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The Physical Characteristics and Performance Profiles of Female Handball Players: Influence of Playing Position

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Abstract: The purpose of the study was to compare physical characteristics and performance values between different playing positions in professional female team handball. Twenty-nine female handball players were categorized as centers (n=6), pivots (n=9), wings (n=8) or goalkeepers (n=16). Measurement of physical characteristics including body height and mass, body mass index; knee muscle strength, scores on the lower limb vertical power (vPower), lower and upper limb performance and trunk extension endurance were determined and compared across playing positions. The goalkeepers had higher knee strength as compared to pivots, wings, and centers ($p<.001$, $\eta p2>.20$). Pivot players achieved higher vPower than wings, centers, and goalkeepers ($p=.011$, $\eta p2=.759$). In addition, goalkeepers and wings achieved higher vPower than centers ($p<.001$, $\eta p2=.759$). No significant differences were observed in trunk extension endurance and upper limb performance results according to playing positions ($p>.05$, $\eta p2<.20$). The pivots and wings had better lower limb performance than goalkeepers and centers ($p<.001$, $\eta p2=.682-.701$). The present study concludes that depending on their play positions, there are differences in terms of physical characteristics, knee muscle strength, vertical power, and lower extremity performance in elite female handball players. These results could help improve coaches' knowledge of elite female teams in the particular in the country where the study was conducted and in others of similar characteristics.

Keywords: Handball team; elite players; knee strength; physical performance; playing position

1. Introduction

Handball is an intermittent team sport with specific requirements for anthropometric features, technical skills, tactical understanding, and physical performance (Marques & González-Badillo, 2006). In terms of physical performance, handball is a complex sport where players jump, run, and throw the ball at high speed, generally requiring maximal intensity efforts performed in a short time-space. It is reported that for handball players, in addition to technical skills and tactics, anthropometric characteristics and physical performance are determinants of competitive success (Vila et al., 2012). Studies investigating handball-specific movements have shown that the number and quality of movements differ greatly depending on play positions. Four different positions are generally defined in handball: goalkeeper, center player, pivot, and winger. Previously published studies are insufficient regarding the role and importance of different physical characteristics according to playing level and positions in female elite handball (Bon et al., 2015; Granados et al., 2007; Vila et al., 2012).

As in all team sports, in handball, technical and tactical efficiency are predominant factors, but physical capabilities must also be well developed in order to become a successful player (Serdar & Bereket, 2001). In today's handball approach, considering that the players might play at any position other than their own, all their physical performance characteristics are expected to be trained and improved equally (Sevim, 2007). Elite handball players are different in terms of speed and agility depending on their play positions (Gençoğlu & Gümüş, 2020). Similarly, studies conducted on handball players have reported significant differences in various physical and anthropometric features between positions (Bon et al., 2015; de Paula Oliveira et al., 2020; Haugen et al., 2016; Zapartidis et al., 2011). Determining anthropometric and physical performance characteristics is essential in identifying the players with the potential to be professionally successful at competitive levels, and it is critical in the process of guiding the players to the most appropriate playing positions (Gontarev et al. 2017).

Handball encompasses characteristics such as endurance, speed, agility, skill, mobility, jumping, and defense (Hermassi et al., 2019). Handball requires all-body trainings for components such as aerobic activity, muscle strength, balance, and flexibility. It consists of vigorous activities such as running, sprinting, and jumping, as well as regular throwing, hitting, blocking and pushing (Gorostiaga et al., 2006). Good agility skills are essential for handball players as the game requires speed and sudden change of direction. As a motor skill that is fundamental in the majority of sports, agility plays an important role in improving sportive performance (Sheppard & Young, 2006). Throwing speed is an important parameter in handball. Throwing is a prominent skill and for high-quality throwing efficiency, upper and lower extremity muscle strength and endurance are essential (Wallace & Cardinale, 1997). However, the speed of ball shot depends not only on muscle strength but also on other aspects such as coordination of body segments and technical skills. Throwing speed is particularly substantial because the faster the ball is thrown into the goal, the less time the defenders and goalkeeper have to save the shot. In years, together with effective trainings and improvement in players' performance, handball has evolved in many ways such as throwing, passing, dribbling, jump shots, rapid attacks, and defense (Granados et al., 2007; Vila et al., 2012). Parallel to the changes in the dynamics of handball, players are required to have well-developed physical performances in both lower and upper extremities aiming at realize their full potential (Cetin & Ozdol, 2012).

