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Differences in Body Fat, Body Mass Index, and Physical Performance of Specific Field Tests in 10-to-12-Year-Old School-Aged Team Handball Players

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Featured Application: This study compared anthropometric and physical fitness characteristics of school-aged handball players. These results may be useful for coaches and trainers, as tests reflect specific characteristics of individual handball playing positions. Consequently, results in herein permit the potential benefits of long-term athletic development as a pathway that could enhance health, fitness, and performance of school-aged team handball players.

Abstract: This study aimed to compare 10-to-12-year-old Qatari male athletes and assess body fat, body mass index, and physical fitness, as well as the difference of these measures between ages. Thirty-five youth handball players volunteered for the investigation and were divided into three groups: 12-year-old players (U12; $n = 12$), 11-year-old players (U11; $n = 11$), 10-year-old players (U10; $n = 12$). Anthropometry was assessed by body mass, body fat percentage (%BF), and body mass index (BMI). Measurements included the Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1), jumping ability (squat and countermovement jumps (SJ and CMJ, respectively)), and sprint tests (10 and 15 m). The power of the upper extremity was measured by a 2-kg overhead medicine ball throw for distance. Except for %BF ($p = 0.387$) and BMI ($p = 0.070$), all anthropometric and demographic parameters were different between age groups. The largest differences were found for body mass ($p = 0.007$) and body height ($p = 0.008$). Regarding fitness parameters, only the medicine ball throw ($p = 0.022$) was different between age groups (U10 vs. U12: $p = 0.009$; U11 vs. U12: $p = 0.048$). There was no difference between groups for jumping (CMJ: $p = 0.586$; SJ: $p = 0.377$), sprinting (10 m: $p = 0.211$; 15 m: $p = 0.194$) and Yo-Yo IR1 ($p = 0.228$). Body fat was the anthropometric parameter with the strongest relationship with physical performance in that lower body fat was related to superior jumping performance and sprint performance. In conclusion, except for %BF and BMI, all anthropometric parameters were different between U10, U11, and U12 handball players. For physical parameters, jumping, sprinting, and endurance performance were not different between age groups. From a practical perspective, coaches can use these findings as reference for the evaluation of their school-aged handball players, as well as for establishing performance goals.

1. Introduction

Team handball is classified as a contact sport with brief high-intensity demands of anaerobic and aerobic fitness [1–4]. Previous handball studies have reported that in addition to technical and tactical skills, anthropometric characteristics and high levels of muscle strength, power, and throwing ball velocity constitute the determining factors for handball performance [5–7].

Many anthropometric and physical fitness differences exist among playing positions [8,9]. In general, handball players show higher basic anthropometrics measures, higher longitudinal and transverse dimensions of the upper limbs, and more muscle mass and fat tissue [1]. Stature and body mass are different between players from different levels of performance and age groups, with elite players demonstrating preferable values [1,2,10]. However, Fieseler et al. [6] reported that backs, pivots, and goalkeepers present greater body mass segments than wings, who are the shortest players and have the lowest body mass.

Despite the dominance of aerobic metabolism in handball, the sport is interspersed with high intensity activities like jumps, throws, changes of direction, and stops that utilize anaerobic metabolism [8,9]. The load imposed on players is determined mostly by the demands of the game. Regarding physical attributes to cope with such a load, backs and wings were found to display the best performances in the standing long jump, 30 m sprint, and shuttle run test, whilst pivots were found to achieve the greatest ball throwing velocity [11].

