SEX AND STANDARD LEVELS DIFFERENCES IN ANTHROPOMETRIC AND PHYSICAL FITNESS CHARACTERISTICS IN YOUTH HANDBALL PLAYERS

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Abstract:

This study analyzed the relationships between throwing velocity and anthropometric and fitness parameters in young female and male handball players of different ages. A total of 159 players participated: females under-16 (FU16, n=44) and under-14 (FU14, n=21); males under-16 (MU16, n=54) and under-14 (MU14, n=40). The following was measured: body height, arm span, body mass, total finger span, hand length, maximal isometric handgrip force, handball throwing velocity, 20-m sprints, countermovement jump, and change of direction. Group MU16 showed significantly (p<.05) greater values of anthropometric characteristics than groups FU16 and MU14. No significant differences were observed between FU14 and MU14 in any of the anthropometric variables analyzed, or between the two female groups (FU16 vs. FU14). MU16 showed significantly (p<.05) better performance in all fitness parameters than FU16 and MU14. No significant differences were observed between FU14 and MU14 or between FU16 and FU14. Throwing performance correlated (p<.05) with almost all the anthropometric and fitness parameters evaluated within each group. Taken together, male handball players showed greater anthropometric and fitness characteristics in the U16 compared to the U14, whereas no substantial differences were observed in female handball players between the two groups. Handball throwing velocity is associated with body and hand dimensions and other physical performance parameters.

Key words: *throwing velocity, vertical jump, sprinting capacity, male, female*

Introduction

Handball is a team sport characterized by intense, intermittent activities such as running, sprinting, jumping, throwing, hitting, blocking, and pushing (Granados, Izquierdo, Ibañez, Bonnabau, & Gorostiaga, 2007; Granados, Izquierdo, Ibáñez, Ruesta, & Gorostiaga, 2013). Besides technical-tactical skills, anthropometric characteristics, speed, strength and agility are critical factors in successful handball performance (van den Tillaar & Ettema, 2003a,b). The handball throw is a fundamental skill that players must develop to increase their own proficiency and their team's performance, since the final match outcome is dependent on a team scoring more goals than its opponents. Basic factors influencing the efficiency of handball throws are accuracy and throwing velocity (van den Tillaar & Ettema, 2003a,b). Anthropometric characteristics of players (body height, hand size and arm span) (Bojić-Ćaćić, Vuleta, & Milanović, 2018; Debanne & Laffaye, 2011; Hasan, Reilly, Cable, & Ramadan, 2007; Matthys, Fransen, Vaeyens, Lenoir, & Philippaerts, 2013a; Mohamed, et al., 2009; Moss, McWhannell, Michalsik, & Twist, 2015; Rousanoglou, Noutsos, & Bayios, 2014; Zapartidis, Vareltzis, Gouvali, & Kororos, 2009) and handgrip force (Vila, et al., 2012) should also be taken into account. The identification of anthropometric and physical fitness characteristics that allow the selection of players with the potential to achieve elite performance levels has long been of great interest to coaches, administrators, and governments. However, identifying handball talent at an early age is complex and there is little available literature on talent identification in youth handball.

Maturation process determines levels of performance between sexes at different chronological stages (Rousanoglou, et al., 2014). In handball, the age levels established by the regulation for international championships are under-16 (U16), under-18 (18) and under-20 (U20) but for younger players each national federation establishes its own age limits, which normally are under-12 (U12) and under-14 (U14). Bompa (1999) and Lidor et al. (2005) suggest that age groups U12 and U14 correspond to age levels that would be within the first years of the second phase in the talent detection and development (ages 10-15 for female players and 10-17 for male players) for most sporting activities. There is some information about differences in standard levels from comparisons between elite and non-elite junior handball players. However, few studies have focused on the early ages of training (U14) (Hammami, et al., 2018; Lidor, et al., 2005; Matthys, Vaeyens, Coelho-E-Silva, Lenoir, & Philippaerts, 2012; Matthys, et al., 2013a,b; Ziv & Lidor, 2009). In summary, the combination of a greater body height, muscular body mass, and hand dimension constitutes an anthropometric advantage for senior handball players. Similar findings have been made for young male players. However, there is little information about the differences between sexes when standard levels are determined by chronological age (Ingebrigtsen, Jeffreys, & Rodahl, 2013; Prieske, Chaabene, Puta, Behm, & Büsch, 2019; van den Tillaar & Cabri, 2012).

