applied sciences

MDPI

Article

Seasonal Changes in Body Composition, Jump, Sprint, and Agility Performance Among Elite Female Handball Players

Mima Stanković [1], Borko Katanić [2,*], Karuppasamy Govindasamy [3], Adela Badau [4,*], Dana Badau [4], Bojan Masanovic [5,6] and Ivana Bojić [1]

1 Faculty of Sport and Physical Education, University of Niš, Čarnojevića 10a, 18000 Niš, Serbia; mima.stankovic974@gmail.com (M.S.); bojicka2003@yahoo.com (I.B.)
2 Montenergin Sports Academy, 81000 Podgorica, Montenegro
3 Department of Sports, Recreation and Wellness, Symbiosis International (Deemed University), Hyderabad Campus, Modallaguda (V), Nandigama (M), Rangareddy, Telangana 509217, India; gowthamadnivog@gmail.com
4 Faculty of Physical Education and Mountain Sport, Transilvania University of Brasov, 500068 Brașov, Romania
5 Faculty for Sport and Physical Education, University of Montenegro, 81400 Niksic, Montenegro; bojanma@ucg.ac.me
6 Western Balkan Sport Innovation Lab, 81000 Podgorica, Montenegro
* Correspondence: borkokatanic@gmail.com (B.K.); adela.badau@unitbv.ro (A.B.)

Abstract: Assessing physical fitness throughout the entire season can provide valuable insights for designing effective training programs to enhance handball performance. Therefore, the aim of this study was to investigate seasonal changes in body composition, jump, sprint, and agility performance among elite female handball players. This study involved fourteen elite female handball players (age 21.98 ± 1.22) who participated in the Serbian Handball Super League and the European Handball Federation (EHF) European Cup during the 2022/23 season. Within the framework of seasonal changes, five measurements were made. Players were tested for height, weight, BMI, body fat and muscle mass percentage, jump performance (CMJ, CMJA, SJ, CMJ right, CMJ left), linear sprint (5 m, 10 m, 20 m), and agility performance (zig-zag and slalom). Repeated measures ANOVA revealed no changes in body composition parameters during the season. Among the five jump performance tests, a significant change was observed only in the CMJ left test, where better values were achieved in the fourth and fifth measurements compared to the initial measurement. In sprints over 5 and 10 m, significant changes were noted between specific measurement points, while no differences were observed in the 30-m sprint. For agility, differences were recorded in four out of five tests, with the best performances in the Zig-Zag tests observed in the third measurement, while in other tests, the best results were most often recorded in the second and fifth measurements. These results indicate that body composition remained stable, while performance improvements were specific to certain physical capacities and time points during the season. These findings can help coaches design targeted strength and agility training aligned with key performance periods, emphasizing short sprints and agility with/without the ball, rather than focusing on body composition changes. However, this study is limited by its small sample size and single-season scope, which may affect the generalizability of the results.

Keywords: seasonal variation; body fat; muscle mass; physical fitness; women's handball players

check for updates

Academic Editor: Burkhard Poeggeler

Received: 18 April 2025
Revised: 20 May 2025
Accepted: 21 May 2025
Published: 22 May 2025

Citation: Stanković, M.; Katanić, B.; Govindasamy, K.; Badau, A.; Badau, D.; Masanovic, B.; Bojić, I. Seasonal Changes in Body Composition, Jump, Sprint, and Agility Performance Among Elite Female Handball Players. *Appl. Sci.* **2025**, *15*, 5846. https://doi.org/10.3390/app15115846

1. Introduction

Over the past few years, handball has developed into a contemporary, rapid game attracting more fans, with women's handball gaining popularity [1,2]. However, female athletes still face disparities, such as lower salaries, less media attention, and a predominance of male coaches in elite teams, while research primarily focuses on male athletes, leaving a gap in knowledge about female team handball [3]. Notably, only 20% of sport and exercise science research centers on female athletes, complicating conclusions about their training [4].

The intermittent sport of female handball is regarded as intricate, multifaceted, and extremely demanding, requiring a great degree of specialized abilities [5]. Handball, like other team sports, relies on a combination of talent and technical skills, as well as physical, tactical, and psychological abilities [6]. The mentioned sport is a game that involves movements with and without a ball, changes in direction of movement with fast and abrupt sprints, various hops, groundings, and crashing into opposing team members when in direct contact. In addition, coordination skills and situation-related motor abilities, among other things, play a role in properly executing these motions [7,8]. In order to develop effective training methods for female team handball, coaches, condition coaches, team staff, and sport physicians should effectively use the pertinent information to evolve more beneficial programs [9].