Profiling can be a valuable means of identifying talent, strengths, and weaknesses, assigning player's positions, category level, and aiding the optimal design of physical fitness programs [12,13]. In this context, several studies have reported differences between age groups, playing positions, and categories for various physical, physiological, and anthropometric variables [11–14]. Therefore, physical and anthropometric parameters, as well as motor testing, have been identified as fundamental to partially predict performance status [1–5]. Some previous studies have proposed specific performance measures that may be useful [12–14]. For example, one study demonstrated that body composition may influence game performance, and, specifically, a larger hand size or greater handgrip strength could create greater ball control, and a larger wingspan may create a higher occupation of space in defensive and offensive actions [8]. Granados et al. [15] showed that a greater lean mass resulted in a superior performance, likely due to the associated increased muscular power and strength. Conversely, Srhoj et al. [16], evaluated different basic motor skills as decisive performance factors, showing that fine motor skills in the upper limbs could be essential for handball performance. In addition, these authors reported that in top-quality team-handball, it is recommendable to select players whose morphological profiles are compatible with position-specific game demands. There have been few studies that to collectively evaluate the physical fitness, anthropometric profile, and muscular power in school-aged team handball players, despite calls for this research [1–3,8,16].

The potential benefits of sport for child athletes extend beyond the mere practice of sport [17]. Children who take part in learning-based sports activities, i.e., activities tailored to their learning needs, will develop better motor, situational, psychological, and social skills than children who take part in activities largely focused on results [17]. In addition, results-based sporting activities may even have a detrimental outcome on the overall learning process [18]. Similarly, expert performance research has found that practice tasks with well-defined goals and sufficient opportunities for repetition and feedback were uniformly associated with optimal improvement. Tasks with the primary goal of improving some aspect of performance have been termed 'deliberate practice' [19].

The paucity of research concerning the physical fitness, anthropometric profile, and muscular power in team handball players is even more pronounced among school-aged team handball players [11, 14]. In fact, no previous studies have investigated the physical fitness and anthropometric variables of

youth players. Though some studies have analyzed physiological characteristics of handball players, little information concerning the physical performance (e.g., jumping, muscle power, sprint ability, and aerobic capacity) and anthropometric characteristics (e.g., body mass, body fat, and body mass index) of youth handball players is available. Identifying and comparing fitness profiles could be important for the optimal construction of training regimens to improve handball performance and in the orthopedic care of these players. Moreover, we feel it is valuable to generate reference data concerning youth handball players for future comparisons and talent identification. Consequently, such profiles may provide benefits in long-term athletic development as a pathway that could enhance the health, fitness, and performance of child handball players. As such, the purpose of this study was to examine anthropometry and physical fitness of 10-to-12-year-old Qatari male handball players. We hypothesized a priori that anthropometric characteristics, sprinting, muscle power, jumping, and aerobic performance would be different between school-aged team handball players of different ages.

2. Materials and Methods

2.1. Subjects

Thirty-five youth male handball players from the same team volunteered to participate in the study and were divided into three groups in which they competed, determined by chronological age according to the Handball Federation rules. The first group comprised ten-year-olds (U10; $n = 12$): age: 10.4 ± 0.22 years; body mass: 44.7 ± 8.2 kg; height: 1.44 ± 0.06 m; and body fat: $24.6 \pm 7.2\%$. The second group comprised eleven-year-olds (U11; $n = 11$): age: 11.4 ± 0.2 years; body mass: 49.2 ± 16.8 kg; height: 1.46 ± 0.10 m; and body fat: $28.7 \pm 9.1\%$. Finally, the third group comprised twelve-year-olds (U12; $n = 12$): age: 12.3 ± 0.2 years; body mass: 71.6 ± 25.3 kg; height: 1.57 ± 0.11 m; and body fat: $23.5 \pm 6.63\%$. The inclusion criteria were (1) aged between 10 and 12 years old and (2) in good health with no evidence of past or present metabolic or cardiovascular disorder. Participants were excluded if they were currently under any medical treatment. All subjects engaged in the same training sessions, supervised by the two team coaches, from the beginning of the competitive season (September) until the end of the current study (March). Players trained, on average, 3.1 ± 0.3 h/week, and training otherwise consisted of motor skills (60% of session time) and basic team handball techniques through playing games (40% of session time). In addition, all subjects engaged in weekly school physical education sessions that lasted for 40 min and mainly consisted of ball games.

