Article

Morphological and Physical Performance-Related Characteristics of Elite Male Handball Players: The Influence of Age and Playing Position

Uros Mohoric 1, Ensar Abazovic 2 and Armin H. Paravlic 3,4,5,*

1 Handball Federation of Slovenia, 1000 Ljubljana, Slovenia
2 Faculty of Sport and Physical Education, University of Sarajevo, 71000 Sarajevo, Bosnia and Herzegovina
3 Institute of Kinesiology, Faculty of Sport, University of Ljubljana, 1000 Ljubljana, Slovenia
4 Institute for Kinesiology Research, Science and Research Centre Koper, 6000 Koper, Slovenia
5 Faculty of Sports Studies, Masaryk University, 625 00 Brno, Czech Republic
* Correspondence: armin.paravlic@fsp.uni-lj.si

Abstract: The aim of the present study was to describe the morphological and performance characteristics of elite handball players using data collected over the last two decades within the talent evaluation program of the Slovenian Handball Federation. A total of 1066 elite male handball players selected for one of the Slovenian national teams (U17, U19, U21 or senior) were recruited. The data were collected from 2007/8 to the 2021/22 season. The main effects were observed for: body height, body weight, and body mass index (BMI). The muscle mass percentage differed only between different age categories ($p = 0.003; \eta^2 = 0.015$), while the fat mass percentage (FM%) differed between playing positions ($p < 0.001; \eta^2 = 0.107$). Post-hoc comparisons showed that, within senior handball players, pivot players were 6.46 cm ($p = 0.009$) taller than wing players and heavier than goalkeepers (12.43 kg, $p = 0.004$), backcourts (13.30 kg, $p < 0.001$) and wings (17.83 kg, $p < 0.001$). Moreover, pivots had a greater BMI than goalkeepers (2.3 kg/m$^2$, $p = 0.003$), backcourts (2.62 kg/m$^2$, $p < 0.001$), and wings (3.07 kg/m$^2$, $p < 0.001$), while FM% was significantly higher in pivots compared to wings (4.32%, $p = 0.010$). Taking into consideration playing positions and age, the main effects were also observed for squat jump height, countermovement jump height, end-running speed, and VO$_{2\text{max}}$ (all $p < 0.001; \eta^2 = 0.017$ to 0.091). Both morphological and performance characteristics clearly differ across playing positions and age categories, which should be a valuable guide for coaches to develop position-specific talent identification programs and training plans.

Keywords: talent identification; morphology; running speed; jumping power; fatigue index; repeated sprinting ability; VO$_{2\text{max}}$; aerobic capacity; cardiorespiratory fitness

1. Introduction

Team sports like handball are known for their high-intensity muscle actions such as running, frequent direction changes, jumping, ball throwing, and frequent physical contact between offensive and defensive players. Therefore, a handball player needs to have highly developed aerobic and anaerobic components of physical fitness to sustain 60 min of vigorous play. As is the case in any other team sports played with a ball, handball has several playing positions. Due to the different technical and tactical demands on the court, each playing position has its own physiological characteristics. For example, Büchel and colleagues [1] reported that during 60 min of effective playing time, wingers spent 15 min more time on the court, on average, compared to backcourt and pivot players. Moreover, wingers have been shown to cover 1.200 m more of total distance than backcourt players (2.882 m) or pivots (2.702 m) [1], while having two to three folds greater total sprinting distance during the course of the match [1,2]. These findings agree with the other studies investigating the importance of morphological and performance-related characteristics in
distinguishing between different playing positions [3–9]. Vast amounts of studies have shown that wingers are shorter and have lower body weight and size, while possessing the highest aerobic capacity when compared to goalkeepers, backcourt players or pivots [4,6–8]. These physical and fitness attributes enable them to cover greater running distances on the court than others. In contrast, pivots have been shown to be amongst the tallest, heaviest and slowest players [2,6–8]. However, they are constantly exposed to direct physical contact with the opponents, while often performing high-intensity activities such as jumping and short agility runs compared to wingers [2,6,7].

With the rise in popularity on the global level there is also a growing interest of sports practitioners and scientists to build the systems that will help them to identify talents with the greatest potential to become elite players.

To become an elite handball player, it is vital that, in addition to technical skills and tactical intelligence, one poses the optimal morphological characteristics and performance-related measures, such as highly-developed muscular power, speed, high-intensity running endurance and ball throwing velocity [5,10–12]. For instance, Massuca and colleagues [5] found that top elite handball players were taller, heavier, had greater muscle mass and had less fat mass than non-top elite players. In addition, elite players outperformed non-elite players in terms of speed, strength, power, and aerobic endurance. Although the published literature identified the existence of playing position-related differences in several players’ domains, such as stature, lower limb explosive power, sprinting speed and aerobic endurance, the majority of studies used a mono-dimensional approach to profiling; that is, investigating a single attribute such as physical, physiological, performance-related or skill-specific characteristics of the players. In addition, some studies designed to investigate the attributes of the elite handball players had not considered different playing positions [5], were lacking at reporting the attributes of goalkeepers [13], or reported a small sample size [7,13]. Thus, it is essential to address some methodological shortcomings in the published literature.

Within this purpose, the authors of the current manuscript would like to present data from a talent identification scheme launched by the Slovenian Handball Federation in 2007. The men’s national handball team of Slovenia achieved notable results during this period on the international level. In the most recent ten international competitions, they placed between 3rd and 10th in the World Championships and 4th and 14th place at the European Championships. Nevertheless, their greatest achievement was taking the bronze medal at the World Championship in France in 2017.

The authors of this manuscript therefore aimed to describe the morphological and performance measures of 1066 elite handball players using data collected over the past two decades as part of the Slovenian Handball Federation’s talent identification program. The primary hypothesis is that elite handball players will differ in selected morphological and physical performance-related characteristics, which will be the age and playing position dependent, respectively.