Since standard level seems to depend on a variety of physical fitness and anthropometric characteristics, it is of interest to determine whether these differences are present in the early ages of training and whether the development of these characteristics differs between sexes. Furthermore, it is potentially useful to determine whether throwing velocity is related to anthropometric and fitness factors in young handball players of both sexes. Determining physical profiles of young handball players will allow the identification of strengths and weaknesses in areas relevant to performance and allow the design of specific, focused training models to improve performance (Moss, et al., 2015). Therefore, the aims of this investigation were to: (a) analyze the evolution of throwing velocity and different fitness parameters (sprinting, change of direction and jump abilities) at different ages in young female and male handball players; and (b) examine the relationships between throwing velocity and different fitness parameters. Our hypothesis is that there are differences in physical performance and anthropometric characteristics between age and sex groups of handball players and that throwing velocity is partially explained by both anthropometric and fitness parameters.

Methods

Participants

A total of 159 young female and male handball players participated in this investigation. The players were members of a development program academy run by a regional handball federation. According to the national handball federation rules, players were matched by their chronological age rather than biological maturation. Thus, in the present study, players were pooled by sexes and age group: females under-16 (FU16, n = 44); males under-16 (MU16, n = 54); females under-14 (FU14, n = 21); and males under-14 (MU14, n = 40). After being informed about the purpose, testing procedures and potential risks of the investigation, written consent was obtained from participants' parents/guardians. No physical limitations, health problems, or musculoskeletal injuries that could affect testing were found in medical examination. None of the participants were using any drugs, medications, or dietary supplements known to influence physical performance. The present investigation was approved by the Research Ethics Committee of Pablo de Olavide University, Sevilla, Spain.

Procedures

A cross-sectional experimental design was used to determine the differences between female and male (F vs. M) handball players of different ages (U16 vs. U14) in anthropometric characteristics and specific handball throwing and fitness parameters such as handgrip force, sprinting, jump and changes of direction (COD) ability and to analyze the relationships between these anthropometric and fitness parameters and handball throwing velocity within each group. All tests were completed at the end of the season (June) and were carried out in two testing sessions. During the first testing session, anthropometric characteristics and handgrip force were measured, and during the second testing session physical fitness measurements were carried out. Following preliminary familiarization and pre-testing, subjects completed a battery of tests in the following order: 1) specific handball throwing testing; 2) 20-m running sprints; 3) countermovement vertical jumps, and 4) COD sprints. Sessions were performed under the direct supervision of the investigators, at the same time of day for each subject and under constant environmental conditions (20ºC, 60% humidity). Before testing, subjects executed a standardized warm-up directed by the primary researcher along with the coach. During the execution of the tests, players were verbally encouraged to give their maximal effort. The tests are explained in detail below.

Anthropometric measures

The following measurements were obtained: a) body height (BH), arm span and body mass (BM) measurements, which were made using set scales (Seca, Barcelona, Spain) with a precision of 0.001 m and 0.01 kg, respectively; b) total finger span (TFS) and hand length (HL) of the dominant hand, following the Visnapuu and Jürimäe's (2007) protocol. TFS was defined as distance between the tip of the thumb and the tip of the little finger, whereas HL was defined as distance from the tip of the middle finger to the midline of the distal fold of the wrist (Fallahi & Jadidian, 2011). Both variables were measured with a 300 mm metal ruler (Visnapuu & Jürimäe, 2007).

Maximal isometric handgrip force test

Maximal isometric handgrip force was evaluated by a handheld handgrip dynamometer (TKK-5401, Nithi Sports, Niigata, Japan), with a scale of 0.1 kg. The subjects performed a familiarization exercise with the device, which also served as a warm-up, consisting of three repetitions with the dynamometer (Vila, et al., 2012). Then, two repetitions at maximum intensity were performed with the dominant hand. The subjects maintained a standing position with the dynamometer set parallel to their body. In this position, the player was asked to exert maximal grip force without arm or wrist movement. The best trial was used for further analysis. For motivational purposes, the players were immediately informed of their performance. Three minutes of rest were provided between trials to minimize the effects of fatigue. Test-retest reliability, measured by the coefficient of variation (CV), was 4.5%. The intraclass correlation coefficient (ICC) was 0.99 (95% confidence interval, CI: 0.98-0.99).

Handball throwing test

Handball throwing velocity was evaluated on an indoor handball court in two situations: standing throw and jump throw. Measurements were conducted following 10 minutes of a standardized warm-up, directed by the researcher, which consisted of performing specific passes and throws, in which velocity was progressively increased. International Handball Federation (IHF) regular balls (size II) were used for these tests. The throw was considered valid if the ball entered directly into the goal without touching the ground. In the jump throw, the players dribbled the ball from midfield (20 m from the goal), performed a three-specific-step approach and threw the ball from a jump without overstepping the 9-m line. In the standing throw, the subjects had to repeat the same approach sequence as in the previous release but once they reached the throwing area, the throw had to be completed with one foot in contact with the floor outside the 9-m line. All players completed three maximal throws of each type, with an interval of two minutes between them. The players were immediately informed of the result of their throw in order to maintain motivation. The fastest throw of each type (standing and jump throw) was kept for further analysis. The speed of each throw was measured using a radar device (Stalker Sport, Applied Concepts Inc, Texas, USA). The radar was placed 2-m behind the indoor handball goal and elevated 1-m from the ground. Coaches supervised the execution of throws to ensure that the throwing tests followed the rules established, and tests were excluded if the cited rules were not obeyed. Test-retest reliabilities as measured by CV were 3.5% for the jump throw and 3.0% for the standing throw, respectively. The ICC values were 0.98 (95% CI: 0.97-0.98) for both types of throw.