All players were in good health and passed a medical examination before starting their handball season. No musculoskeletal injuries were reported in the four weeks prior to the beginning of the study. Measurements were taken during the competitive phase of the handball season. During this period, the training volume for the players consisted of 4.8 ± 0.1 h/week, which included integrated conditioning exercises in addition to weekend matches, but they did not train between the pre-test and post-24 h tests. Prior to the study, all players and parents were informed about the potential risks and benefits associated with participation. All players and their parents/guardians signed informed consent forms. Participants were fully familiarized with the procedures, and they were informed that they could withdraw from the study at any time without penalty. This study was approved by the national university institutional review board (Approval Number: QU-IRB 1163-EA/19) for human subjects and complied with the requirements of the Declaration of Helsinki.

2.2. Procedures and Evaluations

The investigation was completed during an in-season period, from November to December 2019. Test measurements were performed on a regular indoor handball court, at the same time of day (from 17:30 h to 19:30 h), under similar experimental and environmental conditions (temperature of 20.5 ± 0.5 °C and relative humidity of $60 \pm 5\%$), and at least 3 days after a competition. Participants were advised to maintain their normal dietary habits while refraining from drinking high calorie beverages or eating for 4 and 2 h before testing, respectively. They were also asked not to perform

any vigorous physical activity for 24 h before the initial testing. Tests were performed over a period of four days in a fixed order to elicit similar fatigue effects between players. On the first day, anthropometric measurements were followed by vertical jump tests (squat jump and countermovement jump (SJ and CMJ, respectively)). The second day was devoted to sprint performance. On the third day, medicine ball throws were evaluated, followed by the Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1) on the fourth day.

Two weeks after the initial testing period, fitness tests from days 1 to 4 were repeated (i.e., SJ, CMJ, sprints, Yo-Yo IR1, and medicine ball throw) to allow for the assessment of between-day test–retest reliability (Table 1).

Table 1. Intraclass correlation coefficient (ICC) and coefficient of variation (CV) for performance measures. Data were collected two weeks apart and thus represent between-day reliability. CI: confidence interval; SJ = squat jump; CMJ = countermovement jump.

	ICC (95% CI)	CV (95% CI) [%]
SJ (cm)	1.00 (0.96–1.00)	1.5 (1.2–2.3)
CMJ (cm)	0.99 (0.96–1.00)	1.5 (1.1–2.2)
Sprint 10 m (s)	0.97 (0.94–0.99)	5.5 (4.3–8.5)
Sprint 15 m (s)	0.97 (0.94–0.98)	2.1 (1.6–3.1)
Medicine Ball Throw (m)	0.99 (0.96–1.00)	1.2 (0.9–1.8)

Based on the intraclass correlation coefficient (ICC) and coefficient of variation (CV) analyses, all tests showed an excellent test–retest reliability.

The scores of the second set of tests were considered for analyses. Anthropometric assessments and the Yo-Yo IR1 test were only completed once at the initial testing period for convenience reasons related to time and players' schedules.

2.2.1. Day 1—Anthropometry and Squat (SJ) and Counter Movement Jump (CMJ) Tests

Anthropometric assessments were completed once at the initial testing period for convenience related to time and players' schedules. Body mass and height were measured by using a portable digital scale with Tanita Body Fat Analyzer (model TBF 105; Tanita Corporation of America, Inc, Arlington Heights, IL, USA). Body mass was measured with light clothes and without shoes. Height was measured without shoes. The precision of body mass and height measurement was to the nearest 0.1 kg and 0.1 cm, respectively. Body mass index (BMI) was calculated as body mass divided by the square of their height (kg/m^2).

Skinfold thickness was measured to the nearest mm, except for low values (usually 5 mm or less), when it was taken to the nearest 0.5 mm. These readings were made at four sites on all subjects, at the biceps, triceps, subscapular, and supra-iliac areas. These were conducted on the right side of the body with the subject standing in a relaxed condition, although no statistical difference between measurements on either side of the body have been found [20]. Skinfold thickness was determined using a Harpenden caliper (Baty International, Burgess Hill, Sussex, UK). Duplicate readings were taken at each site, and the average of the two was recorded. If the two readings differed by more than 2 mm, a third reading was conducted and the closest two were averaged. The sum of the four skinfold measurements was used as an estimate of body fat according to the sex- and age-specific equation [20], as previously reported in young athletes [21]:

$$\% \text{ Body fat} = (4.95/(\text{Density} - 4.5)) \times 100$$

where Density = 1.162 − 0.063 (LOG sum of 4 skinfolds).