2. Materials and Methods

2.1. Experimental Approach to the Problem

This was a 15 year longitudinal cross-sectional designed study aimed to investigate the morphological and performance profile of male handball players selected from the Slovenian Handball National Association. The data were collected from 2007/8 until the 2021/22 season. Inclusion criteria were defined as follows: active male handball players selected to one of the Slovenian national teams (under 17 [U17], under 19 [U19], under 21 [U21] or seniors), with no history of severe and/or acute neuromuscular injury preventing him to execute any physical movement with the maximal effort without presence of pain. In addition, participants were informed that they should maintain their usual water and food intake and also to refrain from participating in high-intensity activities 48 h before the experiment. All testing procedures were performed following a competition season (June or July), indoors on a standard indoor handball court with a hardwood floor
between 8 a.m. and 12 a.m. and lasted for two days. The ambient temperature ranged between 20 °C and 22 °C.

### 2.2. Participants

1066 elite handball players (mean age: 18.3 ± 2.7 years; height 186.9 ± 6.5 cm; body mass 84.7 ± 11.1 kg; training status 13.2 ± 4.3 years) were recruited for the current study (Table 1). To avoid unnecessary fatigue and acute changes in body fluids, the players were instructed to maintain their usual water and food intake and avoid intense sporting activities 48 h prior the experiment. All of the subjects were informed of the benefits and potential risks of the study and provided written informed consent to participate in the current study. All of the procedures were conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and approved by the Ethics Committee of Faculty of Sport (University of Ljubljana, Ljubljana, Slovenia; ID:535/2016).

| Playing Position | Seniors (n) | U21 (n) | U19 (n) | U17 (n) |
|------------------|-------------|--------|--------|--------|
| Goalkeeper       | 12          | 30     | 50     | 58     |
| Backcourt        | 40          | 80     | 185    | 217    |
| Wing             | 22          | 43     | 86     | 92     |
| Pivot            | 12          | 23     | 46     | 70     |

**Playing experience (years)**

|                        | Seniors | U21     | U19     | U17     |
|------------------------|---------|---------|---------|---------|
| Handball-specific training (times per week) | 8       | 5       | 5       | 5       |
| Strength training (times per week)           | 3       | 1 to 2  | 1 to 2  | 1 to 2  |
| Games played per week on average (n)         | 2       | 2       | 1 to 2  | 1       |

### 2.3. Procedures

The measurements were conducted in the same order as they appear in the following text.

#### 2.3.1. Body Composition Measurements

Body mass and height were measured using a stadiometer and scale anthropometer (GPM, Model 101, Zurich, Switzerland) to the nearest 0.1 cm, while body mass was assessed with multifrequency bioelectrical impedance (InBody 720: Biospace, Tokyo, Japan) to the nearest of 0.05 kg. Additionally, muscle mass percentage (MM%) and fat mass percentage (FM%) were calculated using the manufacturer’s algorithm. The subjects were instructed to follow the manufacturer’s preparation guidelines before the body composition assessment.

#### 2.3.2. Warm-Up Procedure

Before testing, the athletes completed a standard 25 min warm-up routine, consisting of 10 min of self-paced jogging, 10 min of dynamic stretching, and 5 × 30 m of fast running. After the warm-up routine, the athletes conducted the following performance-related measurements:

#### 2.3.3. Sprint and Jumping Performance

A 20 m distance was selected to evaluate sprint performance. The participants performed 2 maximal sprint efforts over the distance of 20 m (with 5 m and 10 m split times) in an indoor sports hall with a 2 min rest period between trials. The fastest trial was used for further analyses. The players were verbally encouraged to sprint as fast as possible during each trial. Sprint times were recorded to 0.4 ms accuracy by photocells (WITTY GATE, Bolzano, Italy).
Jumping performance was evaluated by vertical jump tests, using bilateral force plate (model 9260AA6, Kistler, Winthertur, Switzerland). Before the actual test, a 2–3 warm-up bilateral squat jumps (SJ) and bilateral countermovement jumps (CMJ), with hands placed on the hips, were executed, followed by the actual maximal jump trials. The execution of the test was supervised from the experienced researcher to improve proficiency in jumping technique. Jumps were repeated after a 60 s rest period, until three valid jumps were achieved. In total, a number of trials at each jumping condition ranged between three and five. The jump with the maximal achieved height calculated from take off velocity was taken for further analysis.

2.3.4. Repeated Sprinting Ability

In the repeated sprinting ability (RSA) test, the athletes performed $8 \times 40$ m sprints, starting every 20 s. The sprinting time was measured by two experienced kinesiologists using a hand-held stopwatch Seiko s056 (Seiko Sasaki, Japan). The average time of two assessors was used for further analysis. To calculate the fatigue index (FI), the Fitzmons’ formula was used as follows:

$$FI = 100 \times \left( \frac{\text{total time}}{8 \times \text{best time}} \right) - 100$$

2.3.5. Cardiorespiratory Fitness

Following a repeated sprint ability test, each player had 45 min of rest, on average, after which the aerobic capacity was measured using the field based 30-15IFT test by previously described procedures [14,15]. The 30-15IFT test consisted of 30 s shuttle runs interspersed with 15 s active recovery periods. The running speed was set at 8 km/h for the first 30 s run and increased by 0.5 km/h in each 30 s phase thereafter. The participants were required to run back and forth between two lines, 40 m apart, at the pre-determined pace, guided by a pre-recorded beep sound. The pre-recorded beep allowed the participants to adjust their running speed when they entered a 3 m zone in the middle and at both ends of the testing field. During the 15 s recovery period, the participants walked to the nearest line in the running direction. From this line, they started the next running phase. The participants were instructed to complete as many stages as possible. The test ended when the participants could no longer maintain the required running speed or failed to reach the 3 m zone three consecutive times before the sound signal. The speed of the last successfully completed stage was recorded as the test result; that is, the end-running speed (ERS) [16].