Sprint capacity

The subjects ran two 20-m sprints on an indoor track, separated by a 3-minute rest. The starting position was standardized, with the lead-off foot behind the starting line, which was placed 1-m behind the first-time gate. Photocell gates were placed at the start, and at the 10- and 20-m point. The subjects ran under the premise of running the 20 m in the shortest possible time. The best time of the two attempts in the following splits was recorded: 0-10 m (T10), 10-20 m (T10-20) and 0-20 m (T20). A standardized warm-up protocol was performed, which incorporated several sets of progressively faster 30-m accelerations. Sprint times were measured using photocells (Polifemo Radio Light, Microgate, Bolzano, Italy). Test-retest reliabilities as measured by CV were 2.1%, 2.9% and 1.9% for T10, T20 and T10-20, respectively. The ICC values were 0.94 (0.92-0.95) for T10, 0.92 (0.90-0.94) for T20, and 0.98 (0.97-0.99) for T10-20.

Jump ability

Jump height was calculated to the nearest 0.1 cm from flight time measured with an infrared timing system (Optojump, Microgate, Bolzano, Italy). The displacement of the center of gravity during the flight was estimated from the jump height (h), which was calculated using the recorded flight time as follows

$$h = (g \cdot ft^2) \cdot 8^{-1},$$

where g was the acceleration of gravity (9.81 m·s-2) and ft was flight time (Bosco, Luhtanen, & Komi, 1983). Since take-off and landing positions can affect jump performance, strict instructions were given to all participants to keep their legs straight during the flight time of the jump. The player started from an upright standing position, made a downward movement until approximating a knee angle of 90 degrees, and subsequently pushed off with maximal velocity. All participants completed five maximal CMJs with their hands on their hips, separated by one-minute rests. The highest and lowest values were discarded, and the resulting average value was kept for analysis. The CV for test-retest reliability was 4.1% and the ICC was 0.99 (95% CI: 0.98-0.99).

Change of direction test

The players performed two trials of 10+10 m sprints with a 180° change of direction, separated by a 3-minute rest. The starting position was standardized, with the leading foot behind the start/finish line, which was placed 1-m behind the time gate (Polifemo Radio Light, Microgate, Bolzano, Italy). A photocell gate was placed at the start/finish line. Each player ran from the start/finish line, completely crossed the 10-m line with either the right or left foot and turned by 180° to sprint back to the start/finish line in the shortest possible time. The best time of the two attempts was recorded. The CV for test-retest reliability was 2.4% and the ICC was 0.94 (95% CI: 0.91-0.95).

Statistical analyses

Values are reported as mean ± standard deviation (SD). Statistical significance was established at the p≤.05 level. Test-retest absolute reliability was measured by the standard error of measurement (SEM), which was expressed in relative terms through CV, whereas relative reliability was assessed by the ICC (95% CI) calculated with the one-way random effects model. The SEM was calculated as the root mean square of the total mean square intra-subject. The distribution of each variable was examined using the Kolmogorov-Smirnov normality test. Homogeneity of variance was verified using Levene's test. The statistical differences between the groups (FU16 vs. FU14 vs. MU16 vs. MU14) were tested using an ANOVA with Bonferroni post-hoc comparisons. Effect sizes (ES) were calculated using Hedge's g on the pooled SD (Cohen, 1988) and 90% CI were calculated for all dependent variables. Probabilities were also calculated to establish whether the true (unknown) differences were lower, similar or higher than the smallest worthwhile difference or change (.2 x between-subject SD) (Cohen, 1988). Quantitative chances of better or worse effects were assessed qualitatively as follows: <1%, almost certainly not; 1-5%, very unlikely; 5-25%, unlikely; 25-75%, possible; 75-95%, likely; 95-99%, very likely; and >99%, most likely (Batterham & Hopkins, 2006; Hopkins, Marshall, Batterham, & Hanin, 2009). If the chances of obtaining beneficial/better or detrimental/worse were both >5%, the effect was assessed as unclear (Batterham & Hopkins, 2006; Hopkins et al., 2009). Pearson's correlation coefficients (r) and (95%CI) were calculated to establish the respective relationships between throwing velocity and the rest of the variables measured within each group. Inferential statistics based on the interpretation of the magnitude of effects were calculated using a purpose-built spreadsheet (Hopkins, 2006). The remaining statistical analyses were performed using SPSS software version 21.0 (SPSS Inc., Chicago, IL).