Physical fitness is essential for elite handball players to avoid injuries and enhance performance [10]. Physical fitness testing during the entire season could be very useful in designing effective training programs to improve handball performance [11,12]. When designing a training program for team sports athletes, it's crucial to consider their totally different movement patterns [13]. Previous research has revealed that a special motoric component based on specific agility and explosiveness is significantly responsible for handball performance. This supported the idea that, in addition to maintaining all physical characteristics at a high standard during the playing season, they should also take into account the unique skills of handball players [14,15].

Assessing seasonal changes is especially essential in sports science and practice [16]. Previous research found a variety of physical fitness among female handball players. Bojić et al. [17] found significant changes and improved outcomes in the following parameters at the end of the season based on explosive strength measurements: CMJ right = 0.002 and CMJ left 0.018, but no significant changes were observed in the other two-leg jumps. On the contrary, the study's results with two measurements revealed statistically significant changes and weaker results in nearly all evaluated variables [18]. Only the maximum speed in a 30 m sprint and agility without a ball showed improvements (new envelope test and slalom run). A different research investigation found equivalent results. Moreover, most anthropometric measurements do not change much throughout the competitive season, with the exception of slight fat redistribution. This study found that female handball players have comparable body mass and BMI both before and after the season [19]. However, no study has been discovered that investigates changes in elite female handball players in five distinct assessments during a season.

Despite a few studies examining elite handball players' physiological aspects, little is known about elite female handball players' physical and body composition. There is limited information regarding the adaptation of physical fitness during one competitive season in elite female athletes [4], especially in handball. Sprint and agility are particularly important for handball players due to the frequent need for rapid changes in direction, quick acceleration, and deceleration, which are key components of success in both attacking and defending situations [20,21]. These tests provide valuable insights into the athletes' ability to perform game-specific movements, which is critical for optimal performance during competition. Therefore, the aim of this study was to investigate seasonal changes in body composition, jump, sprint, and agility performance among elite female handball players. The hypothesis of this study is that significant seasonal changes will occur in body composition, jump, sprint, and agility performance among elite female handball players. Since this is the first study that closely tracks seasonal changes in physical fitness among elite female handball players, analyzing these parameters across five measurement points throughout the season, it is clear that the research will make a significant contribution to this field and fill existing gaps in the literature.

2. Materials and Methods

2.1. Participants

In this study, fourteen elite female handball players from ZRK Naisa (Nis, Serbia) participated, who competed in the Serbian Handball Super League and took part in the European Handball Federation (EHF) European Cup during the 2022/23 season. These athletes had a mean age of 21.98 ± 1.22 years, a height of 173.18 ± 7.17 cm, and a body mass of 66.69 ± 8.90 kg (Table 1). The study's eligibility standards were senior handball players aged ≥18 years, with a training age of ≥5 years, without a recent injury (>12 months) or any illness at that moment. Initially, 18 participants participated in this study; however, after withdrawals (two players changed clubs during the season, and two players could not undergo testing during certain periods due to injuries), complete data for all five measurements were ultimately obtained from 14 players. All participants took part voluntarily and were informed about the purpose of this research. The study was conducted in compliance with the Declaration of Helsinki, and the University of Niš (Republic of Serbia) approved this study (decision No. 04-1769/2). In line with the Declaration of Helsinki, written consent was also obtained from the participants before the study began.

Table 1. Characteristics of the female handball player sample at baseline.

Variables	Handball Players
Age	21.98 ± 1.22
Body Height	173.18 ± 7.17
Body Mass	66.69 ± 8.90
BMI	22.15 ± 1.66

Legend: The values are presented in mean and standard deviation (M ± SD); BMI—body mass index.

2.2. Procedures

All testing sessions were conducted in the morning hours, between 9:00 and 12:00. Tests were always performed on Mondays to ensure that the athletes were well rested and had sufficient recovery time after their previous training. The testing protocol was identical across all sessions during the season, and the same assessors conducted all measurements. All testing was conducted on dry ground, with temperature variations that could not be controlled. Participants initially were analyzed for anthropometric characteristics and body composition utilizing five parameters: height, mass, BMI, body fat, and muscle mass percentage. After that, they began with a structured warm-up consisting of 8 min of light jogging, 5 min of static exercise, and 2 min of high-intensity sprinting. All participants were assessed and tested on 12 fitness components following a warm-up. These tests comprised linear sprints of 5 m, 10 m, and 20 m, and agility performance with and without a ball (zig-zag and slalom). The participants performed squat jumps (SJ), countermovement jumps (CMJ), countermovement jump single leg (CMJ right and CMJ left), and arm-driven countermovement jumps (CMJA).