In addition to the ERS, the maximal oxygen uptake ($VO_{2\text{max}}$) and maximal heart rate ($HR_{\text{max}}$) were calculated from the 30-15IFT test.

2.4. Statistical Analysis

The statistical analyses were conducted with the SPSS statistical software (version 27, IBM, USA). All of the data were presented as mean ± SD and 95% of confidence intervals. The normality of data distribution was confirmed by using the Shapiro-Wilk test. The comparison of the morphological and physical performance-related measures between different age categories (Seniors vs. U21 vs. U19 vs. U17) and playing positions (Goalkeeper vs. Backcourts vs. Wings vs. Pivots) was analyzed using a two-factor univariate general linear model. Where significant effects were found for age, playing positions or age*playing positions interactions, pairwise comparisons were used to address these differences for each variable, independently. The effect size for the dependent variables was reported as partial eta-squared. The statistical significance was accepted at $p < 0.05$, if not stated differently in the tables.
3. Results

For the purpose of the current study, a total of 1066 elite male handball players were measured, as shown in Table 1.

Table 2 shows the comparison of the main morphological variables between different playing positions and age categories. Considering both categorical variables, the main effects were observed for: body height, body weight, BMI and BM% (Table 2). The MM% differed only between different age categories ($p = 0.003; \eta^2 = 0.015$), while the FM% differed between playing positions ($p < 0.001; \eta^2 = 0.107$). There were no significant playing position*age categories interactions for any of the variables assessed within this category. Post-hoc comparisons showed that within senior handball players, pivot players were 6.46 cm ($p = 0.009$) taller than wing players, pivots were heavier than goalkeepers (12.43 kg, $p = 0.004$), backcourts (13.30 kg, $p < 0.001$) and wings (17.83 kg, $p < 0.001$). Moreover, pivots had greater BMI than goalkeepers (2.3 kg/m$^2$, $p = 0.003$), backcourts (2.62 kg/m$^2$, $p < 0.001$), and wings (3.07 kg/m$^2$, $p < 0.001$), while the FM% was significantly higher in pivots compared to wings (4.32%, $p = 0.010$) only. There were no other significant morphological differences for senior players.

Table 3 shows the comparison of the main speed and power-related performance measures between different playing positions and age categories. Considering both categorical variables, the main effects were observed for: SJ height and CMJ height (Table 3). Running velocity on 5 m ($p < 0.001; \eta^2 = 0.025$), 10-m ($p < 0.001; \eta^2 = 0.036$), and 20 m ($p = 0.002; \eta^2 = 0.014$) differed only between playing positions, whereas the CMJ/SJ ratio differed for age categories only ($p = 0.008; \eta^2 = 0.012$). There was a significant playing position*age categories interaction for CMJ/SJ ratio ($p = 0.001; \eta^2 = 0.029$).

Table 4 shows the comparison of the main variables derived from 30-15IFT and RSA testing. Considering both categorical variables, the main effects were observed for: ERS and $\text{VO}_{2\text{max}}$ (both $p < 0.001; \eta^2 = 0.025$ to 0.091) (Table 4). The $\text{HR}_{\text{max}}$ differed only between different age categories ($p < 0.001; \eta^2 = 0.028$). In addition, there were no significant playing position*age categories interactions for any variable assessed within this category.
### Table 2. The demographic and morphological profile of elite handball players based on age category and playing position.

| Variables          | Playing Position | Age Categories | Main Effects | Interactions | Differences between Age Categories |
|--------------------|-----------------|----------------|--------------|--------------|-----------------------------------|
|                    |                 | Seniors        | U21          | U19          | U17                               |                                    |
| Age (years)        | Goalkeeper      | 25.3 ± 2.9     | 20.3 ± 0.4   | 18.4 ± 0.5   | 16.2 ± 0.7                        | 0.946; 0.418; 1574.3; *p < 0.001; [0.843] |
|                    | Backcourt       | 25.1 ± 2.9     | 20.3 ± 0.5   | 18.4 ± 0.6   | 16.1 ± 0.7                        | 0.638; 0.765; [0.005]              |
|                    | Wing            | 25.4 ± 2.6     | 20.3 ± 0.5   | 18.3 ± 0.5   | 16.2 ± 0.7                        | [NA]                               |
|                    | Pivot           | 24.7 ± 2.3     | 20.2 ± 0.4   | 18.5 ± 0.5   | 16.1 ± 0.7                        | [NA]                               |
| Body height (cm)   | Goalkeeper      | 190.1 ± 4.1    | 188.7 ± 3.7  | 186.8 ± 5.0  | 185.5 ± 6.3                        | [NA]                               |
|                    | Backcourt       | 190.3 ± 6.1    | 190 ± 5.7    | 189.1 ± 5.8  | 185.3 ± 6.0                        | [NA]                               |
|                    | Wing            | 187.3 ± 4.9    | 184.3 ± 4.3  | 184.1 ± 4.8  | 180.2 ± 5.2                        | [NA]                               |
|                    | Pivot           | 193.7 ± 5.6    | 192.1 ± 6.6  | 190.8 ± 6.8  | 188.3 ± 7.5                        | [NA]                               |
| Body weight (kg)   | Goalkeeper      | 93.4 ± 8.7     | 94 ± 7.2     | 89.4 ± 10.1  | 82.3 ± 9.9                         | [NA]                               |
|                    | Backcourt       | 92.5 ± 8.0     | 89.7 ± 7.6   | 86.7 ± 8.0   | 78.6 ± 8.9                         | [NA]                               |
|                    | Wing            | 88.7 ± 7.1     | 82.7 ± 5.9   | 78.7 ± 6.3   | 72 ± 7.1                           | [NA]                               |
|                    | Pivot           | 105.8 ± 12.0   | 99.3 ± 9.8   | 95.4 ± 9.5   | 90.5 ± 11.6                        | [NA]                               |
| Body mass index (kg/m²) | Goalkeeper   | 25.8 ± 1.8     | 26.4 ± 1.9   | 25.6 ± 2.4   | 23.9 ± 2.5                         | 1.127; 0.341; [0.009]              |
|                    | Backcourt       | 25.5 ± 1.4     | 24.8 ± 1.6   | 24.2 ± 1.9   | 22.9 ± 2.1                         | [NA]                               |
|                    | Wing            | 25.1 ± 1.4     | 24.3 ± 1.4   | 23.2 ± 1.5   | 22.1 ± 1.7                         | [NA]                               |
|                    | Pivot           | 28.1 ± 2.0     | 26.9 ± 2.0   | 26.2 ± 1.8   | 25.5 ± 2.7                         | [NA]                               |
| Muscle mass (%)    | Goalkeeper      | 51.4 ± 2.7     | 51.1 ± 3.4   | 50.5 ± 3.8   | 50.1 ± 3.5                         | 0.452; 0.716; [0.001]              |
|                    | Backcourt       | 50.8 ± 3.3     | 51.5 ± 3.8   | 50.6 ± 3.7   | 51.1 ± 3.4                         | 13.71; 0.249; [0.012]              |
|                    | Wing            | 52.5 ± 3.3     | 51.5 ± 3.8   | 51.1 ± 3.8   | 50.1 ± 3.6                         | [NA]                               |
|                    | Pivot           | 54.2 ± 3.6     | 51.6 ± 3.4   | 49.6 ± 3.7   | 50.1 ± 3.2                         | [NA]                               |
| Fat Mass (%)       | Goalkeeper      | 12.6 ± 2.2     | 15 ± 4.4     | 13.3 ± 4.3   | 13.5 ± 4.5                         | 0.452; 0.716; [0.001]              |
|                    | Backcourt       | 11.9 ± 2.9     | 11.1 ± 2.8   | 10.6 ± 3.1   | 10.4 ± 3.4                         | [NA]                               |
|                    | Wing            | 9.4 ± 2.3      | 9.6 ± 2.4    | 9.2 ± 2.1    | 9.8 ± 3.2                         | [NA]                               |
|                    | Pivot           | 13.7 ± 3.5     | 13.8 ± 3.2   | 13.8 ± 3.7   | 14.2 ± 4.2                         | [NA]                               |