Results

Anthropometric characteristics

The mean ± SD age and anthropometric characteristics of the four groups are displayed in Table 1. MU16 presented significantly (p<.05) greater values in body height, arm span, TFS and HL than FU16, but no significant differences in BM. No significant differences were observed for any of the variables analyzed between FU14 and MU14. Moreover, no significant differences were found between the two female groups (FU16 vs. FU14). MU16 showed significantly (p<.05) greater values in all anthropometric variables analyzed than MU14. The magnitude-based inference approach is reported in Figure 1.

Physical fitness parameters

Mean ± SD values of the fitness parameters are reported in Table 2. MU16 showed significantly (p<.05) better performance in all fitness parameters analyzed (handgrip force, throwing velocity, sprinting, CMJ and COD) than FU16. No significant differences were observed between FU14 and MU14 or between FU16 and FU14. MU16 showed significantly (p<.05) better values in all fitness variables analyzed than MU14.

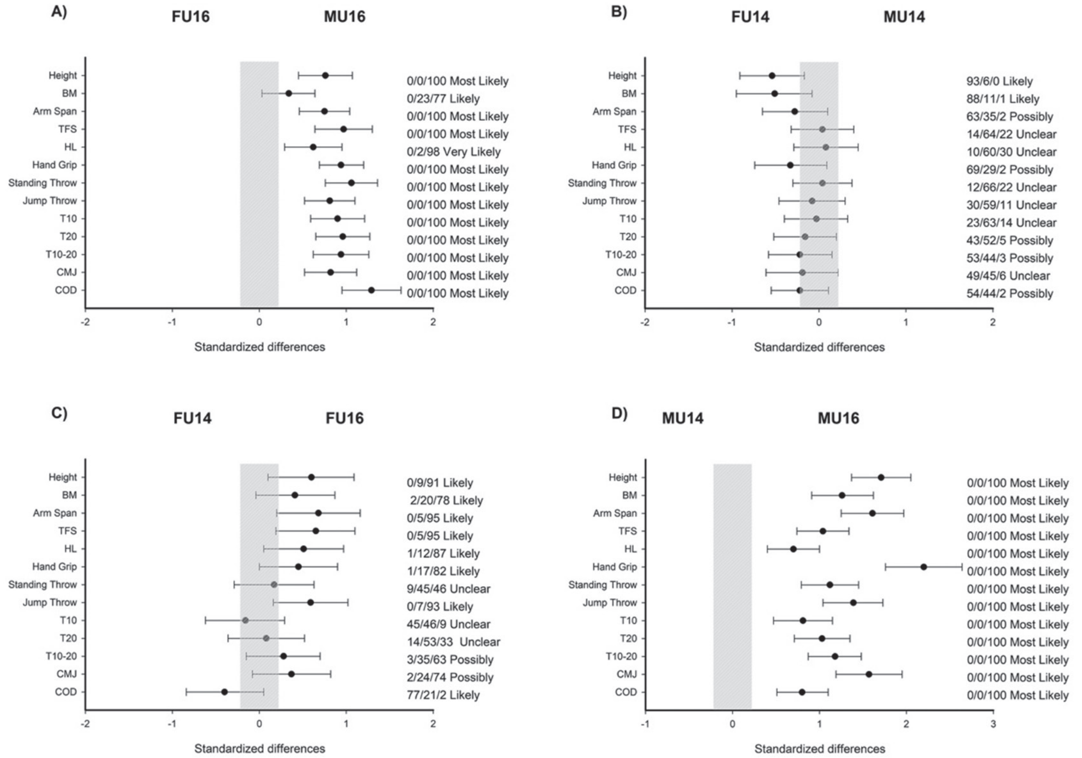
Relationships between anthropometric characteristics, fitness parameters and throwing velocity

Relationships between throwing velocity and anthropometric characteristics and fitness parameters within each group are reported in Table 3. The two male groups, MU16 and MU14, showed significant relationships between throwing velocity and all anthropometric and fitness parameters evaluated (p<.001 – .05), except between BM and jump

Table 1. Age and anthropometric characteristics

	FU16	MU16	FU14	MU14
Age (year)	14.2 ± 0.7	14.0 ± 0.7	12.4 ± 0.7	12.2 ± 0.7
Body height (m)	1.65 ± 0.06^{α}	1.71 ± 0.08	1.62 ± 0.05	1.57 ± 0.07^{δ}
Body mass (kg)	60.2 ± 9.2	64.3 ± 12.0	55.9 ± 9.9	50.1 ± 11.0^{δ}
Arm span (m)	1.67 ± 0.06^{α}	1.74 ± 0.10	1.63 ± 0.06	1.60 ± 0.09^{δ}
TFS (cm)	21.20 ± 1.01^{α}	22.31 ± 1.14	20.46 ± 1.09	20.52 ± 1.70^{δ}
HL (cm)	18.23 ± 0.96^{α}	18.89 ± 1.06	17.69 ± 1.00	17.81 ± 1.50^{δ}

Note. Data are mean ± SD. TFS: total finger span; HL: hand length; FU16: female under-16 years of age (n = 44); MU16: male under-16 years of age (n = 54); FU14: female under-14 years of age (n = 21); MU14: male under-14 years of age (n = 40). ^{α} Denotes significant differences between FU16 and MU16 (p<.05). ^{δ} Denotes significant differences between MU14 and MU16 (p<.05).