Anthropometric parameters are another prominent factor as fundamental in order to determine the success of the performance in handball (Hermassi et al., 2019). Regarding anthropometry, one study in female handball players demonstrated that the higher values of fat-free mass resulted in a higher performance, especially because of the increase in the muscular power and strength (Granados et al., 2013). On the other hand, one study showed that the anthropometric differences between playing positions may indicate the advantageous characteristics that the respective position demands (Hermassi et al., 2019). Analyzing player profiles, determining their abilities according to their strengths and weaknesses, optimizing the design of strength and conditioning training programs, and assigning game positions accordingly can be valuable tools in handball (Krüger et al., 2014). Knowing the physical performance characteristics of the players can enable coaches to take into account the strengths and weaknesses of each player during training sessions, prevent potential injuries due to muscle weakness, and monitor players' progress throughout the season. Furthermore, since each position requires specific skills, position-specific evaluation results can enable coaches to focus on each player's performance aspects peculiar to their position (Šbila et al., 2004; Vurgun et al., 2020). Few studies have compared the anthropometric and physical characteristics for female handball players of different playing positions. Although some studies have analyzed some physiological characteristics of elite handball players, little information is available concerning the physical (e.g., vertical power, trunk endurance, knee muscle strength) and anthropometric characteristics of current professional handball players. Examination of fitness profiles could be of great importance for optimal construction of training regimens to improve handball performance such players. Therefore, the aim of this study is twofold: first to describe the physical characteristics, knee muscle strength, scores on the lower limb vertical power, lower and upper limb performance, and trunk extension endurance of the lower limbs in female handball players and secondly to identify the possible differences in these parameters in terms of individual playing positions. Our primary hypothesis was that these physical characteristics and performance values vary among female handball players of different playing positions.

2. Materials and Methods

Subjects — A total of 39 elite female handball players (mean age:24.15±6.47 years; BMI:22.18±2.36 kg/m2) from the premier Turkish professional handball league with a regular competitive background in handball (11.92 ±3.47 years) were included in this cross-sectional study. Player positions were identified for each athlete by their coaches or through self-report as: goalkeepers, centers, pivots, or wings. All athletes (6 goalkeepers, 9 pivots, 8 wings and 16 centers) were asymptomatic and had passed medical examinations prior to inclusion and participation in the study. Physical characteristics of the players are shown in Table 1. Exclusion criteria included history of injury or surgery that may affect their lower and upper limbs and any lower and upper limb injuries within the last three months. The leg used to kick the ball was identified as the dominant leg. The dominant shoulder was defined as the hand used for throwing the ball. Players who voluntarily agreed to participate in the study provided written informed consent. The study was approved by the Ethical Committee of University (registration number 2020/242), in accordance with the Helsinki Declaration. Participants were assured that they could withdraw from the trial at any time without penalty. The study was registered with clinicaltrials.gov (NCT04563585).