* sig different compared to goalkeepers within the same age category; $ sig different compared to backcourt players within the same age category; # sig different compared to wing players within the same age category; ¥ sig different compared to pivot players within the same age category; bolded values – significant difference was found; p value was accepted at p < 0.0125.
Table 3. The sprinting and power performance profile of elite handball players based on age category and playing position.

| Variables                          | Playing Position | Age Categories | Playing Position | Age Categories | Differences between Age Categories |
|------------------------------------|------------------|----------------|------------------|----------------|-----------------------------------|
|                                    | Seniors          | U21            | U19              | U17            |                                   |
|                                    | Mean      | SD      | Mean      | SD      | Mean      | SD      | Mean      | SD      | F Value; p Value; $\eta^2$ |
| Running velocity on 5 m line (m/s) | Goalkeeper       | 4.56    | 0.22     | 4.57    | 0.23     | 4.53    | 0.29 $\#$ | 4.54    | 0.27     | 8.52; p < 0.001; [0.025] |
|                                    | Backcourt        | 4.60    | 0.22     | 4.70    | 0.27     | 4.70    | 0.25 *    | 4.66    | 0.25     | 2.13; 0.095; [0.006] |
|                                    | Wing             | 4.51    | 0.52     | 4.73    | 0.29     | 4.69    | 0.24 *    | 4.66    | 0.26     | 0.738; 0.674; [0.007] |
|                                    | Pivot            | 4.51    | 0.30     | 4.52    | 0.22     | 4.59    | 0.29     | 4.55    | 0.27     | 0.695; 0.714; [0.005] |
|                                    |                  |                |                  |                |                  |                                    |
| Running velocity on 10 m line (m/s)| Goalkeeper       | 4.10    | 0.26     | 4.15    | 0.41 $\#$ | 4.07    | 0.4 $\#$  | 4.14    | 0.43     | 12.41; p < 0.001; [0.036] |
|                                    | Backcourt        | 4.21    | 0.38     | 4.44    | 0.48 *    | 4.41    | 0.45 *    | 4.34    | 0.45 Y   | 2.26; 0.080; [0.007] |
|                                    | Wing             | 4.14    | 0.74     | 4.52    | 0.48 *    | 4.44    | 0.43 *    | 4.34    | 0.48 Y   | 0.846; 0.574; [0.008] |
|                                    | Pivot            | 4.09    | 0.45     | 4.07    | 0.38 $\#$ | 4.19    | 0.52     | 4.10    | 0.45 $\#$ | 0.649; 0.756; [0.006] |
|                                    |                  |                |                  |                |                  |                                    |
| Running velocity on 20 m line (m/s)| Goalkeeper       | 6.62    | 0.55     | 6.50    | 0.61     | 6.71    | 0.89     | 6.93    | 0.88     | 4.88; 0.002; [0.014] |
|                                    | Backcourt        | 6.75    | 0.72     | 6.92    | 0.74     | 6.84    | 0.73     | 7.15    | 0.91     | 4.30; 0.005; [0.013] |
|                                    | Wing             | 7.02    | 1.04     | 7.04    | 0.72     | 6.90    | 0.66     | 7.13    | 0.86     | 0.695; 0.714; [0.006] |
|                                    | Pivot            | 6.81    | 0.86     | 6.64    | 0.65     | 6.70    | 0.85     | 6.77    | 0.79     | S = U21 = 19 = U17     |
|                                    |                  |                |                  |                |                  |                                    |
| Squat Jump Height (cm)             | Goalkeeper       | 33.80   | 6.21     | 33.92   | 4.61     | 32.56   | 3.78 $\#$ | 31.48   | 5.44     | 10.56; p < 0.001; [0.032] |
|                                    | Backcourt        | 37.70   | 6.16     | 35.35   | 5.31     | 34.42   | 5.33     | 33.42   | 4.75 Y   | 12.21; p < 0.001; [0.036] |
|                                    | Wing             | 36.11   | 5.42     | 36.81   | 5.16     | 35.67   | 4.55 *    | 33.62   | 4.04 Y   | 0.552; 0.837; [0.005] |
|                                    | Pivot            | 32.94   | 5.51     | 33.56   | 4.03     | 32.50   | 4.86 #    | 30.60   | 4.42 $\#$ | S = U21 = U19 = U17   |
|                                    |                  |                |                  |                |                  |                                    |
| Countermovement Jump Height (cm)   | Goalkeeper       | 41.03   | 4.86     | 38.72   | 4.50     | 36.32   | 4.27     | 34.02   | 5.55 $\#$ | 5.49; 0.001; [0.017] |
|                                    | Backcourt        | 40.68   | 5.02     | 38.69   | 5.60     | 37.52   | 5.44     | 36.41   | 5.15 $\#$ | 19.52; p < 0.001; [0.057] |
|                                    | Wing             | 40.22   | 5.68     | 40.27   | 6.33     | 38.76   | 4.52 Y   | 37.01   | 4.50 *    | 0.649; 0.756; [0.006] |
|                                    | Pivot            | 38.27   | 3.59     | 36.29   | 4.30     | 35.65   | 4.99 #    | 33.71   | 5.10 $\#$ | S = U21 = U19 = U17   |
|                                    |                  |                |                  |                |                  |                                    |
| CMJ/SJ ratio                       | Goalkeeper       | 1.15    | 0.10     | 1.15    | 0.13     | 1.12    | 0.08     | 1.09    | 0.12     | 0.839; 0.473; [0.03] |
|                                    | Backcourt        | 1.12    | 0.17     | 1.10    | 0.10     | 1.09    | 0.08     | 1.09    | 0.12     | 3.93; 0.008; [0.012] |
|                                    | Wing             | 1.16    | 0.19     | 1.04    | 0.26     | 1.09    | 0.10     | 1.10    | 0.08     | 3.26; 0.001; [0.029] |
|                                    | Pivot            | 1.16    | 0.10     | 0.99    | 0.34     | 1.10    | 0.11     | 1.11    | 0.12     | S = U21 = U19 = U17   |