The SJ and CMJ variables (jump height) were determined using photoelectronic cells (Optojump Next, Microgate, Italy), as described by Glatthorn et al. [22]. Jump heights were measured from the

recorded contact and the flight time of vertical jumps with a frequency of 1 kHz. The SJ began with subjects' knees at 90°, avoiding any downward movement. Subjects then performed a vertical jump with their arms akimbo by pushing upwards with their legs. After first being instructed to jump as fast and high as possible, the CMJ began from an upright position, with players making a rapid downward movement to a knee angle of ~90° with their hands on their hips and hereafter beginning to push-off. Both tests were performed without an arm swing by keeping the hands fixed at the level of the pelvis and with knees and ankles extended at take-off and landing. The best performance of four jumps was recorded for each test, and a 30 s recovery was given between each trial.

2.2.2. Day 2—Sprint Tests

Prior to sprint testing, each subject performed a 5 min warm up consisting of 3 min of running, change of direction activities, and dynamic stretching. Subjects sprinted 15 m from a standing position, with their front foot 0.2-m behind the starting photocell beam. Times at 10 and 15 m were recorded by paired photocells (PHOTOCELLS (Kit Racetime2 SF)) that were located ~1 m above the ground at the start and finish lines. The height of the photocells was adjusted in accordance with the height of the participant's hip. Three trials were separated by 6–8 min of recovery, with the fastest time being used in analysis.

2.2.3. Day 3—Medicine Ball Overhead Throw

Subjects held a 2-kg medicine ball in both hands in front of the body with their arms relaxed. The standing player grasped the medicine ball with both hands, and, on the given signal, forcefully threw the ball over their head backwards. The score was measured from the front of the standing line to the place where the ball landed. The medicine ball was lightly covered with chalk powder (magnesium carbonate) to absorb sweat and to ensure a firm grip on the ball. The talc also marked the floor where the ball landed, allowing for a precise measurement of the throwing distance. Four trials were performed with a 1-min rest between each trial, and distance was recorded to the closest cm. The best of four throws was subsequently used for analysis.

2.2.4. Day 4—Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1)

To assess intermittent endurance performance, the players completed the Yo-Yo IR1, which was performed as described by Krustrup et al. [23]. A standardized warm up comprised of 5 min of low-intensity running was followed by the test, in which 20 m shuttle runs were performed at increasing velocity until exhaustion, with 10 s intervals of active recovery (2 × 5 m of jogging) between runs. The test was concluded when the participant twice failed to reach the front line in time (objective evaluation) or felt unable to complete another shuttle at the required speed (subjective evaluation). The total distance covered was considered as the test score. Subjects were familiarized with the test using at least one trial. The reliability of the Yo-Yo IR1 has been established with CV of 3.6% and an ICC of 0.94 [23].

2.3. Statistical Analyses

All variables were tested for normal distribution (Shapiro–Wilk Test) and the assumption of variance homogeneity (Levene's Test for equality of variances). Descriptive statistics (median, mean, standard deviation (SD), minimum, maximum, and 95% confidence intervals (95% CI)) were ascertained for all variables. The mean differences of anthropometric and performance parameters between (adjacent) age groups (U10 vs. U11 vs. U12) were tested using the Kruskal–Wallis H test and the Mann–Whitney U test for post-hoc testing, because data were not normally distributed. Pearson's product moment correlations determined relationships between anthropometric (independent variables) and performance parameters (dependent variables). The criteria adopted for interpreting the magnitude of correlations (r) between measures were: <0.1: trivial; 0.1–0.3: small; 0.3–0.5: moderate; 0.5–0.7: large; 0.7–0.9: very large; and 0.9–1.0: almost perfect [24]. A power calculation (nQuery Advisor 4.0; Statistical

Solutions, Saugus, MA, USA) showed that with a sample size of 7 in each group, the study had 80% power to detect a difference between means of 3.0 cm (main outcome: CMJ height) using a two-sided *t*-test with a significance level of $p < 0.05$ while assuming a common standard deviation of 2.0 cm [25]. All statistical analyses were performed using SPSS version 25.0 for Windows (IBM, Armonk, NY, USA).