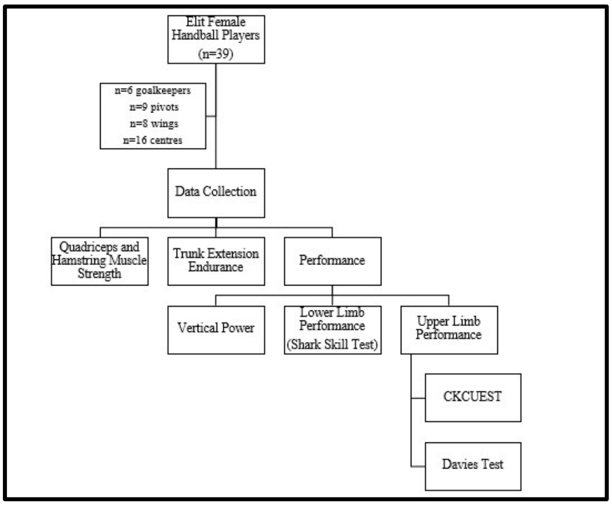

Figure.1. Flow chart for study participants

Experimental Design — This study investigated the compare anthropometric data and physical performance characteristics between different playing positions in professional female team handball selected from the Turkish professional handball league. Our hypothesis is that there are differences in terms of anthropometric profile, knee muscle strength, scores on the lower limb vertical power, lower and upper limb performance, trunk extension endurance in female handball players by playing positions. Therefore, the players were divided in the order of their specific playing position (centers, wings, pivots, and goalkeepers). The independent variable was the handball specific playing position (centers, wings, pivots, and goalkeepers), and the dependent variables were the anthropometric profile, knee muscle strength, scores on the lower limb vertical power, lower and upper limb performance, and trunk extension endurance. Anthropometrics data including body height and mass, body mass index (BMI); knee muscle strength, scores on the lower limb vertical power (vPower) , lower limb performance on a Shark Skill Test (SST), trunk extension endurance, upper limb performance on Davies test (DT) and Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) were determined and analyzed d for all the players who took part in this study.

Methodology — *Physical characteristics* — An electronic weight scale (HD-351 Tanita, Illinois, USA) was employed for body mass measurement (to the nearest 0.1 kg), a portable stadiometer (SECA, Leicester, UK) for stature (to the nearest 1 mm). BMI was calculated as the quotient of body mass (kg) to height squared (m2).

Muscle Strength — Maximal voluntary isometric (MVIC) knee flexion and extension strength were measured using a handheld dynamometer (HHD) (Lafayette Instrument Company, Lafayette, IN). The intraclass coefficients (ICC) for knee flexion and extension measurement with the HDD (Lafayette Instrument Company, Lafayette, IN) were declared to be 0.84-0.95, and standard error of measurement (SEM) values ranged from 3.6 to 4.5 (Hébert et al., 2011). For strength measurement using the HHD, the participants were asked to sit with their legs dangling over the end of a standard, adjustable examination table, with hips and knees flexed to 90°, with a distance of 1–2 cm between the popliteal fossae and the table end. Two stabilization belts were placed, one on the thighs to reduce compensations and the second at the ankle of the evaluated limb to maintain hip and knee flexion at 90° (Martins et al., 2017). To evaluate knee extensor muscles, the dynamometer was placed on the anterior part of the lower leg, above the talotibial joint line, and to evaluate knee flexor muscles, the dynamometer was placed on the posterior part of the leg, 1–2 cm above the lateral malleolus. In both cases, the examiner produced a resistance force in the horizontal direction to counter the force developed by the participant and maintain an isometric contraction of the knee extensor and flexor muscles (Muff et al., 2016). The participants performed two practice trials, rested for 30s and then performed the two measure trials. For each muscle group, the participants carried out 3 MVICs for 5 seconds. The interval between consecutive measurements of the same limb was 30s and that between the limbs was 60s. All maximal trials with the HHD were also accompanied by verbal encouragement to ensure maximal effort. The highest value obtained during measurements was recorded for each trial (Hirano et al., 2020).