* sig different compared to goalkeepers within the same age category; $ sig different compared to backcourt players within the same age category; # sig different compared to wing players within the same age category; Y sig different compared to pivot players within the same age category; bolded values – significant difference was found; p value was accepted at p < 0.0125.
Table 4. The cardiorespiratory fitness profile of elite handball players based on age category and playing position.

| Variables | Playing Position | Seniors | U21 | U19 | U17 | Playing Position | Age Categories | Playing Positions * Age categories | Differences between Age Categories |
|-----------|------------------|---------|-----|-----|-----|------------------|----------------|-----------------------------------|----------------------------------|
| End-running speed (30-15IFT) | Goalkeeper | 18.57 | 1.64 | 19.23 | 1.25 | 18.71 | 1.17 | 18.74 | 1.25 | | 23.8; p < 0.001; [0.069] | | | S = U21 = U19 = U17 |
| | Backcourt | 20.16 | 1.11 | 20.12 | 0.98 | 19.87 | 1.13 | 19.53 | 1.33 | | 8.11; p < 0.001; [0.025] | | | (S = U21 = U19); U21 > U17 |
| | Wing | 20.19 | 0.95 | 20.42 | 1.07 | 20.22 | 1.01 | 19.83 | 1.12 | | 0.510; 0.868; [0.005] | | | S = U21 = U19 = U17 |
| | Pivot | 19.63 | 1.19 | 19.86 | 0.98 | 19.42 | 0.95 | 19.22 | 1.30 | | 0.703; 0.707; [0.006] | | | S = U21 = U19 = U17 |
| VO₂ max (mL/kg/min) | Goalkeeper | 50.81 | 4.22 | 50.47 | 2.82 | 48.66 | 2.67 | 48.16 | 2.79 | | 18.9; p < 0.001; [0.035] | | | (S = U21 = U19); U21 > U17 |
| | Backcourt | 54.16 | 2.73 | 52.44 | 2.33 | 51.21 | 2.46 | 49.87 | 2.76 | | 32.99; p < 0.001; [0.091] | | | (S = U21 > U19 > U17); (S = U21 = U19 = S > U17) |
| | Wing | 54.54 | 2.57 | 52.35 | 7.43 | 52.18 | 2.24 | 50.68 | 2.33 | | 0.703; 0.707; [0.006] | | | (S = U21 = U19 = S > U17) |
| | Pivot | 52.40 | 3.12 | 51.48 | 2.14 | 50.12 | 2.06 | 48.87 | 2.82 | | 0.936; 0.493; [0.011] | | | S = U21 = U19 = U17 |
| HRmax (bpm) | Goalkeeper | 185.00 | 9.83 | 194.15 | 6.41 | 194.85 | 6.84 | 195.08 | 6.67 | | 0.706; 0.548; [0.002] | | | (S = U21; (U21; U19; U17) > S |
| | Backcourt | 189.88 | 10.40 | 192.23 | 9.05 | 194.78 | 10.12 | 196.21 | 9.14 | | 8.50; p < 0.001; [0.028] | | | (S = U21 > U19; S > U17) |
| | Wing | 192.08 | 8.04 | 191.97 | 6.22 | 195.97 | 10.31 | 196.51 | 9.29 | | 0.737; 0.675; [0.008] | | | S = U21 = U19 = U17 |
| | Pivot | 193.25 | 11.39 | 191.77 | 8.43 | 193.76 | 9.00 | 196.49 | 8.43 | | 1.103; 0.347; [0.004] | | | S = U21 = U19 = U17 |
| Fatigue index | Goalkeeper | 5.64 | 4.47 | 4.79 | 1.91 | 4.54 | 2.37 | 5.51 | 2.70 | | 1.093; 0.353; [0.004] | | | S = U21 = U19 = U17 |
| | Backcourt | 4.32 | 1.51 | 4.59 | 2.06 | 4.69 | 1.88 | 5.02 | 2.07 | | 0.936; 0.493; [0.011] | | | S = U21 = U19 = U17 |
| | Wing | 3.76 | 1.60 | 4.67 | 1.78 | 4.72 | 2.01 | 4.95 | 1.95 | | 1.103; 0.347; [0.004] | | | S = U21 = U19 = U17 |

