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Original Article

Relationship between throwing accuracy and performance indices in female and male adolescent handball players

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Abstract:
The purposes of this study were to (i) investigate the relationship between overhead throwing accuracy and anthropometric and maturity characteristics, kinesthesis, self-efficacy, and the angular kinematics of the hand and (ii) examine the differences in all variables in the study between female and male adolescent handball players. Methods: The participants of this study were 30 handball players aged 14–16 years (n = 15 females, n = 15 males). Anthropometric and maturity characteristics were recorded for each player; psychomotor indices and overhead throwing accuracy were then tested. Results: Several correlations were revealed between overhead throwing accuracy and the subject parameters this study. Specifically, for the adolescent females, chronological age (r= 0.586; p= 0.022) and the age of peak high velocity (APHV) (r= 0.645; p= 0.009) had a positive effect on the throwing accuracy, while ectomorphy (r= -0.520; p= 0.047) and kinesthesis (r= -0.603; p= 0.017) had a negative effect. For the adolescent males, the APHV (r= 0.659; p= 0.008), the standing height (r= 0.714; p=0.003), and the sitting height (r= 0.554; p= 0.032) positively affected the throwing accuracy, while mesomorphy (r= -0.526; p= 0.044) affected it negatively. Between the two genders, significant differences were detected for the parameters of chronological age (F=6.63; p= 0.016), APHV (F=14.56; p=0.001), standing height (F=7.28; p=0.01), mesomorphy (F=10.71; p=0.003), biacromial breadth (F=22.34; p=0.000), forearm length (F=4.82; p=0.03), and hand width (F=8.37; p=0.007), as well as the level (F=13.54; p=0.001) and strength of self-efficacy (F=12.38; p=0.001). Conclusion: These findings may provide important information to formulate coaching interventions with the choice of suitable exercises with a view to improving the throwing efficacy of handball players.
Key Words: Maturity, Anthropometric characteristics, Kinesthesis, Self-efficacy, Angular kinematics of the hand

Introduction

Many researchers have examined the relationship between throwing accuracy and a variety of performance indices with the aim of improving the performance of handball players (Bayios et al., 2001; Rousanoglou et al., 2014; Wagner et al. 2011). In this study, we focused on maturity and anthropometric characteristics, kinesthesis, self-efficacy, and segmental kinematics.

Focusing on improvements in the throwing performance of handball players, many researchers have dealt with throwing accuracy and its correlation with various characteristics (Rousanoglou et al., 2015). One of these is anthropometric characteristics, which have been found to significantly affect accuracy (Burton et al., 1992; Visnapuu & Jürimäe, 2009). More specifically, hand characteristics are very important and, in particular, the most accurate throwing attempts are the ones in which hand width is equal to the ball diameter (Burton et al., 1992), while the arm length and the forearm length negatively affect accuracy (Bayios et al., 2001).

Relating to psychomotor indices, there are many studies that correlate throwing accuracy with kinesthesis and self-efficacy in various sports (Chase et al., 1994; Helper & Chase, 2008; Miller & McAuley, 1987). Regarding the striking skill, no relationship between accuracy and kinesthesis has been found (Zisi et al., 2003). However, in basketball shots, an important relationship was detected between these parameters and throwing accuracy (Rajeeva & Venkatesh, 2015). Self-efficacy was found to be a predictive parameter of throwing accuracy in basketball as well as in softball (Helper & Chase 2008). Additionally, Chase et al. (1994) found a positive correlation between these factors and throwing in basketball for athletes ranging from 9 to 12 years old. Although the effect of kinesthesis and self-efficacy has been studied in various sports, there is no related research for handball throwing.

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Various studies in the past have investigated the factors that influence the shooting efficacy in handball. The results of Van den Tillaar, R., & Ettema, G. (2009) showed that significant differences in shooting performance (accuracy and ball speed) between the dominant and non-dominant hand. Urban, Gutierrez & Moreno, (2015) noticed relations between motion kinematics, shooting efficacy and ball speed in handball. Researchers Nuno et al., (2016) noticed that shooting efficacy and release speed drops significantly as natural fatigue increases. Hore (1996) noticed a significant correlation between throwing accuracy and the starting point of the throwing wrist. Later, it was noticed that the exact ball release time in different finger directions for various goal points is important (Chowdhary & Challis, 1999; Watts et al., 2004). Recently, it was discovered that in order to have a constant time range of ball release, the central neurological center synchronizes the torque of the wrist and the finger torque with feed-forward adjustments (Shibata et al., 2018). Two recent studies (Crozier et al., 2019; Gromeier et al., 2017) concluded that throwing accuracy is gender independent. Therefore, the purpose of this study was two-fold: (i) to investigate the relationship between overhead throwing accuracy and maturity and anthropometric characteristics, kinesthesis, self-efficacy, and the angular kinematics of the hand; and (ii) to examine the differences in all variables in the study between female and male adolescent handball players.