Lower Extremity Vertical Power — Lower extremity vertical power was assessed using the VertiMetric (Lafayette Instrument Company, Lafayette, IN) according to protocols suggested by Ambegaonkar et al. (Ambegaonkar et al., 2018). In studies conducted by previous investigators examining the device Intervisit relative reliability (ICC) and standard error of measurement (SEM) of the VertiMetric device ranged from 0.85 to 0.91 and 2.1 to 2.7, respectively. (Nakajima & Baldridge, 2013;

Nuzzo et al., 2011). A countermovement jump with arm swing was used in measuring vertical jump (VJ) height. At the moment preceding the jump, the participants could freely flex the hip, knee, and ankle joints and prepare the upper limbs for a sudden upward thrust, in an effort to promote the highest VJ possible. The rest time between jumps was 20s. The participant's VJ height was calculated as the difference between their maximum jump height and standing reach height. Vertical power (vPower, watts) was calculated using the maximal jump height of three trials in a published equation that included participants' anthropometrics, where vPower = [51.9 x VJ (cm)] + [48.9 x mass (kg)]-2007 (Sayers et al., 1999).

Trunk Extension Endurance — Trunk extension endurance was measured using the Biering–Sorensen test as described elsewhere (Keller et al., 2001). The Biering–Sorensen test has excellent test-retest reliability (ICC=0.93-0.98) (Keller et al., 2001; Mannion et al., 1997). The minimal detectable change (MDC) values for trunk extension endurance measurement with the Biering–Sorensen test in females and males were declared to be 23.5 s and 20 s, respectively (McGill et al., 1999). The participant was initially on the examination table in the prone position with the upper edge of the iliac crests aligned with the edge of the table. The trunk then was raised to the horizontal position with hands crossed over the chest. The lower body was fixed to the table by two non-elastic straps. The test was continued until the participant could no longer control the horizontal posture, or until he or she reached the limit for fatigue or pain. The total time from the onset of the test to trunk flexion and loss of the static neutral position was recorded as the endurance time or the isometric holding time (in seconds) with a stopwatch (Adedoyin et al., 2011; Keller et al., 2001).

Upper Limb Performance — Davies Test — The Davies test (DT) was used to assess upper body agility and stabilization (Clark et al., 2008). Two pieces of tape were placed 36 inches apart on the ground. The participant began in a push-up position with one hand on each piece of tape. The participant was then asked to quickly touch their right hand with the left hand and continue to perform alternating touches on each side for a period of 15 seconds. The number of lines touched by both hands was recorded. The test was repeated three times (Clark et al., 2008).

Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) — The CKCUEST was used to assess shoulder performance function and stability according to the protocol suggested by Goldbeck and Davies (Goldbeck & Davies, 2000). The CKCUEST is a measurement with moderate to excellent reliability (de Oliveira et al., 2017; Silva et al., 2019). The CKCUEST presented reliability (ICC) of the average touches score, normalized score, and power score were ranging from 0.77 to 0.92, 0.80 to 0.94 and 0.91 to 0.98, and the minimal detectable change (MDC) values were 6.01, 3.74 and 17.98, respectively (de Oliveira et al., 2017; Silva et al., 2019). The participant started in a push-up position, with hands placed 36 inches (90 cm) apart on two lines. After a training set, the participant touched alternatively and as quick as possible, the floor with a hand crossing over the supporting hand during three sets of 15s with a 45s recovery. The CKCUEST score was computed by averaging the number of touches performed during three maximal sets.

Lower Limb Performance —The Shark Skill Test (SST) was used to assess lower extremity agility and neuromuscular control. The nine-box grid was taped on the floor, 3×3 boxes each measuring 6×6 inches. The participant stood at the center of the box grid with hands on hips standing on one leg. They were then asked to hop to each box in a designated pattern, always returning to the center box. The test was performed twice with each foot (four times in total) and the best score was recorded (in seconds) (Clark et al., 2008) (Figure.2).