* sig different compared to goalkeepers within the same age category; $ sig different compared to backcourt players within the same age category; # sig different compared to wing players within the same age category; ¥ sig different compared to pivot players within the same age category; bolded values—significant difference was found; p value was accepted at p < 0.0125.
4. Discussion

The present study aimed to provide morphological and performance characteristics of elite handball players taking into consideration different playing positions and age categories. We found that players differed between age categories and playing positions for body height, body weight, BMI and BM%, SJ, CMJ, ERS and VO$_{2\text{max}}$. The MM%, CMJ/SJ ratio and HR$_{\text{max}}$ differed only between different age categories, while FM% and running velocity on 5 m, 10 m, and 20 m differed between playing positions only.

No difference was found between U21 and seniors, whilst U19 differed from them only in body weight and, consequently, BMI. The U17 players’ muscle mass and fat mass percentage has been found to be similar but all other body measures differed significantly from their older counterparts. Our results are in line with previous findings [6,7,13,17–19], showing that anthropometric measurements are characterized by playing positions. Furthermore, these differences were found across the whole sample, regardless of their age. Pivots have been shown to be the tallest and the heaviest in all age categories, supporting previous reports [17–19]. Taking into consideration pivots’ average offence play area, their involvement in low- and high-intensity physical contacts and duels during both offense and defense play [20], their height is very important for greater area coverage, scoring in difficult situations and also for creating scoring opportunities for teammates.

Speed and power-related variables showed somewhat different results from anthropometry comparisons. Running velocity, measured at 5 m and 10 m, did not differ between age categories but differed between playing positions. In contrast, the 20 m sprinting performance showed no difference between playing position, however it differed between U19 and U17 backcourts, showing that U19 players were faster. Similar U17-U19 differences in sprinting performance were observed recently by Gabrys et al. [19], who found a difference between pivots but no other playing position at 5, 10 and 30 m. The jump performance showed playing position differences in the U17 and U19 categories but not in U21 and S, with pivots demonstrating the smallest both SJ and CMJ height in all age categories. Age category differences occurred only when the U17 team was compared to their older counterparts, while no differences were found between U19, U21 and S. These differences were most likely due the maturity [21,22], experience [10] and anthropometric factors (e.g., body height). The eccentric utilization ratio did not differ between subjects, showing a similar stretch-shortening cycle performance throughout all age and playing position categories.

The aerobic capacities were similar for all positions in the S group. The end-running speed achieved in the 30-15$_{\text{IFT}}$ differed between playing positions in U21, U19 and U17, whilst VO$_{2\text{max}}$ differed only in the U19 and U17 group. Goalkeepers and wingers were shown to be the slowest and the fastest players in all three age categories, respectively. Only backcourts differed within the age category, with U21 showing better results than U17. In general, we found higher 30-15$_{\text{IFT}}$ end-running speeds and VO$_{2\text{max}}$ values when compared to previous research including handball players [3,16,23]. The VO$_{2\max}$ values showed to be lowest in the youngest group (U17), with no S, U21 and U19 differences, with the exception of backcourts, where U19 had a smaller VO$_{2\max}$ than S and U21, but larger than U17. Furthermore, the same positional differences were observed for VO$_{2\text{max}}$ in both U19 and U17, with wings showing the highest maximum aerobic capacity. Taking into consideration that wings usually run more than their teammates [20,24,25] and that their repeated-sprint ability is required during most counter-attacks [20], we provided further evidence confirming the previous findings by Schwesig et al. [26]. No HR$_{\text{max}}$ differences were found to be significant between playing positions, but older goalkeepers and backcourts showed lower values than their younger counterparts.

Previous research has shown the importance of morphological dimensions in handball [8]. The data from the current study showed that Slovenian backcourts and pivots were shorter, and wings were higher, than handball players from leading European National teams, such as Denmark, Croatia and Spain [4,27,28], with Denmark being current world champions and European championship second runner-up [29]. Interestingly, the BMI
was lower in all playing positions than those found in Croatian and Danish national team players [4,27], with Spanish pivots having a BMI greater than 30 kg/m². Furthermore, 5 m and 20 m sprint times (Supplementary Tables) were ≈0.2–0.3 s shorter in the Danish [27] and Norwegian [30] national teams, respectively. The CMJ height was, interestingly, higher than that observed in the Norwegian team, but lower than the Danish national team [27,31], and the VO₂max values were lower than those observed in elite Danish handball players, regardless of the playing position [27,31], and Croatian wings [4].

A general absence of differences in the morphological variables between the Senior, U21 and U19 teams (the most of variables assessed) underlines the importance of morphological dimensions after the accelerated growth and development phase. Another indicator is that the majority of the morphological characteristics differ between Senior and U21, on one side, and U17, on the other. Considering all of the morphological differences occurring in all of the measures assessed, the fact that they diminish with increasing age and decreasing the number of selected players, we can hypothesize that scouts could pay more attention to body height, primarily.