The hypotheses investigated were (a) that there was a correlation between overhead throwing accuracy and anthropometric characteristics, kinesthesis, self-efficacy, and the angular kinematics of the hand in adolescent handball players; and (b) that there were no differences between female and male adolescent handball players related to the subject variables.

Material & methods

Participants

The participants of this study were 30 handball players (n = 15 females, n = 15 males), aged 14–16 years old (M = 15.1, SD = 0.54). They were free of injury, without any medical problems, and they had taken up handball at least one year before the tests were carried out.

Procedures

All participants took part voluntarily after invitation. Prior to the study, the athletes and their parents were fully informed about the purpose and the procedures of this study. Written parental consent was obtained for each participant and all signed a consent form. The procedure of the study was approved by the Ethical Committee of the School of Physical Education and Sports Science of the National and Kapodistrian University of Athens. Data from each participant were acquired in two meetings. During the first meeting, the anthropometric characteristics of each participant were recorded and they were subsequently tested in terms of their kinesthetic ability. In the second meeting, before the measurement tests, the participants had a warm-up session which included overhead throwing trials. Following that, they answered questions regarding self-efficacy in throwing accuracy and then the main test of throwing accuracy was started.

Anthropometric and maturity indices

The measured parameters of anthropometric data were standing height, sitting height, body mass, arm length, forearm length, hand length, hand width, five skinfold thicknesses (biceps, triceps, subscapular, suprailiac, and calf), three circumferences (calf and biceps girth (relaxed and tensed)), and three breadths (femur, humerus, biacromial). The precise anatomical sites of measurement by the respective somatometric instruments and the measurement procedures were all carried out according to Norton et al. (2000). The sum of four skinfold thicknesses (biceps, triceps, subscapular, suprailiac) was used for the determination of body density which was calculated taking chronological age into consideration (Durnin & Womersley, 1974). Percent body fat (%BF) was estimated using the Siri equation (1956). Body mass index (BMI) and fat free mass were used in this procedure. Somatotype components (endomorphic–mesomorphic–ectomorphic) were calculated according to the equation recommended by Heath and Carter (1990). The components of peak height velocity (PHV) and age peak height velocity (APHV) were calculated according to the equation recommended by Mirwald et al. (2002).

Psychomotor indices

Kinesthetic ability

For the kinesthesis test, a kinesthesiometer (Lafayette Instrument Company; Model 16014) was used. This standardized motor learning tool measures arm movement. An adjustable finger guide and elbow saddle increases examinee comfort while keeping the examinee's arm in position. For the process of assessing the kinesthetic ability of the upper limbs, the subject was placed opposite the examiner with the forearm of the dominant hand on the elbow saddle of the kinesthesiometer, in a 0 degree position. The examinee was wearing a mask so that he could not see. The examiner moved the examinee's hand to a certain point on the arc, e.g., in the 30-degree position, and returned it to the starting point (at 0 degrees). The examinee had to try to repeat the exact same movement, that is, to reach the exact same point that the examiner had previously established. The same procedure was repeated for five points of the arc (e.g. 30, 45, 60, 75, and 85 degrees). The order of the degree placement was not identical for all the examinees. Score: The deviation in degrees from the predetermined target point was recorded.

Self-efficacy

To evaluate the self-efficacy regarding throwing the ball for the needs of the present study, both the level and power of self-efficacy were measured. More specifically, participants were asked: (a) to note the overall score they believed that they would achieve from the sum of the five successful throws in the throw measurement; this was summed to give the examinee a score from 5 to 40 (Level of Self-Efficacy); and (b) to show their degree of confidence that they were capable of achieving this score (Power of Self-Efficacy) on a percentage scale (Not at all sure 0% 10% 20% 30% 40% Somewhat confident 50% 60% 70% 80% 90% 100% Absolutely sure).

Throwing accuracy data collection

The participants had a warm-up session for at least 15 minutes, which included general and stretching exercises. Participants were also given a short period of familiarization with the target, which included only six or seven test throws to minimize the learning outcome within the study (Hopkins, 2000).