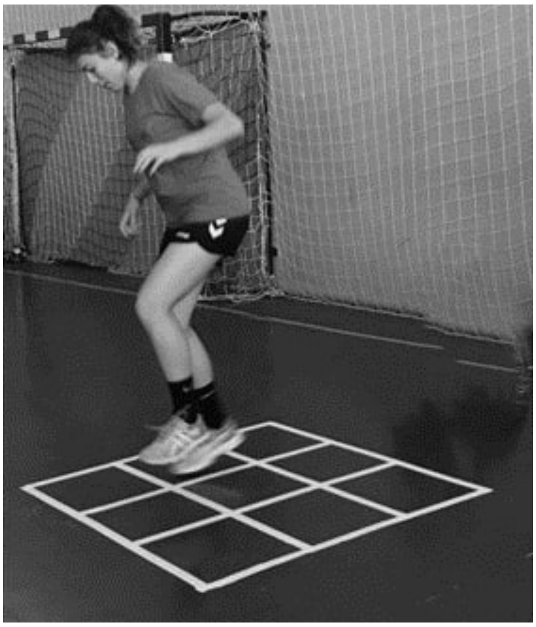

Figure 2. Shark Skill Test

Statistical Analysis

SPSS 25 Statistics Software (SPSS Inc. Chicago, IL) was used for all statistics analyses. Descriptive statistics [mean, standard deviation (SD), minimum, maximum, and 95% confidence intervals (95% CI)] were ascertained for all variables. A 1-way analysis of variance together with a Tukey honestly significant difference post hoc test was used to determine if significant differences existed among 4 playing positions (center, wing, pivot, and goalkeeper). Differences between means were considered statistically significant if p<.05 and partial eta-squared (ηp2) values were >.20 (Richardson, 2011). Because of the small number of cases (e.g., position-specific analysis) and in order to avoid an overestimation of mean differences, the decision of significance was made primarily based on ηp2 values.

3. Results

Physical characteristics of the players are shown in Table 1. Table 1 shows that center players were taller than wing players (p=.013, ηp2=.260). Goalkeepers were heavier than wing players (p=.014, ηp2=.258). Goalkeepers showed higher BMI than wing players (p=.047, ηp2=.201).

Quadriceps and Hamstring isometric muscle strength results of the female handball players are shown in Table 2. Goalkeepers had better strength in both muscle group than other pivots (p<.001, ηp2>.20), wings (p<.001, ηp2>.20), and centers (p<.001, , ηp2>.20). No significant differences trunk extension endurance in for Biering–Sorensen test across playing positions were observed (p>.05, ηp2=.094) (Table 2).

Table 2 shows that pivot players achieved higher vPower than wings (p<.001, ηp2=.759), centers (p<.001, ηp2=.759), and goalkeepers (p=.011, ηp2=.759) in lower extremity vertical power. In addition, goalkeepers and wings achieved higher vPower than centers (p<.001, ηp2=.759).

Table 3 shows that no significant differences in CKCUEST and DT across playing positions (p=.735-.989, ηp2<.20). Pivots had better dominant and non-dominant lower limb performance in SST than goalkeepers and centers (p<.001, ηp2=.701 and ηp2=.682, respectively). Similarly, wing players had better dominant and non-dominant lower limb performance in SST than goalkeepers and centers (p<.001, ηp2=.701 and ηp2=.682, respectively). (Table 3).