The relevance of the players’ capacity to develop a considerable amount of force in a short time is further demonstrated by the lack of significant differences across age groups in power-related factors. In fact, it has been shown that this ability is an important and essential physical component for the majority of in-game specific movements in handball [20,32]. Furthermore, if we compare the values we have obtained with those previously reported for the champion and runner-up teams, it is clear that the better teams tend to have better sprinting and jumping abilities. Therefore, a lack of speed and/or jumping ability should be considered as a limiting factor in the selection process of handball players.

Important findings concerning aerobic capacity can also be derived from the current results. First, we found that the Slovenian national handball team has a lower VO₂max than the better ranked national teams, which means that their aerobic strength and conditioning requires further improvements. Furthermore, if we consider the overall training frequency and intensity (Supplementary Tables), the VO₂max tends to increase, whereas the HRmax decreases with age, suggesting increased training-induced cardiovascular adaptation. In addition, the fact that the differences between playing positions in the U17 and U19 teams tend to decrease with age suggests that these functional capacities should not be considered as limiting factors in the early selection process.

We must acknowledge some limitations in the current study. Although the provided results can be useful to coaches and practitioners working in handball, more younger handball players under the U17 age categories could be included in further studies. This could be of great importance for the selection of handball players from the youngest age. In addition, future studies should aim to identify the same characteristics of elite female players, as the current literature is sparse.

Given the large sample of elite handball players analyzed, the results of the current study can offer useful guidance for talent identification programs, as well as sports-specific and position-specific training concepts.

5. Conclusions

The present study provides the morphological and performance characteristics of elite handball players, considering different playing positions and age categories. Although there are positional and age differences in the players’ body composition and aerobic fitness, scouts and coaches’ primary focus should be on body height and power-related variables. These findings are important to consider when talent identification programs are in question. Both morphological and performance characteristics clearly differ across playing positions and age categories, which should be a valuable reference for coaches to develop position-specific training regimes and to make their training concepts more effective.
Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app122311894/s1, Supplementary Tables.

Author Contributions: Conceptualization, U.M. and A.H.P.; Data curation, U.M.; Formal analysis, U.M., E.A. and A.H.P.; Investigation, U.M.; Methodology, U.M.; Project administration, U.M.; Supervision, A.H.P.; Visualization, U.M.; Writing—original draft, U.M.; Writing—review and editing, E.A. and A.H.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study protocol was reviewed and received full ethical clearance.

Data Availability Statement: All data generated are available within the present manuscript.

Acknowledgments: The authors thank the handball players and coaches for their cooperation and involvement in this study. We would like to thank the Slovenian Handball Federation for their support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Büchel, D.; Jakobsmeier, R.; Döring, M.; Adams, M.; Rücker, U.; Baumeister, J. Effect of playing position and time on-court on activity profiles in german elite team handball. Int. J. Perform. Anal. Sport 2019, 19, 832–844. [CrossRef]
2. Póvoas, S.C.; Ascensão, A.A.; Magalhães, J.; Seabra, A.F.; Krustrup, P.; Soares, J.M.; Rebelo, A.N. Physiological Demands of Elite Team Handball With Special Reference to Playing Position. J. Strength Cond. Res. 2014, 28, 430–442. Available online: https://journals.lww.com/00124278-201402000-00016 (accessed on 20 October 2022). [CrossRef] [PubMed]
3. Mohorič, U.; Šibila, M.; Štrumbelj, B. Positional differences in some physiological parameters obtained by the incremental field endurance test among elite handball players. Kinesiology 2021, 53, 3–11. [CrossRef]
4. Sporiš, G.; Vuleta, D.; Milanović, D. Fitness profiling in handball: Physical and physiological characteristics of elite players. Coll. Antropol. 2010, 34, 1009–1014. [PubMed]
5. Massuça, L.M.; Fragoso, I.; Teles, J. Attributes of top elite team-handball players. J. Strength Cond. Res. 2014, 28, 178–186. [CrossRef]
6. Massuca, L.; Branco, B.; Miarka, B.; Fragoso, I. Physical fitness attributes of team-handball players are related to playing position and performance level. Asian J. Sport Med. 2015, 6, 2–6. [CrossRef]
7. Schwesig, R.; Hermassi, S.; Fieseler, G.; Irlenbusch, L.; Noack, F.; Delank, K.S.; Chelly, M.S. Anthropometric and physical performance characteristics of professional handball players: Influence of playing position. J. Sport Med. Phys. Fitness 2017, 57, 1471–1478. [CrossRef]
8. Ghobadi, H.; Rajabi, H.; Farzad, B.; Bayati, M.; Jeffreys, I. Anthropometry of world-class elite handball players according to the playing position: Reports from men’s handball world championship 2013. J. Hum. Kinet. 2013, 39, 213–220. [CrossRef]
9. Martinez-Rodriguez, A.; Martinez-Olivia, M.; Hernández-García, M.; Rubio-Arias, J.; Sánchez-Sánchez, J.; Sánchez-Sáez, J.A. Body composition characteristics of handball players: Systematic review. Arch. Med. Del. Deport. 2020, 37, 52–61.
10. Hammani, M.; Hermassi, S.; Gaamouri, N.; Aloui, G.; Comfort, P.; Shephard, R.; Chelly, M.S. Field Tests of Performance and Their Relationship to Age and Anthropometric Parameters in Adolescent Handball Players. Front. Physiol. 2019, 10, 1–12. [CrossRef] [PubMed]
11. Bjørndal, C.T.; Andersen, S.S.; Ronglan, L.T. Successful and unsuccessful transitions to the elite level: The youth national team pathways in Norwegian handball. Int. J. Sport Sci. Coach. 2018, 13, 533–544. [CrossRef]
12. Foretic, N.; Pavlinovic, V.; Versic, S. Shooting Speed Differences between Playing Positions in Top Level Handball. Sport Mont. 2022, 20, 21–24. [CrossRef] [PubMed]
13. Hermassi, S.; Laudner, K.; Schwesig, R. Playing level and position differences in body characteristics and physical fitness performance among male team handball players. Front. Bioeng Biotechnol. 2019, 7, 1–12. [CrossRef] [PubMed]
14. Mohoric, U.; Sibila, M.; Abazovic, E.; Jovanovic, S.; Paravlic, A.H. Comparison of the Field-Based Intermittent Running Fitness Test 30-15 and the Treadmill Multistage Incremental Test for the Assessment of Cardiorespiratory Fitness in Elite Handball Players. Int. J Environ. Res. Public Health. 2022, 19, 3535. [CrossRef] [PubMed]
15. Paravlic, A.H.; Simunic, B.; Pisot, R.; Rauter, S.; Stuhec, S. The reliability, validity and usefulness of the 30–15 intermittent fitness test for cardiorespiratory fitness assessment in military personnel. Sci. Rep. 2022, 7, 16087. [CrossRef] [PubMed]
16. Buchheit, M. The 30-15 intermittent fitness test: Accuracy for individualizing interval training of young intermittent sport players. Strength Cond. J. 2008, 22, 365–374. [CrossRef] [PubMed]
17. Leuciuc, F.V.; Petrariu, I.; Pricop, G.; Rohozneau, D.M.; Popovici, I.M. Toward an Anthropometric Pattern in Elite Male Handball. *Int. J. Environ. Res. Public Health.* 2022, 19, 2839. [CrossRef] [PubMed]