Note. FU16: female under-16 years of age (n = 44); MU16: male under-16 years of age (n = 54); FU14: female under-14 years of age (n = 21); MU14: male under-14 years of age (n = 40); BM: body mass; TFS: total finger span; HL: hand length; jump throw: handball throwing from a jump; standing throw: handball throwing from a three-step approach while maintaining contact with the ground; T10: 10 m sprint time; T10-20: 10-20 m split sprint time; T20: 20 m sprint time; CMJ: countermovement jump height; COD: 180º 10 + 10 m change of direction sprint.

Figure 1. Between-group comparisons for anthropometric and fitness parameters. FU16: Bars indicate uncertainty in the true mean changes with 90% confidence intervals. Trivial (shaded) areas were calculated from the smallest worthwhile change. Note. The percent values indicate the likelihood of having a beneficial/better, similar, or detrimental/poorer effect for the first group compared with the second group (i.e., COD-0 vs. COD-12.5). A reduction of time in the running variables was interpreted as a positive effect.

Table 2. Descriptive values of strength, sprint, jump height and throwing velocity of the four groups, mean (± SD) for each group

	FU16	MU16	FU14	MU14
Handgrip (N)	268.02 ± 38.24	345.45 ± 80.85	247.84 ± 42.5	230.9 ± 51.06$^{\delta}$
Standing throw (m·s^{-1})	18.43 ± 1.96$^{\alpha}$	21.15 ± 2.52	18.13 ± 1.69	18.31 ± 2.03$^{\delta}$
Jump throw (m·s^{-1})	19.32 ± 1.74$^{\alpha}$	21.25 ± 2.33	18.24 ± 1.77	18.06 ± 2.25$^{\delta}$
T_{10} (s)	2.09 ± 0.11$^{\alpha}$	1.97 ± 0.13	2.08 ± 0.09	2.08 ± 0.13$^{\delta}$
T_{20} (s)	3.66 ± 0.20$^{\alpha}$	3.43 ± 0.24	3.68 ± 0.20	3.73 ± 0.28$^{\delta}$
T_{10-20} (s)	1.57 ± 0.10$^{\alpha}$	1.46 ± 0.11	1.60 ± 0.11	1.65 ± 0.15$^{\delta}$
CMJ (cm)	25.7 ± 4.6$^{\alpha}$	30.5 ± 5.8	24.1 ± 4.1	23.2 ± 4.6$^{\delta}$
COD (s)	5.32 ± 0.27$^{\alpha}$	4.95 ± 0.28	5.22 ± 0.25	5.32 ± 0.44$^{\delta}$

Note. Data are mean ± SD. FU16: female under-16 years of age (n = 44); MU16: male under-16 years of age (n = 54); FU14: female under-14 years of age (n = 21); MU14: male under-14 years of age (n = 40); jump throw: handball throwing from a jump; standing throw: handball throwing from a three-step approach while maintaining contact with the ground; T_{10}: 10 m sprint time; T_{10-20}: 10-20 m split sprint time; T_{20}: 20 m sprint time; CMJ: countermovement jump height; COD: 180º 10 + 10 m change of direction sprint. $^{\alpha}$ Denotes significant differences between FU16 and MU16 (p<.05). $^{\delta}$ Denotes significant differences between MU14 and MU16 (p<.05).

throw for the MU14 group. For the FU14 group, significant relationships existed between standing throw and all anthropometric and fitness parameters evaluated (p<.001 – .05). However, no relationships were found between jump throw and BM, TFS and T10-20 for this group (Table 3). For the FU16 group, significant relationships existed between jump throw and all anthropometric and fitness parameters evaluated (p<.001 – .05), except for HL, handgrip force and CMJ. However, significant relationships were only found between standing throw and body height, BM, arm span and TFS (Table 3).