Table.1. Physical characteristics of the players

	Goalkeeper (n=6)	Center (n=16)	Pivot (n=9)	Wing (n=8)	Total (n=39)	p*	Partial eta-squared (η_p^2)
	Mean±SD (95% CI)	Mean±SD (95% CI)	Mean±SD (95% CI)	Mean±SD (95% CI)	Mean±SD (95% CI)		
Age (Years)	26.00±7.82 (19.79-25.21)	25.63±6.74 (22.03-29.22)	24.44±6.00 (19.83-28.06)	19.50±3.46 (19.60-22.40)	24.15±6.46 (22.06-26.05)	0.137	0.144
Height (m)	1.72±0.04 (1.67-1.76)	1.73±0.04[A] (1.71-1.76)	1.72±0.06 (1.66-1.77)	1.65±0.06 (1.60-1.70)	1.71±0.06 (1.69-1.73)	**0.013**[¥]	**0.260**[β]
Body Mass (kg)	72.50±10.57[B] (61.40-83.60)	67.00±5.93 (63.84-70.16)	64.56±10.84 (56.22-72.89)	58.13±5.22 (53.76-62.49)	65.46±8.87 (62.59-68.34)	**0.014**[¥]	**0.258**[β]
BMI (kg/m²)	24.47±3.22[C] (21.09-27.85)	22.14±1.61 (21.28-23.00)	21.64±2.78 (19.50-23.78)	21.15±1.53 (19.86-22.43)	22.18±2.36 (21.41-22.95)	**0.047**[¥]	**0.201**[β]

Note: * One-way ANOVA, ¥ $p<0.05$, β $\eta p2 > 0.20$ A: Significantly centers > wings, B: Significantly goalkeepers > wings, C: Significantly goalkepers > wings, CI=Confidence interval, SD: Standard deviation, BMI: Body mass index

Table.2. Parameters of knee muscle strength, trunk extension endurance and vertical power descriptive data in relation to playing position.

Playing Positions	Biering-Sorenson (second)	D-Quadriceps Strength (kg)	ND-Quadriceps Strength (kg)	D-Hamstring Strength (kg)	ND-Hamstring Strength (kg)	Vertical Power (watts)
	Mean±SD (95% CI)	Mean±SD (95% CI)	Mean±SD (95% CI)	Mean±SD (95% CI)	Mean±SD (95% CI)	Mean±SD (95% CI)
Goalkeepers (n=6)	108.0 ± 42.6 (63.2-152.7)	22.9 ± 1.4[A] (21.4-24.4)	20.3 ± 1.7[A] (18.5-22.1)	22.6 ± 1.5[A] (20.9-24.2)	20.5 ± 2.6[A] (17.7-23.3)	3046.1 ± 301.9[B] (2729.2-3363.0)
Centers (n=16)	87.2 ± 29.3 (71.6-102.8)	12.4 ± 1.7 (11.5-13.4)	12.6 ± 1.5 (11.8-13.5)	15.6 ± 2.3 (14.3-16.9)	15.8 ± 1.7 (14.8-16.7)	2267.3 ± 278.7 (2118.8-2415.9)
Pivots (n=9)	106.3 ± 59.7 (60.3-152.2)	14.3 ± 4.5 (10.7-17.8)	12.8 ± 3.6 (10.0-15.7)	15.5 ± 1.4 (14.4-16.7)	15.7 ± 1.4 (14.5-16.8)	3584.1 ± 431.4[C] (3252.4-3915.7)
Wings (n=8)	123.3 ± 55.5 (76.9-169.7)	15.3 ± 4.2 (11.8-18.8)	14.0 ± 3.1 (11.4-16.6)	15.0 ± 1.0 (14.1-15.9)	15.4 ± 1.5 (14.2-16.7)	2819.6 ± 166.1[D] (2680.7-2958.5)
ANOVA (p; η^2_p)	$p = 0.319$ $\eta^2_p = 0.094$	**$p = 0.000$ $\eta^2_p = 0.580$**	**$p = 0.000$ $\eta^2_p = 0.570$**	**$p = 0.000$ $\eta^2_p = 0.678$**	**$p = 0.000$ $\eta^2_p = 0.514$**	**$p = 0.000$ $\eta^2_p = 0.759$**

CI: Confidence Interval, Significant mean differences for the total sample are highlighted in bold, A: Significantly goalkeepers > centers, pivots and wings, B: Significantly goalkeepers > centers, C: Significantly pivots > goalkeepers, centers and wings, D: Significantly wings > centers, D: Dominant, ND: Non-dominant

Table.3. Parameters of CKCUEST, DT and SST descriptive data in relation to playing position.