18. Fieseler, G.; Hermassi, S.; Hoffmeyer, B.; Schulze, S.; Irlenbusch, L.; Bartels, T.; Schwesig, R. Differences in anthropometric characteristics in relation to throwing velocity and competitive level in professional male team handball: A tool for talent profiling. *J. Sports Med Phys. Fitness.* 2017, 57, 985–992. [CrossRef] [PubMed]

19. Gabrys, T.; Stanula, A.; Gupta, S.; Szmatlan-Gabrys, U.; Benešová, D.; Wicha, L.; Baron, J. A Comparative Study on the Performance Profile of Under-17 and Under-19 Handball Players Trained in the Sports School System. *Int. J. Environ. Res. Public Health* 2020, 17, 7979. Available online: https://www.mdpi.com/1660-4601/17/21/7979 (accessed on 20 October 2022). [CrossRef]

20. Karcher, C.; Buchheit, M. On-Court demands of elite handball, with special reference to maturation positions. *Sport Med.* 2014, 44, 791–814. [CrossRef]

21. Pearson, D.T.; Naughton, G.A.; Torode, M. Predictability of physiological testing and the role of maturation in talent identification for adolescent team sports. *J. Sci. Med. Sport* 2006, 9, 277–287. [CrossRef]

22. Hammami, R.; Sekulic, D.; Selmi, M.A.; Fadhloun, M.; Spasic, M.; Uljevic, O.; Chaouachi, A. Maturity Status as a Determinant of the Relationships Between Conditioning Qualities and Preplanned Agility in Young Handball Athletes. *J. Strength Cond. Res.* 2018, 32, 2302–2313. Available online: https://journals.lww.com/00124278-201808000-00024 (accessed on 20 October 2022). [CrossRef]

23. Buchheit, M.; Laursen, P.B.; Kuhle, J.; Ruch, D.; Renaud, C.; Ahmaidi, S. Game-based training in young elite handball players. *Int. J. Sports Med.* 2009, 30, 251–258. [CrossRef]

24. Šibila, M.; Vuleta, D.; Pori, P. Position-Related Differences in Volume and Intensity of Large-Scale Cyclic Movements of Male Players in Handball. *Kinesiology* 2004, 36, 58–68. Available online: http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=14001197&site=ehost-live (accessed on 14 November 2022).

25. Michalsik, L.B.; Aagaard, P.; Madsen, K. Locomotion characteristics and match-induced impairments in physical performance in male elite team handball players. *Int. J. Sports Med.* 2013, 34, 590–599. [CrossRef]

26. Schwesig, R.; Koke, A.; Fischer, D.; Fieseler, G.; Jungermann, P.; Delank, K.S.; Hermassi, S. Validity and Reliability of the New Handball-Specific Complex Test. *J. Strength Cond. Res.* 2016, 30, 476–486. Available online: https://journals.lww.com/00124278-201602000-00023 (accessed on 20 October 2022). [CrossRef]

27. Bøgild, P.; Jensen, K.; Kvorning, T. Physiological Performance Characteristics of Danish National Team Handball Players 1990–2016: Implications on Position-Specific Strength and Conditioning Training. *J. Strength Cond. Res.* 2020, 34, 1555–1563. Available online: https://journals.lww.com/10.1519/JSC.0000000000003318 (accessed on 20 October 2022). [CrossRef]

28. Ramos Campo, D.J.; Sanchez, F.M.; Garcia, P.E.; Arias, J.A.R.; Cerezal, A.B.; Clemente Suarez, V.J.; Jiménez Díaz, J.F. Body Composition Features in Different Playing Position of Professional Team Indoor Players: Basketball, Handball and Futsal. *Int. J. Morphol.* 2014, 32, 1316–1324. [CrossRef]

29. IHF Ranking. Available online: https://archive.ihf.info/en-us/thegame/rankingtable.aspx (accessed on 14 November 2022).

30. Shalfawi, S.A.I.; Seiler, S.; Haugen, T.A. Shooting Velocity Aspects in Norwegian Elite Team Handball. *Serbian J. Sport Sci.* 2014, 8, 33–40.

31. Michalsik, L.B.; Madsen, K.; Aagaard, P. Physiological capacity and physical testing in male elite team handball. *J. Sports Med. Phys. Fitness.* 2015, 55, 415–429.

32. Pereira, L.A.; Nimphius, S.; Kobal, R.; Kitamura, K.; Turisco, L.A.L.; Orsi, R.C.; Loturco, I. Relationship between change of direction, speed, and power in male and female national olympic team handball athletes. *J. Strength Cond. Res.* 2018, 32, 2987–2994. [CrossRef]