Table 3. Matrix of relationships between throwing velocity and anthropometrics characteristics and fitness parameters within each group

		Height	Body mass	Arm Span	TFS	HL	Hand Grip	T_{10}	T_{20}	T_{10-20}	CMJ	COD
FU16	Standing throw	.56*** (0.36 to 0.71)	.46** (0.24 to 0.64)	.53*** (0.32 to 0.69)	.37* (0.13 to 0.57)	.27 (0.02 to 0.49)	.21 (-0.04 to 0.44)	-.23 (-0.46 to -0.02)	-.22 (-0.45 to -0.03)	-.18 (-0.55 to -0.11)	.03 (-0.41 to 0.07)	-.30 (-0.51 to -0.05)
	Jump throw	0.59*** (0.40 to 0.73)	0.49** (0.27 to 0.66)	.47** (0.25 to 0.65)	.36* (0.12 to 0.56)	.25 (0.00 to 0.47)	.31 (0.06 to 0.52)	-.33* (-0.54 to -0.09)	-.35* (-0.55 to -0.11)	-.33* (-0.54 to -0.09)	.17 (-0.09 to 0.40)	-.45** (-0.63 to -0.22)
FU14	Standing throw	.49* (0.15 to 0.73)	.46** (0.11 to 0.71)	.65** (0.37 to 0.82)	.45 (0.10 to 0.70)	.46 (0.11 to 0.71)	.55* (0.23 to 0.76)	-.44* (-0.70 to -0.08)	-.46* (-0.71 to -0.11)	-.44* (-0.70 to -0.08)	.59** (0.28 to 0.79)	-.49* (-0.73 to -0.15)
	Jump throw	0.57* (0.25 to 0.78)	.37 (0.00 to 0.65)	.60** (0.30 to 0.79)	.39 (0.02 to 0.66)	.55* (0.23 to 0.76)	.53* (0.20 to 0.75)	-.44* (-0.70 to -0.08)	-.47* (-0.72 to -0.12)	-.37 (-0.65 to 0.00)	.48* (0.13 to 0.72)	-.49* (-0.73 to -0.15)
MU16	Standing throw	.67*** (0.52 to 0.78)	.34* (0.12 to 0.53)	.64*** (0.48 to 0.76)	.46*** (0.26 to 0.62)	.57*** (0.39 to 0.71)	.62*** (0.46 to 0.74)	-.49*** (-0.64 to -0.30)	-.53*** (-0.68 to -0.35)	-.54*** (-0.68 to -0.36)	.34* (0.12 to 0.53)	-.43*** (-0.60 to -0.23)
	Jump throw	.64*** (0.48 to 0.76)	.30* (0.08 to 0.49)	0.62*** (0.46 to 0.74)	.48*** (0.28 to 0.64)	.58*** (0.41 to 0.71)	.58*** (0.41 to 0.71)	-.46*** (-0.62 to -0.26)	-.52*** (-0.67 to -0.33)	-.54*** (-0.68 to -0.36)	.31* (0.09 to 0.50)	-.50*** (-0.65 to -0.31)
MU14	Standing throw	.69*** (0.52 to 0.81)	.45** (0.21 to 0.64)	.60*** (0.40 to 0.75)	.50** (0.27 to 0.67)	.53** (0.31 to 0.70)	.76*** (0.62 to 0.85)	-.56*** (-0.72 to -0.36)	-.61*** (-0.75 to -0.41)	-.69*** (-0.81 to -0.52)	.64*** (0.45 to 0.77)	-.74*** (-0.84 to -0.59)
	Jump throw	.57*** (0.36 to 0.72)	.21 (-0.06 to 0.45)	.58*** (0.37 to 0.73)	.47** (0.24 to 0.65)	.43** (0.19 to 0.62)	.72*** (0.56 to 0.83)	-.64*** (-0.77 to -0.44)	-.69*** (-0.81 to -0.52)	-.69*** (-0.81 to -0.52)	.63*** (0.44 to 0.77)	-.63*** (-0.77 to -0.44)

Note. FU16: female under-16 years of age (n = 44); MU16: male under-16 years of age (n = 54); FU14: female under-14 years of age (n = 21); MU14: male under-14 years of age (n = 40); handball throwing from a jump; T_{10}: 10 m sprint time; T_{10-20}: 10-20 m split sprint time; T_{20}: 20 m sprint time; CMJ: countermovement jump height; COD: 180º 10 + 10 m change of direction sprint. *Denotes significance at p≤.05; **Denotes significance at p≤.01. ***Denotes significance at p≤.001.

Discussion and conclusions

Several studies have analyzed anthropometric, physical fitness, and handball-specific characteristics of youth female and/or male handball players (Hammami, et al., 2018; Lidor, et al., 2005; Matthys, et al., 2012, 2013a,b; Mohamed, et al., 2009; Rousanoglou, et al., 2014; Zapartidis, et al., 2009). However, to our knowledge, this is the first study that has compared both anthropometric and fitness characteristics on a large sample of young female and male handball players of different ages and, at the same time, has presented the relationships between anthropometric and fitness parameters and handball throwing velocity. The main findings of the present study were that although no differences were found between the youngest female and male groups (FU14 vs. MU14), the oldest male players (MU16) showed better fitness performance and higher anthropometric values with respect to the female group of the same age (FU16). Moreover, no significant differences between the two female groups (FU16 vs. FU14) were observed. These findings indicate that anthropometric and fitness development in adolescent handball players seem to be sex-dependent. This study improves understanding of the quintessential anthropometric and fitness characteristics as related to the age and sex of each player.