3. Results

3.1. Normal Distribution and Variance Homogeneity

Only the variables body height ($p = 0.882$), body fat ($p = 0.603$), and CMJ ($p = 0.812$) were normally distributed. One parameter (body mass: $p = 0.012$) did not have variance homogeneity. Therefore, we calculated the median and arithmetic means in order to allow for a comparison of the presented results as means ± standard deviations (Tables 2–4) with other studies. Moreover, nonparametric tests (the Kruskal–Wallis H test and the Mann–Whitney U test) were used to evaluate parameter differences depending on age.

Table 2. Demographic and anthropometric characteristics in relation to age groups. Bold font denotes $p < 0.05$.

	Body Height (m)	Body Mass (kg)	BMI (kg/m^2)	Body Fat (%)
	Median **Mean ± SD** **(95% CI)**	**Median** **Mean ± SD** **(95% CI)**	**Median** **Mean ± SD** **(95% CI)**	**Median** **Mean ± SD** **(95% CI)**
U10 ($n = 12$)	1.45 1.44 ± 0.06 (1.39–1.50)	45.0 44.7 ± 8.2 (34.0–55.4)	21.8 21.3 ± 3.1 (17.4–25.2)	26.6 24.6 ± 7.2 (20.1–29.2)
U11 ($n = 11$)	1.44 1.46 ± 0.10 (1.40–1.51)	44.0 49.2 ± 16.8 (38.0–60.4)	22.8 22.7 ± 5.7 (18.7–26.8)	26.5 28.7 ± 9.1 (24.0–33.5)
U12 ($n = 12$)	1.57 1.57 ± 0.11 (1.52–1.62)	71.0 71.6 ± 25.3 (60.8–82.3)	27.0 28.8 ± 9.4 (25.0–32.7)	22.6 23.5 ± 6.6 (19.0–28.0)
Kruskal–Wallis (p)	**$p = 0.008$**	**$p = 0.007$**	$p = 0.070$	$p = 0.387$
Significant Differences between Adjacent Age Groups (p)	U11/U12: **$p = 0.013$**	U11/U12: **$p = 0.025$**		-

BMI—body mass index.

Table 3. Jumping and sprinting performance in relation to age groups.

	Jumping Performance (cm)		Sprinting Performance (s)	
	CMJ	**SJ**	**10 m**	**15 m**
	Median **Mean ± SD** **(95% CI)**	**Median** **Mean ± SD** **(95% CI)**	**Median** **Mean ± SD** **(95% CI)**	**Median** **Mean ± SD** **(95% CI)**
U10 ($n = 12$)	21.9 21.6 ± 3.03 (20.0–23.1)	16.8 16.6 ± 3.58 (14.3–18.9)	2.74 2.59 ± 0.54 (2.30–2.88)	3.85 3.63 ± 0.53 (4.44–7.05)
U11 ($n = 11$)	23.0 21.8 ± 2.92 (20.2–23.5)	18.1 18.3 ± 4.43 (15.9–20.7)	2.32 2.35 ± 0.42 (2.05–2.66)	3.33 3.43 ± 0.46 (3.76–5.60)
U12 ($n = 12$)	22.3 22.6 ± 2.05 (21.0–24.2)	18.5 19.2 ± 3.73 (16.9–21.5)	3.00 2.77 ± 0.52 (2.48–3.07)	3.99 3.82 ± 0.46 (3.76–5.60)
Kruskal–Wallis (p)	$p = 0.586$	$p = 0.377$	$p = 0.211$	$p = 0.194$
Significant Differences between Adjacent Age Groups (p)	-	-	-	-

CMJ—countermovement jump; SJ—squat jump.

Table 4. Aerobic capacity measuring in the Yo-Yo IR1 and medicine ball throw in relation to age groups. Bold font denotes $p < 0.05$.

