. Are there any differences in physical fitness and throwing velocity between national and international elite female handball players? *J Strength Cond Res*, 2013 Mar; 27(3): 723-32
- Gutiérrez M, Garcia PL, Parraga J, Rojas FJ. Effect of opposition on the handball jump shot. *J Hum Movement Stud*, 2006; 51: 257-275
- Hasan AA, Reilly T, Cable NT, Ramadan J. Anthropometric profiles of elite Asian female handball players. *J Sports Med Phys Fitness*, 2007; 47(2): 197-202
- Higham DG, Pyne DB, Anson JM, Dziedzic CE, Slater GJ. Distribution of fat, non-osseous lean and bone mineral mass in international Rugby Union and Rugby Sevens players. *Int J Sports Med*, 2014; 35(7): 575-582
- Hoff M, Almasbakk B. The effects of maximum strength training on throwing velocity and muscle strength in female team-handball players. *J Strength Cond Res*, 1995; 9(4): 255-258
- Koley S, Singh AP. An Association of Dominant Hand Grip Strength with Some Anthropometric Variables in Indian Collegiate Population. *Anthropologischer Anzeiger*, 2009; 67(1): 21-28
- Lee RC, Wang Z, Heo M, Ross R, Janssen I, Heymsfield SB. Total-body skeletal muscle mass: development and cross-validation of anthropometric prediction models. *Am J Clin Nutr*, 2000; 72(3): 796-803
- Malina RM, Bouchard C, Bar-Or O. *Growth, Maturation, and Physical Activity*. USA: Human Kinetics; 2004
- Malina RM, Meleski BW, Shoup RF. Anthropometric, body composition, and maturity characteristics of

- selected school-age athletes. *Pediatr Clin North Am*, 1982; 29(6): 1305-1323
- Manchado C, Tortosa-Martinez J, Vila H, Ferragut C, Platen P. Performance factors in women's team handball: physical and physiological aspects-a review. *J Strength Cond Res*, 2013; 27(6): 1708-1719
- Maszczyk A, Gołaś A, Pietraszewski P, Roczniok R, Zając A, Stanula A. Application of Neural and Regression Models in Sports Results Prediction. *Procedia - Soci Behavio Sci*, 2014; 117: 482-487.
- Maszczyk A, Golas A, Czuba M, Krol H, Wilk M, Stastny P, Goodwin J, Kostrzewa M, Zajac A. EMG Analysis and Modelling of Flat Bench Press Using Artificial Neural Networks. *SAJRPER*. 2016; 38(1): 91-103
- Milanese C, Piscitelli F, Lampis C, Zancanaro C. Anthropometry and body composition of female handball players according to competitive level or the playing position. *J Sports Sci*, 2011; 29(12): 1301-1309
- Oliver JF, Sosa PI. Need and proposal for change in the size of women's handball ball. supported by a scientific study: "The coverage index of the ball". *Women and Handball: Scientific and Practical Approaches*. Viena, Austria: European Handball Federation. 106-111; 2013
- Portillo J, Gonzalez-Rave JM, Juarez D, Garcia JM, Suarez-Arrones L, Newton RU. Comparison of running characteristics and heart rate response of international and national female rugby sevens players during competitive matches. *J Strength Cond Res*, 2014; 28(8): 2281-2289
- Rampinini E, Impellizzeri FM, Castagna C, Coutts AJ, Wisloff U. Technical performance during soccer matches of the Italian Serie A league: effect of fatigue and competitive level. *J Sci Med Sport*, 2009; 12(1): 227-233
- Rivilla-García J, Sampedro-Molinuevo J. Influence of the opposition in throwing accuracy in elite and amateur handball players. *Br J Sports Med*, 2010; 44(14): 359-364
- Rivilla J, Grande I, Sampedro J, Van den Tillaar R. Influence of opposition on ball velocity in the handball jump throw. *J Sports Sci & Med*, 2011; 10: 534-539
- Schantz P, Randallfox E, Hutchison W, Tyden A, Astrand PO. Muscle-Fiber Type Distribution, Muscle Cross-Sectional Area and Maximal Voluntary Strength in Humans. *Acta Physiol Scand*, 1983; 117(2): 219-226
- Sherwood DE, Schmidt R. The relationship between force and force variability in minimal and near-maximal static and dynamic contractions. *J Motor Behav*, 1980; 12: 75-89
- Skoufas D, Kotzamanidis C, Hatzikotoylas K, Bebetos G, Patikas D. The relationship between the anthropometric variables and throwing performance in handball. *J Hum Mov Sci*, 2003; 45: 469-484
- Srhoj V, Marinovic M, Rogulj N. Position specific morphological characteristics of top-level male handball players. *Coll Antropol*, 2002; 26(1): 219-227
- Stewart A, Marfell-Jones M, Olds T, Ridgen H. *International Standards for anthropometric assessment*. New Zealand: Lower Hutt; 2011
- Suarez-Arrones L, Nunez FJ, Portillo J, Mendez-Villanueva A. Match running performance and exercise intensity in elite female Rugby Sevens. *J Strength Cond Res*, 2012; 26(7): 1858-1862
- van den Tillaar R, Ettema G. Effect of body size and gender in overarm throwing performance. *Eur J Appl Physiol*, 2004, 91(4): 413-418
- van den Tillaar R, Ettema G. A comparison between novices and experts of the velocity-accuracy trade-off in overarm throwing. *Percept Mot Skills*, 2006; 103(2): 503-514
- Vila H, Fernández JJ, Rodríguez FA. Multidimensional evaluation of handball players: talent selection by discriminant analysis In M. Koskolou, N. Geladas & Klissouras (Eds.), (Vol. I, pp. 621). Athens: ECSS, University of Athens: Proceedings of the 7th Annual Congress of the European College of Sport Science; 2002
- Vila H, Manchado C, Rodriguez N, Abrales JA, Alcaraz PE, Ferragut C. Anthropometric profile, vertical jump, and throwing velocity in elite female handball players by playing positions. *J Strength Cond Res*, 2012; 26(8): 2146-2155

- Visnapuu M, Jurimae T. Handgrip strength and hand dimensions in young handball and basketball players. *J Strength Cond Res*, 2007; 21(3): 923-929
- Wagner H, Pfusterschmied J, von Duvillard SP, Muller E. Performance and kinematics of various throwing techniques in team-handball. *J Sports Sci & Med*, 2011; 10(1): 73-80
- Zapartidis I, Gouvali M, Bayios I, Boudolos K. Throwing effectiveness and rotational strength of the shoulder in team handball. *J Sports Med Phys Fitness*, 2007; 47(2): 169-178
- Zapartidis I, Toganidis T, Varelzlis I, Christodoulidus T, Kororos P, Skoufas D. Profile of young women's handball players by playing position. *Serbian J Sports Sci*, 2009; 3: 53-60

Corresponding author:**Carmen Manchado**

University of Alicante

Carretera de San Vicente del Raspeig s/n

03690 San Vicente del Raspeig

Spain

Tel: +34 630730844

Fax: 965903464

E-mail: Carmen.manchado@ua.es