Previous studies have already shown that larger anthropometric dimensions are beneficial to handball players (Mohamed, et al., 2009; Skoufas, Kotzamanidis, Haztikotoulas, Bebetsos, & Patikas, 2003; Zapartidis, et al., 2009). However, literature concerning youth elite handball players is still scarce. Hand dimension is an important tool in those sports where handgrip actions with either the ball or the opponent are constant. For the TFS and HL variables, the male groups (MU16 and MU14) showed very similar values to those provided by Mohamed et al. (2009) and Zapartidis et al. (2009) for male handball players of the same age. For the female players, the FU14 group presented similar values to those reported by Mohamed et al. (2009). The FU16 group showed similar values to the Spanish elite female players in HL but greater TFS than these players (Vila, et al., 2012). Moss et al. (2015) found that elite youth players were on average 11 cm taller and 11 kg heavier than non-elite players. In the present study, MU16 exhibited greater values in anthropometric parameters (height, BM, arm span, TFS and HL) than FU16 and MU14, with no significant differences between the other groups. These data may be explained by the sex differences in developmental maturation of the musculo-skeletal system (Malina, Bouchard, & Bar-Or, 2009). No significant differences were found between sexes at U14 (FU14 and MU14) or between the two female groups (FU16 vs. FU14). However, a huge development can be observed in male handball players from U14 to U16 in terms of both entire body (height, BM and arm span) and hand (TFS and HL) dimensions. In accordance with our findings, a previous study also observed increases in BM and HL in male youth handball players (Rousanoglou, et al., 2014). Another study found no significant differences in anthropometry between U18 and U16 players within either sex, although these players were older than those participating in the present study (U16 and U14) (Ingebrigtsen, et al., 2013). Thus, important criteria for talent selection to handball, such as height, BM, arm span and hand dimensions (Rousanoglou, et al., 2014; Zapartidis, Nikolaidou, Vareltzis, & Kororos, 2011), reflect different maturation statuses in young male and female handball players.

Earlier studies have suggested that higher ball throwing velocities are a pivotal factor for attaining higher handball performance levels (Gorostiaga, Granados, Ibáñez, & Izquierdo, 2005; Ortega-Becerra, Pareja-Blanco, Jiménez-Reyes, Cuadrado-Peñafiel, & González-Badillo, 2018; Wagner, Buchecker, von Duvillard, & Müller, 2010). The standing and jump throw velocities observed for handball players in this study were similar to those reported in the literature for both sexes (Moss, et al., 2015; Ortega-Becerra, et al., 2018; Rousanoglou et al., 2014; Zapartidis et al., 2009). In the present study, MU16 displayed a greater throwing velocity (of both the standing throw and jump throw) than female handball players of the same age (FU16) and male U14 handball players (MU14) (Table 2). No significant differences were observed between the other groups. A higher throwing velocity (of both the standing and jump throw) has been observed in elite handball players compared to non-elite handball players (Ortega-Becerra, et al., 2018). It has been previously suggested that slower throwing velocities in non-elite players may be explained by a poor throwing technique and lower strength of the upper and lower body limbs (Wagner, et al., 2010). In line with this, MU16 also produced a greater handgrip force than female handball players of the same age (FU16) and male U14 handball players (MU14), with no significant differences between the other groups (Table 2). These findings may suggest that high handgrip values are required for achieving elite performance levels, which may provide an advantage in successfully performing the strength-demanding physical actions required in handball game situations involving regular handgrip interactions with either the ball or opponents. In addition, the significant differences in throwing velocity between men and women are in line with other studies (Hoff & Almåsbakk, 1995; van den Tillaar & Ettema, 2004), although those studies were performed with senior handball players. Differences in throwing performance between sexes have been explained by anthropometric dimensions (van den Tillaar & Ettema, 2004). In this regard, similar to throwing velocity, no differences in anthropometric values were observed between the youngest female and male groups (FU14 vs. MU14) and no significant differences were observed between the two female groups (FU16 vs. FU14).