	Aerobic Capacity	Throwing Performance
	Yo-Yo IR 1 (m)	Medicine Ball Throw (m)
	Median Mean ± SD (95% CI)	Median Mean ± SD (95% CI)
U10 (*n* = 12)	400 433 ± 268 (239–628)	4.50 4.48 ± 0.64 (4.03–4.93)
U11 (*n* = 11)	560 596 ± 387 (394–799)	4.70 4.76 ± 0.55 (4.29–5.23)
U12 (*n* = 12)	560 613 ± 331 (419–808)	5.45 5.49 ± 1.01 (5.04–5.94)
Kruskal–Wallis (*p*)	$p = 0.228$	**$p = 0.022$**
Significant Differences between Adjacent Age Groups (*p*)	-	**U11/U12: $p = 0.048$**

Yo-Yo IR1—Yo-Yo Intermittent Recovery Test Level 1.

3.2. Anthropometric Data

The anthropometrics of each age group are presented in Table 2. Except for body fat ($p = 0.387$) and BMI ($p = 0.070$), all anthropometric parameters displayed differences between age groups at the $p < 0.05$ level (Table 2). The largest differences were found for body mass ($p = 0.007$) and body height ($p = 0.008$). For anthropometric data, no differences were detected between U10 and U11. When comparing U11 and U12, only body height ($p = 0.013$) and body mass ($p = 0.025$) were significantly different.

3.3. Physical Fitness Data

The peak sprint performance in U11 is worth noting (Table 3). For this parameter, the U11 players were faster than the players in the U10 and U12 (Table 3). Surprisingly, U12 athletes showed the slowest sprint performance.

There was no effect of group for jump (Table 4) or Yo-Yo IR1 performance (Table 4). However, U12 athletes threw the medicine ball further than U11 athletes ($p = 0.048$; Table 4). Otherwise, there were no other pairwise differences between adjacent age groups.

3.4. Relationships between Anthropometric and Physical Fitness Data

Correlations of practical value were found between anthropometric and physical fitness parameters (Table 5). The most prevalent and largest relevant relationships were detected for body fat and performance parameters. Sprint performance was highly correlated with body fat independent of age. The correlation coefficients ranged from r = −0.565 (U12, sprint 15 m) to r = −0.849 (U11, sprint 10 m). The largest correlation coefficient was calculated for U11 and the parameters of body fat and CMJ (r = −0.919). The medicine ball throw was the performance parameter with the fewest correlations concerning anthropometric variables. Only body fat (U11) showed a relevant relationship (r = −0.584) to the medicine ball throw. BMI had the least relevant correlations with physical fitness parameters. Only two relevant correlations were found (U10, CMJ: r = −0.531; U11, SJ: r = −0.505).

Table 5. Correlation coefficients between anthropometric and physical fitness parameters in relation to age groups. Only relevant correlation coefficients (r ≥ 0.5) are reported.

	r			
	U10	**U11**	**U12**	**Total**
Body Height	SJ (−0.821) CMJ (−0.572)	CMJ (−0.728) Yo-Yo IR1 (−0.552) SJ (−0.522)	15 m sprint (0.733)	-
Body Weight	CMJ (−0.663) SJ (−0.599)	CMJ (−0.582) SJ (−0.577) Yo-Yo IR1 (−0.518)	-	-
BMI	CMJ (−0.531)	SJ (−0.505)	-	-
Body Fat	15 m sprint (−0.790) 10 m sprint (−0.746) Yo-Yo IR1 (−0.506)	CMJ (−0.919) 10 m sprint (−0.849) 15 m sprint (−0.811) Yo-Yo IR1 (−0.720) Medicine ball throw (−0.584)	10 m sprint (−0.815) CMJ (−0.805) SJ (−0.730) 15 m sprint (−0.565)	10 m sprint (−0.797) 15 m sprint (−0.744) CMJ (−0.513)

4. Discussion

The aim of this study was to examine the anthropometry and physical fitness of 10-to-12-year-old Qatari male handball players. The main findings of this study were that except for body fat percentage (%BF), all anthropometric parameters were different between age groups. Past studies have shown that large anthropometric dimensions are advantageous in handball [1,2,5,12–14]. For the physical parameters, jumping, sprinting, and aerobic capacity did not significantly differ between age groups, but we did observe age-related differences in the medicine ball throw.