In the ball throw test, each examinee took an initial throwing position while sitting in a seat behind a line at a distance of 6 meters from the target (Fig. 1a). The subject was fixed to the seat using a lashing strap in the area under the saber-toothed position, in order to isolate the lower body and involve only the muscles of the chest and upper limbs in the act (Derbyshire, 2007). The initial position for the throw was with the anterior surface of the chest opposite the target, the torso upright, the shoulder at a 90-degree abduction (0-degree when upper extremity is at the side of the torso), and the elbow at a 90-degree flexion (0-degree at full elbow extension) (Fig. 1a). The throwing of the ball (size 2 ball with a circumference of 54-56 centimeters and a weight of 325-375 grams) was done with the dominant hand. The instruction given to the participants was to throw towards the center of the target with the greatest possible accuracy and the throw was considered valid only when it hit the target. Each examinee had five targeted attempts. There was a break of 1 minute between throws (Rousanoglou et al., 2014) to prevent fatigue (Hopkins, 2000) and the most accurate of the five attempts (Rousanoglou et al., 2014; Derbyshire, 2007) was recorded.

The target was a 0.80 cm x 0.80 cm square, from the center of which, eight concentric circles were drawn with a radius of 5, 10, 15, 20, 25, 30, 35, and 40 cm (Fig. 1b). The accuracy followed a declining score (8, 7, 6, 5, 4, 3, 2, 1) with grade 8 corresponding to the 5 cm radius circle and grade 1 to the 40 cm radius circle. The target position was on the side of the throwing hand, specifically, opposite the examinees' eyes3. To obtain the data, the deviation of the ball from the center of the target was recorded using a video camera (HDR-PJ410).

Hand angular kinematics data collection

An inertial sensor (MTx) (Xsens Technologies B.V., NL, sampling at 100 Hz) positioned on the dorsal surface of the hand was used to collect 3D angular kinematics data for the throwing hand. To ensure the positions of the inertial sensor, the participant wore a glove provided by Xsens, which has specific pockets for the sensors (Fig. 1a). The angular kinematics data concerning the x-, y-, and z-axes correspond to the horizontal (roll) (X, pronation and supination of the wrist), vertical (pitch) (Y, flexion and extension of the wrist joint), and lateral (yaw) (Z, ulnar/radial deviation) directions of the tested hand .Data analysis concerned the maximum angular kinematics of the hand for the arm-cocking of the ball and at ball release. The directions of the x-, y-, and z-axes corresponding to the arm-cocking of the ball and at ball release are shown in Fig. 1c and Fig 1.d.

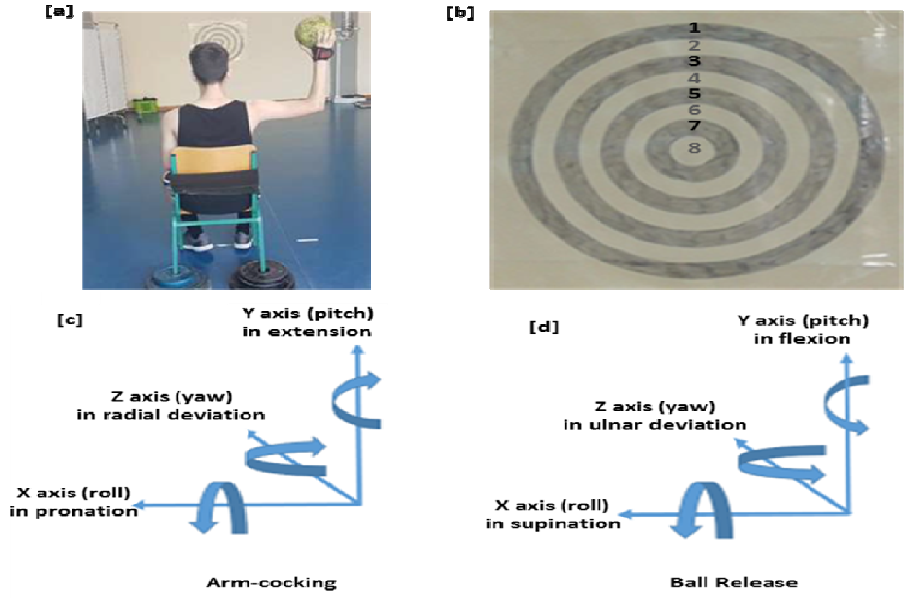

Figure 1. [a] Starting position of the participants [b] the target with the scoring scale and the anatomical correspondence of the roll, pith, yaw axes at the arm-cocking of the ball [c] and the ball release [d]