The ability to sprint over short distances and execute rapid changes of direction may be crucial for match outcomes, allowing players to relocate themselves during transitions between attack and defense phases, and during fast breaks and offensive breakthroughs (Michalsik, Aagaard, & Madsen, 2013). Earlier studies have found that players of a higher standard achieve better sprint and COD performances than lower standard players; this applies for both male (Matthys, et al., 2013a,b; Zapartidis, et al., 2009) and female (Moss, et al., 2015) handball players. In contrast, Gorostiaga et al. (2005) reported no differences in vertical jumping and sprinting performance in handball players with different playing standards. In the present study, MU16 players showed greater CMJ performance than FU16 and MU14 ($p<.001$), whereas no differences were found for jump performance between FU16 and FU14 or between FU14 and MU14 (Table 2). Our CMJ data are partially in line with those obtained by Ortega-Becerra et al. (2018), who reported greater vertical jump performance in elite than in U18 and U16 handball players, with no significant differences between U18 and U16 players. To our knowledge, this is the first study to analyze COD performance at different playing ages and for both sexes in handball players. In this regard, MU16 achieved better sprint and COD performances than FU16 and MU14, with no significant differences between FU14 and MU14 or between FU16 and FU14. Previous studies have also found a better COD performance for youth elite handball players than for youth non-elite players (Matthys, et al., 2013a, 2013b; Mohamed, et al., 2009). In addition, a previous study has also shown that elite players have superior 20-m sprint performances compared to U18 and U16 players, although no differences were observed between U18 and U16 (Ortega-Becerra, et al., 2018). These data from different studies suggest that talent scouts should give special attention to players who have an ability to sprint and can rapidly change directions. Overall, the playing-level differences in physical performance are likely associated with maturation, which differs between sexes, as well as improving with training experience (Malina, et al., 2009). As the standard level improves, the chronological age and training experience of the players also increases. Increased training experience probably generates efficient movement patterns in ball throwing and in jump, sprint and COD tasks, allowing for greater force production (Aagaard, 2003).

Previous studies analyzing the association between anthropometric and performance characteristics in team handball have focused on throwing velocity (Gorostiaga, et al., 2005; Ortega-Becerra, et al., 2018; van den Tillaar & Ettema, 2004; Wagner, et al., 2010). However, none of them have analyzed these relationships within age and sex groups. In accordance with earlier studies (Debanne & Laffaye, 2011; Skoufas, et al., 2003; van den Tillaar & Ettema, 2004; Zapartidis, et al., 2009), significant relationships were observed between throwing velocity and general anthropometric parameters (height, BM and arm span), except between BM and jump throw for the MU14 and FU14 groups. Among these factors, height and arm span appear to have the strongest relationships with throwing velocity (Table 3). Throwing velocity depends not only on muscle strength but also on throwing technique, which is related to the capacity to coordinate complex fast sequential actions of body segments, progressing from the larger leg and trunk actions to the faster moving actions of the more distal segments (Jöris, Edwards van Muyen, van Ingen Schenau, & Kemper, 1985). On this basis, it could be suggested that longer limbs (both legs and arms) may allow players to attain faster velocities in the more distal segments. With regard to the relationships between throwing velocity and hand dimensions and strength, significant relationships were observed between throwing velocity and TFS, HL and handgrip, except between HL, handgrip and both kinds of throwing for the FU16 group. In agreement with our findings, van den Tillaar and Ettema (2004) observed a significant relationship between handgrip strength and throwing velocity in both female (r = .49) and male (r = .43) handball players. Moreover, positive relationships between hand dimensions and throwing velocity have been previously reported. Hand length and hand width (with the fingers adducted), along with handgrip strength, may improve the ability to strongly grab the ball, which seems to be an important factor for a fast shot. Thus, together with body height and arm span, hand dimensions and handgrip strength should also be considered when selecting handball players.

With regard to the relationships between fitness measures and handball throwing velocity, significant relationships were observed between sprinting, jump and COD performance and throwing velocity, except for the FU16 group, where non-significant relationships were found between all these variables and the standing throw. These findings indicate that players with higher explosive performance in the lower limbs may be able to throw the ball (both with and without jumping) at higher velocities than those with lower values. This assumption is supported by previous studies that showed significant relationships between throwing velocity and sprinting and jumping capacity (Ortega-Becerra, et al., 2018). Thus, as previously suggested, higher jump height and faster running may contribute to throwing performance (Ortega-Becerra, et al., 2018). In addition, it seems that all relationships were higher in both male groups than in the female groups.

Male handball players showed greater anthropometric characteristics, hand dimensions and strength, throwing velocities, jump height, running sprint capacity, and COD performance in the U16 as compared to the U14 age group, whereas no substantial changes were observed in female handball players from U14 to U16. In addition, the present findings suggest that handball throwing velocity is strongly associated with height and arm span, hand dimensions and strength, along with explosive performance such as vertical jumping, sprinting and COD performance. Taken together, our results suggest that training programs should be focused on improving throwing velocity, along with jumping, sprinting and COD performance. In addition, different maturation processes between sexes seem to affect handball performance. Further studies should analyze long-term adaptations to strength training programs in both genders at different stages. Our results highlight the contribution of anthropometric and hand dimensions and handgrip strength, together with explosive performance, in handball throwing velocity, suggesting the need for coaches to include upper and lower limb strength programs for improving handball players' throwing velocity.

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