Playing Positions	CKCUEST (times)	DT (times)	D-SST (second)	ND-SST (second)
	Mean±SD (95% CI)	Mean±SD (95% CI)	Mean±SD (95% CI)	Mean±SD (95% CI)
Goalkeepers (n=6)	25.8 ± 4.6 (20.9-30.7)	23.1 ± 2.8 (20.1-26.1)	5.8 ± 0.4 (5.3-6.4)	6.0 ± 0.5 (5.3-6.6)
Centers (n=16)	25.6 ± 7.6 (21.6-29.7)	24.3 ± 3.3 (22.5-26.1)	6.3 ± 0.6 (5.9-6.7)	6.4 ± 0.8 (6.0-6.8)
Pivots (n=9)	23.5 ± 4.2 (20.3-26.7)	20.7 ± 4.9 (16.9-24.5)	8.0 ± 0.5¥ (7.6-8.4)	7.7 ± 1.1¥ (6.8-8.6)
Wings (n=8)	27.0 ± 8.8 (19.6-34.3)	24.7 ± 2.1 (22.9-26.5)	7.6 ± 0.4ᶲ (7.2-8.0)	7.5 ± 0.6ᶲ (6.9-8.0)
ANOVA (p; η^2_p)	p = 0.773 η^2_p = 0.030	p = 0.079 η^2_p = 0.174	**p = 0.000** **η^2_p = 0.701**	**p = 0.000** **η^2_p = 0.682**

CI: Confidence Interval, Significant mean differences for the total sample are highlighted in bold, ¥: Significantly pivots > goalkeepers and centers, ϕ: Significantly wings > goalkeepers and centers, CKCUEST: Closed Kinetic Chain Upper Extremity Stability Test, DT: Davies Test, SST: Shark Skill Test, D: Dominant, ND: Non-dominant

4. Discussion

This study was conducted to examine the differences in physical characteristics and performances of elite female handball players according to their playing positions. According to the results, BMI and body weight of goalkeepers were higher than those of wings; and their knee muscle strength was higher than all other players. Moreover, lower extremity performances of pivot and wing players were better than other position players, whereas all players were found to be similar in terms of upper extremity performance and lumbar extensor endurance.

Our study results revealed that the body weight and BMI of the goalkeepers were higher than the wings. One possible reason for this might be that goalkeepers are engaged in intense aerobic training, their energy consumption is less than other position players, and they play a position that requires higher level of stability. Another possible reason might be that wings need to keep their BMI lower as their position demands more speed, agility, and pace. In line with these results, Villa et al. stated that the speed performance of wings was particularly higher than other players (Vila et al., 2012). They reported that speed and agility are essential for wings as their position requires rapid change of direction, sudden acceleration, and rapid throw-in. The researchers also stated that wings are shorter than those in other positions, a quality that helps with better agility. Consistent with these results, in our study wings were on average shorter than other players (Gontarev et al., 2017). The same study also reported that goalkeepers are similar to other positions in terms of body mass index, but this situation varies in different leagues (Vila et al., 2012).

In this study, knee muscle strength of the goalkeepers was found to be higher than other positions, whereas their quickness and agility were lower. This might be due to the fact that goalkeepers' lower extremity training mainly focuses on hypertrophy and strength rather than quickness and agility. Studies have reported that in professional athletes, the ratios of type 1 or type 2 muscle fibers vary depending on their sports and training types (Gorostiaga et al., 1999; Monsef Cherif et al., 2012). While type 2 muscle fibers are more common in athletes engaged in quickness and speed trainings (Monsef Cherif et al., 2012), those engaged in sports that require endurance, weightlifting or stability have more of type 1 fibers (Gorostiaga et al., 1999; Haun et al., 2019). Considering the movement patterns and training styles of the goalkeepers, lower levels of agility and quickness in goalkeepers in our study is consistent with other studies in the relevant literature. Therefore, in comprising exercise and training programs for athletes, their play positions and movement patterns should be taken into consideration. Based on this, in handball, since the muscle strength of the goalkeepers is higher compared to other positions, it is recommended to include exercises with small number of repetitions and heavier weight in goalkeepers' training programs, while for the wings or center players it is recommended to increase the number of repetitions, decrease the weight, and add multi-direction exercises (Monsef Cherif et al., 2012).