Statistical Analyses

For the needs of the statistical analysis in this study, SPSS version 23.0 (IBM statistics) was used. For each variable of the dataset, the mean value, the standard deviation, and the coefficient of variation (%) were calculated. The analysis was divided into two parts based on the study hypotheses. The first hypothesis was that there was a correlation between overhead throwing accuracy and anthropometric characteristics, kinesthesis, self-efficacy, and angular kinematics of the hand in adolescent handball players. This hypothesis was analyzed with Pearson's r correlation to examine the correlation between the independent variables (anthropometric characteristics, kinesthesis, self-efficacy, angular kinematics of the hand) and the dependent one (overhead throwing accuracy). The second hypothesis was that there were no differences between female and male adolescent handball players related to the subject variables. One-way ANOVA analysis for independent samples was performed to compare the two genders in terms of overhead throwing accuracy, anthropometric characteristics, kinesthesis, self-efficacy, and angular kinematics of the hand during throwing. The importance level was defined as $p < 0.05$.

Results

The mean values of the target score (accuracy performance) for the female and male groups did not show a statistically significant difference between the two groups.

Correlation between throwing accuracy and performance indices.

Throwing accuracy was significantly correlated with specific maturity indices, anthropometric characteristics, and psychomotor indices, whereas no significant correlation was found between throwing accuracy and the angular kinematics of the hand (Fig. 2). The significant correlations between throwing accuracy and the performance indices were not gender consistent. In specific, throwing accuracy was positively correlated to APHV and chronological age but negatively correlated to ectomorphy and kinesthesis for the females (Fig. 2). With regard to the males, throwing accuracy was positively correlated with APHV, standing height, and sitting height, whereas it was negatively correlated with mesomorphy (Fig. 2).

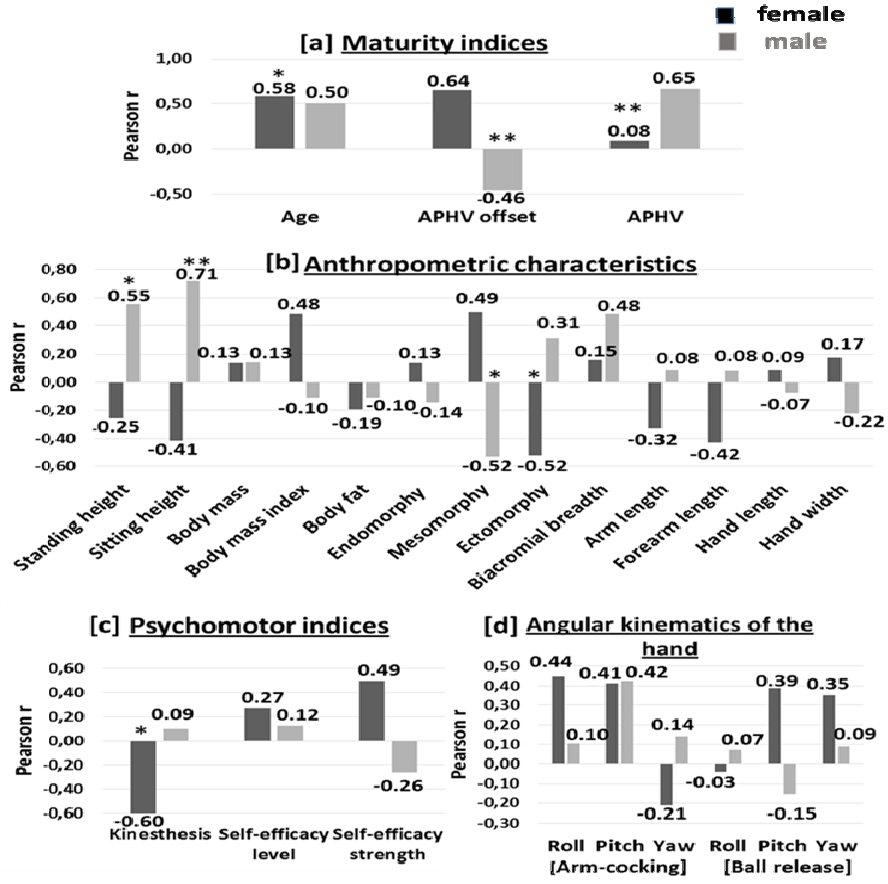

Figure 2. Correlation of throwing accuracy with the maturity indices [a], the anthropometric characteristics [b], the psychomotor indices [c] and angular kinematics of the hand [d].
*significant correlations at p≤ 0.05, ** significant correlations at p≤ 0.01

Gender differences in throwing accuracy and performance indices.