About half of the subjects in this study (18/35, 51%) were overweight. In contrast, no subject had a %BF value below 6%. %BF ranged from 13 to 43%. That 51% of the youth handball players in this study were classified as overweight is startling, as this is more than within the general population in Qatar [26]. The overweight and obesity prevalence among the players in this study was also higher than the global prevalence of obesity and overweight (18%) reported by the World Health Organization (WHO) in 2016. Recently, Hermassi et al. [1] reported that adolescent handball players from the Qatar handball first league presented a %BF of 27.7 ± 8.67%, which is considered relatively high for young athletic populations. Due to sedentary lifestyles, the number of overweight adolescents in Qatar is increasing whilst physical activity levels and motor skills are declining [1].

Literature concerning youth handball players is scarce, but some studies have compared the height of these athletes from different levels [14,27]. In team-handball, body height is important for throwing in offense or blocking in defense, and high body mass was important during one-on-one actions [28]. Wagner et al. [29] demonstrated that taller team-handball players with greater body mass can achieve a higher jump throwing ball velocity. The reported mean height of the players at the highest level of competition was 1.76 m (mean age: 14.1 years) [14], 1.57 m (U13) [26], and 1.74 m (U14) [30]. In this study, the mean height of the total handball sample was 1.49 m, which differed from values reported in other studies [14,27,30], but these studies investigated different age groups.

A limited number of studies have assessed the anthropometric characteristics of youth and adult male handball players [8,14,27,31]. However, comparisons are difficult because of different age ranges and test procedures. For height and body mass, handball players appear to be between volleyball players on the one hand and soccer and field hockey players on the other. Nevertheless, the occurrence of being overweight in our study was unexpected given the average BMI of elite adult handball players. Of our young handball players, 34% (*n* = 13) showed a BMI > 25 kg/m^2 and 11% (*n* = 5) > 30 kg/m^2. Additionally, the BMI of players participating in our study was 24.3 ± 7.22 kg/m^2, which was similar to values reported by other studies [32,33]. Consequently, the current values of BMI found in our players should not be attributed to sport-specific physiological adaptations. It is unlikely that the high BMI in our study was due to a healthy increase in muscle mass alone, and it might not be without health consequences. The prevalence of being overweight in our sample warrants further investigation to

determine the consequences of excessive weight in young handball players and to develop exercise interventions targeting weight management. Increasing competitive levels in older handball athletes typically comes with a reduction in body fat and body mass. However, a concern of coaches is to ensure that any decreases in body mass and body fat occur without a concomitant decrease in lean mass.

Sprint performance did not significantly differ between age groups. However, sprint velocity for short distances and the ability to accelerate and decelerate with and without change of directions are fundamental in team handball. In many game situations, such as during a fast break or while returning to defense after a lost ball, players sprint for about 10–30 m [13]. Players are required to cover distances with maximal speed from the phase of attack to the phase of defense after a lost ball or to prevent a fast break. The average difference between age groups ranged from 6% (U10 to U11; 15 m sprint) to 18% (U11 to U12; 10 m sprint). The 15 m sprint times in the present study were 3.82, 3.43, and 3.63 s for the U12, U11, and U10, respectively. Zapartidis et al. [11] described that in young male handball players aged 14.3 years, backs and wings displayed the best 30 m sprint performances. However, all players in the current study showed similar sprint times to those of similar ages on the Greek national team [11]. Researchers who have compared elite to sub-elite players or elite to amateur handball players have reported differences in sprinting ability [30].