The wing and pivot players in our study had higher scores in quickness and agility tests compared to goalkeepers and center players. According to several studies in different team sports, one of the most basic movements for pivot or wing players is to evade the opponent by changing direction with quick leg movements and join the attack (Vila et al., 2012; Wagner et al., 2014; Zapartidis et al., 2011). Therefore, athletes playing in these positions are expected to have the ability to change direction faster than center players or goalkeepers (Massuca et al., 2015; Wagner et al., 2014).

Similarly, in our study, although there were differences in anthropometric values in the upper extremity functionality measurements, no difference was found between positions in terms of upper extremity performance tests. Contrary to our results, Vila et al. stated that the upper extremity performance parameters of center players were better than wings (Vila et al., 2012). Cherif et al. also reported that center players had better upper extremity performance and shooting values than wings and forward players than back players (Cherif et al., 2016). Upper extremity performance parameters are important in sports such as handball. However, the results of the studies in the literature on this subject is contradictory. According to previous studies, although every team player has different anthropometric values, there is no difference in upper extremity performance tests due to the same trainings and similar shooting and passing activities in all position players (Rousanoglou et al., 2014). Also, since all athletes perform similar muscle activation and movement patterns at approximately similar speeds, there is no difference between positions. One possible reason for these contradictory results might be the use of different functional and performance tests in samples with different ages and anthropometric values. Further studies are needed to evaluate upper extremity functionality, agility, and quickness parameters in handball players.

In our study, no difference was found in terms of lumbar core strength between the players. The reason might be the fact that our participants were elite athletes, and all had a strong core and lumbar extensor muscles. All these athletes have been practicing handball professionally for more than five years and are engaged in regular training programs. Handball players perform intensive core and abdominal strengthening training as a team. In order to assess the core strength of these athletes in more details, comparative studies with different groups are needed including all core strength and endurance tests.

The main limitation of this study, especially regarding positional subgroups, is the small sample size. Therefore, these data should be interpreted with caution and in comparison, with similar investigations. It is evident, that this sample size is not powerful enough to generate statements about anthropometrics and positional success for an entire sport. Furthermore, currently, there is still unclear debate as to whether vertical jump is a good indicator for lower extremity power output (Morin et al., 2019). Therefore, the use of vertical jump test in this study was another limitation of this study.

5. Practical Applications.

Considering these differences, it is recommended to plan performance-oriented training programs, preventive exercise programs and post-injury rehabilitation programs for elite female handball players specific to the positions. In this framework, the positional demands of the game are different, muscle mass and lower limb performance should be developed according to the individual playing positions and skill of the handball players, especially for pivot and wing players. Furthermore, in future studies, it seems to be worth to include further performance tests with a focus on knee muscle strength or lower limb performance to improve the position-specific profiling, especially for pivots or goalkeepers.

6. Conclusions

The present study concludes that depending on their play positions, there are differences between elite handball players in terms of physical characteristics, knee muscle strength, vertical power, and lower extremity performance. In this work, the goalkeepers had higher knee strength as compared to pivots, wings, and centers. Also, in female handball players in particular pivot players achieved higher vPower than wings, centers, and goalkeepers while goalkeepers and wings achieved higher vPower than centers. In female handball players, there were no significant differences in trunk extension endurance and upper limb performance results according to playing positions. Finally, the pivots and wings had better lower limb performance than goalkeepers and centers. These results could help improve coaches' knowledge of elite female teams in the particular in the country where the study was conducted and in others of similar characteristics. However, further profiling of handball players is required before definitive reference data can be presented.

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