The females had significantly ($p \leq 0.05$) greater chronological age, greater APHV, shorter standing height, lower mesomorphy, lower biacromial breadth, shorter forearm length, and lower hand width than the boys (Table 1). Regarding the psychomotor indices, the females had similar kinesthesis as the males ($p > 0.05$) but lower self-efficacy indices ($p \leq 0.05$) (Table 2). No significant gender difference was found for the angular kinematics of the hand (Table 2).

Table 1. Mean and standard deviation (SD) of throwing accuracy as well as of the maturity indices and anthropometric characteristics

	Female (n = 15)		Male (n = 15)			
	M	SD	M	SD	F	p value
Throwing accuracy (n)	6.13	1.55	5.93	1.27	0.14	0.703
Maturity indices						
Chronological age (years)	15.49	0.99	14.72	0.59	6.63	0.016*
APHV offset (years)	0.97	0.45	1.18	0.81	0.71	0.405
APHV (years)	14.49	0.83	13.53	0.52	14.56	0.001**
Anthropometric characteristics						
Standing height(cm)	164.96	8.26	171.90	5.55	7.28	0.012*
Sitting height(cm)	88.14	3.25	89.74	4.18	1.35	0.252
Body mass (kg)	61.90	7.03	67.10	11.85	2.13	0.154
Body mass index (Kg/m^2)	22.73	1.94	22.60	2.99	0.02	0.884
Body fat (%)	22.32	3.52	24.93	5.18	2.61	1.116
Endomorphy	4.29	0.92	3.40	1.53	3.67	0.065
Mesomorphy	2.21	1.12	3.52	1.13	10.71	0.003*
Ectomorphy	2.00	1.01	2.55	1.24	1.50	0.234
Fat-free body mass (kg)	48.00	5.12	49.91	6.24	0.83	0.362
Biacromial breadth (cm)	40.14	2.22	44.48	2.78	22.34	0.000**
Arm length(cm)	34.48	3.31	36.26	2.08	3.12	0.084
Forearm length (cm)	24.92	1.66	26.28	1.72	4.82	0.037*
Hand length (cm)	18.98	1.56	19.82	0.79	3.51	0.072
Hand width(cm)	20.92	1.16	22.36	1.53	8.37	0.007*

*p ≤ 0.05, **p ≤ 0.001

Table 2. Mean and standard deviation (SD) of the psychomotor indices and angular kinematics of the hand

Variable		Female (n=15)		Male (n=15)			
		Mean	SD	Mean	SD	F	p value
Psychomotor indices							
Kinesthesis (°)		4.72	2.69	5.40	2.53	0.51	0.470
Self-efficacy	Level (n)	30.40	4.20	22.60	7.04	13.54	0.001**
	Strength (%)	0.74	0.09	0.56	0.16	12.38	0.001**
Angular kinematics of the hand							
Arm-cocking	Roll (°)	59.88	10.19	53.88	15.37	1.59	0.214
	Pitch (°)	13.20	13.64	7.11	7.27	2.33	0.137
	Yaw(°)	56.79	26.60	64.46	18.67	0.83	0.363
Ball release	Roll (°)	171.63	27.29	154.98	23.25	3.23	0.086
	Pitch (°)	19.48	23.09	20.94	10.39	0.05	0.821
	Yaw(°)	84.72	28.33	90.88	27.85	0.36	0.553

*p ≤ 0.05, **p ≤ 0.00

Discussion

This study attempted to investigate the relationship between overhead throwing accuracy and the anthropometric and maturity characteristics, kinesthesis, self-efficacy, and the angular kinematics of the hand in adolescent handball players. Furthermore, we tried to detect any differences between the two genders for the subject parameters.

A correlation was detected between overhead throwing accuracy and age for the adolescent females. More specifically, the overhead throwing accuracy was higher for older adolescent female players. However, the same was not true for the adolescent male players (no correlation was detected between the throwing accuracy and age). The improvement in throwing accuracy with age is known in literature (Gromeier, Koester, & Schack, 2017; Grassi, Turci, Shirai & Sforza, 2006). The results of the study revealed that the adolescent female players were more accurate during their APHV, while the male players were more accurate when they were older than their APHV. The outcome was that maturity played an important role in overhead throwing accuracy for both genders, and this is in agreement with the fact that maturity is dominant in talent detection (Fernαndez-Romero et al., 2017; Vaeyens, Lenoir, Williams, & Philippaerts, 2008).