In our study, jump performance was similar between age groups. The average difference between age groups ranged from 1% (U10 to U11; CMJ) to 10% (U10 to U11; SJ). Our results support previous research that described mean values for sub-elite male and female players [30] since handball is a contact sport where jumping, hitting, blocking, and pushing are common, thus making strength a necessity to perform at the highest level in youth and adult team handball [1–3]. Significant differences regarding the parameters of body height, body mass, and throwing performance were only found in comparison with the U12 group of handball players. In previous research, elite players were reported to perform, on average, 8.2% better on the CMJ and 8.4% better on the five-jump test compared with the non-elite players over a three-year period [13]. In this age group, a small difference in maturation may imply a substantial difference in body height and weight (mass), associated with a considerable difference in performance [34]. This finding is supported by the fact that during pre-puberty, before the growth spurt, there are small within-group differences in anthropometrics [35]. However, the growth spurt is preceded by a rapid increase in body fatness, also known as the 'pre-pubertal fat wave' [36], and a rapid increase in fat free mass can subsequently be observed, particularly in boys [37]. However, a high variability in the timing of biological maturation can be observed between individuals of the same sex, resulting in early and late maturers [36,37].

Handball players should be able to perform repeated high-intensity actions, and well-developed intermittent aerobic fitness is considered an important determinant for handball players at the elite level [27]. In the current study, Yo-Yo IR1 performance was similar between groups, although large variations existed within groups, which may have resulted in differences not reaching the $p < 0.05$ level. The difference in Yo-Yo IR 1 performance between age groups differed from 3% (U11 to U12) to 38% (U10 to U11). Significantly better performance (11%) for an endurance shuttle run was found by Mohamed et al. [38] in elite U16 handball players but not within our sample. The results of the current study confirm that intermittent aerobic fitness should be well-developed in youth handball players in order to maintain intermittent efforts during games [27]. Unfortunately, to the best of the authors' knowledge, no information is available in the international scientific literature regarding Yo-Yo IR1 test performance in youth, male team handball players. In addition to competitive level and gender, differences in Yo-Yo IR1 performance may also be dependent on the period of the competitive season when the test is performed.

For throwing performance, the average difference between groups was 6% (U10 to U11) and 15% (U11 to U12). Team handball is characterized by explosive actions performed at high velocities; therefore, success in competition depends on the well-developed muscular power of the upper and lower limbs [39,40]. The higher values of maximum power and strength of the upper limbs provide a clear advantage for maintaining repeated muscle contractions during an entire match. Because

strength and power are thought to be important for throwing velocity, the medicine ball throw is an optimal test/movement to predict the power of upper limbs in handball players. These findings provide information for the assessment and evaluation of player performance, and they may help to develop and optimize positional training regimes. These findings may also be beneficial in the prevention, evaluation, and treatment of injuries commonly sustained by handball players.

In the present study, body fat was negatively associated with all performance variables with the exception of sprint performance. We observed that a lower body fat was negatively associated with sprint performance. In contrast to body fat, the BMI was not found to be associated with performance parameters (15 vs. 2 relevant correlation coefficients). Interestingly, in contrast to the U10 and U11 groups, a large body height led to a relevant reduction of 15 m sprint performance in the U12 group. This could have been a result of the growth process in conjunction with a temporary reduction of the coordination of the lower and upper limbs.

The main limitation of the present study was its cross-sectional design and that sexual maturation was not considered. A previous study indicated that maturation status explains a small part of the variance in aerobic fitness independent of %BF [41]. We believe this increased the variability within our sample, as demonstrated by the large SDs and 95% CIs in anthropometry measures. To rectify this limitation, an increased sample size or maturation status may add additional insight in future investigations. Thus, future studies should include an assessment of sexual maturation when examining the relationship between anthropometry and physical performance in youth. Since the design of this study was cross-sectional, it was hard to investigate causality in the studied relationships. Finally, it would be advantageous for further studies to include laboratory tests of fitness relative to the studied population, rather than field tests. However, further profiling studies of elite youth male and female handball players are necessary in order to establish reference data.

5. Conclusions

These results may be useful for coaches and trainers, as they were based on tests that reflect the specific characteristics of individual handball playing positions. The findings of the current study may assist in identifying performance capabilities and player development based on a child's anthropometric measurements and fitness records.

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