The results of this study do not support the findings of Burton et al. (1992) and Visnapuu and Jürimäe (2008) as regards there being a correlation between the anthropometric characteristics of the hand and throwing accuracy for the participants of the experiment. Significant parameters for overhead throwing accuracy were found, namely, body height and the sitting height of male players. This was in accordance with previous studies (Grassi et al., 2006; Visnapuu & Jürimäe, 2008; 2009; Sibila & Pori, 2009). In the present study, the analyzed data with regard to the relationship between anthropometric characteristics and overhead throwing accuracy were acquired from experiments in which the participants were seated for the purpose of monitoring the correct execution of the action of the throwing hand (Starting position; Arm-cocking; Ball release) to investigate the angular shift of the wrist (palm) (Roll(o), Pitch(o) ,Yaw(o)) in relation to efficacy. The experimental restriction on throwing position may have affected the results relating to the mesomorphy for male players (negatively influencing throwing accuracy), as it is known that the dominant component of somatotype for handball players is mesomorphy (Noutsos et al., 2019).

In the current study, the results did not show any significant relationship between the level or strength of self-efficacy and throwing accuracy for the tested age group (14–16 years old) for either gender. Different conclusions are drawn in other studies where the players were from different age groups, e.g., 18–23 years old and 9–12 years old (Chase et al., 1994). As far as kinesthesis is concerned, the results of this study were contradictory as compared with the literature for other sports (especially for the adolescent female handball players) (Zisi et al., 2003; Rajeeva, & Venkatesh, 2015). As a result of the complexity of the specific psychomotor index, further research is necessary in order to draw a conclusion about the relation between kinesthesis and throwing accuracy.

On the basis of the present study results, the maximum angular kinematics of the hand, measured for the arm-cocking of the ball and at ball release of the throw, do not affect accuracy. From the analysis of the coefficient of variation (%) (CV), the roll, pitch, and yaw axes during the cocking phase and the release phase showed very high values (CV > 10%), which indicates irregularities in the data. It is possible that the angular kinematics of the hand may not affect overhead throwing accuracy in female or male adolescent handball players due to the small range of motion. In order to come to a conclusion regarding the relationship between the kinematics of the hand and throwing accuracy, more kinematic indices have to be studied.

The results of this study show no significant differences between the two genders relating to the angular kinematics of the hand during ball throwing. This was in accordance with the conclusions of the study of Gromeier et al. (2017), in which it is noted that this outcome is expected, as the pattern of kinematic movements is the same. Statistically significant differences between the two genders were detected for the APHV parameter. The mean value for the adolescent females was greater than that of the adolescent males. These values were in accordance with literature, as the APHV was 12/-4 for adolescent females and 14/-4 for adolescent males in the study of Tanner et al. (1975). Significant differences between groups were also detected for the chronological age, body lengths, mesomorphy, and self-efficacy. More specifically, the adolescent males' average values for self-efficacy were higher than those for the adolescent females. The same conclusions were also drawn in the studies of Chase et al. (1994) and Gao et al. (2009).

Conclusion

In throwing accuracy correlations, the following conclusions appear:

1. Correlation was detected between overhead throwing accuracy and the chronological age, for the adolescent female handball players. More specifically, the overhead throwing accuracy was higher for older females. However, the same was not true for the adolescent male players (no correlation between the throwing accuracy with the chronological age of the players was detected for the adolescent males).

2. Maturity had an important role in overhead throwing accuracy for both genders. The adolescent female players were more accurate during their APHV, the adolescent male players were more accurate when they were older than their APHV.

3. The adolescent male handball players who had higher standing and sitting heights were more accurate.

4. The high performance in kinesthetic abilities for the adolescent female handball players was negatively correlated with the overhead throwing accuracy.

5. Concerning the somatotype, the adolescent females were more accurate when the factor of ectomorphy was not dominant. While for the adolescent males, this was the case for the factor of mesomorphy.

6. The arm anthropometric characteristics, the body indexes (body texture indicators), the self-efficacy and the angular displacements of the hand during overhead throwing do not seem to have any correlation with the overhead throwing accuracy for the handball players of 14 to 16 years old.

Based on the present study results regarding the comparison between the two genders, important differences were detected for chronological age, APHV, standing height, mesomorphy, biacromial breadth, forearm length, hand width and self-efficacy. For the rest of the subject parameters, no significant differences were noticed between the two genders.

Conflicts of interest

The authors declare that they have no competing interests.

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