Within the framework of seasonal changes, five measurements were made. The first measurement (I) was conducted just before the season 2022/23 (after the preparation period; beginning of September 2022), and the second measurement (II) was conducted in the season (end of October 2022). The third measurement (III) was conducted after the first half of the season, in the transitional period (end of December 2022), and the fourth measurement (IV) was conducted after the preparation period before the season (beginning of February 2023). In contrast, the fifth measurement (V) was conducted after the second half of the season (April 2023). Time-based cutoff points were determined based on previous studies that assessed seasonal variations in athletes [22,23]. All tests were conducted in the same order at all five measurement points.

During the season, the players followed their regular training program. For the purposes of this study, Table 2 presents a typical in-season weekly training schedule. In the 2022/23 season, the players participated in 25 competitive matches.

Table 2. Typical in-season weekly training.

Day	Morning Session	Evening Session
Monday	Aerobic conditioning (60–70% HRmax); Emphasis on recovery and endurance volume	Technical-tactical drills in motion (ball handling, passing, coordination under load)
Tuesday	High-intensity training (explosive power, agility, speed, specific endurance) or Strength training (gym session)	Submaximal execution of technical-tactical drills (with and without the ball)
Wednesday	Position-specific shooting drills Goalkeeper-specific training Individual skill development	High-intensity technical-tactical session (small-sided games, transition play)
Thursday	Rest or optional recovery (e.g., mobility, stretching, or hydrotherapy)	Tactical systems rehearsal (offensive and defensive schemes, situational play)
Friday	Group tactical shooting (finishing under pressure, 7-m throws, positional play)	Review of tactical strategies and set plays (match preparation)
Saturday	Game day	-
Sunday	Day off	-

2.3. Measurements

2.3.1. Body Composition

Body height (BH), body mass (BM), body fat percentage (BF%), and muscle mass were measured using an anthropometer (SECA 214, Hamburg, Germany) and the Tanita body fat scale (model BC-418MA), respectively. Additionally, body mass index (BMI) was evaluated using the equation: body mass (kg)/body height (m)^2.

2.3.2. Jump Performance (CMJ, CMJA, SJ)

Three different types of vertical jumps were utilized to determine jump height (cm): countermovement jump (CMJ), CMJ with arm swing (CMJA), and squat jump (SJ). Two photoelectric devices (Optojump, Microgate, Bolzano, Italy) were applied to quantify the flight time between takeoff and landing in cm. Before the assessment, the participants received instructions to jump as high as they possibly. During the CMJ test, participants were required to place their hands on their hips and flex their knees (about 90°) in order to jump upward with no moving their hands away from their hips. The CMJA test was completed in the same manner as the CMJ test, with the exception that the hands were free throughout all phases of the greatest jump. The SJ test was conducted with knees flexed at 90° and hands on the waist as the beginning position (3 s), jumping upward without moving the hands away from the hips. In addition, for the jump to be performed successfully, the participants were required to prevent any knee or trunk countermovement. Each leap was accomplished after three tries, with one minute of passive rest and three minutes of passive rest between tests. For every assessment, the highest scoring result (cm) was considered. All of the previously presented tests have been validated and shown to be reliable elsewhere [24,25].

2.3.3. Linear Sprint (Running 0–30 m)

The linear sprinting tests performed in this study were 10 m, 20 m, and 30 m long. The running speed was measured with three sets of photocell infrared gate timing devices (Microgate, Polifemo Radio Light, Bolzano, Italy). The approaches were reviewed with the players prior to testing. The starting point was set at 30 cm before the first pair of photocells. Participants were instructed to run as fast as possible over a 30-m length from a standing start. The timing device started automatically as participants crossed the first gate at the starting point, with 10 and 20 m split times. The time it took to finish the first 10 m of the 30-m test was used to assess acceleration. The participants completed three sessions with at least three minutes of rest between each [24]. The best performance from the three attempts was utilized for further study. It should be noted that the linear sprint tests from 10 to 30 m were all reliable [26].

2.3.4. Agility Test

Agility test (Figure 1) involves movements specific to handball, including forward and backward running, as well as diagonal sliding steps [27]. The setup is illustrated in Figure 1. The player starts from the initial position and runs straight forward to a cone placed 2.5 m away. Then, they move diagonally backward to cone 3, which is positioned 3.5 m to the right of the starting point. Next, the player slides diagonally forward to cone 4, followed by straight backward running to cone 5, located 5 m behind cone 4. Finally, the player moves diagonally forward again to cone 3 and then diagonally backward to return to cone 1. Timing is recorded using the same equipment applied in the sprint tests. Two attempts are allowed, with a three-minute rest period between them, and the faster result is used for analysis. Test-retest reliability is confirmed with an intraclass correlation coefficient of 0.92, while the typical measurement error is 2.3% [27].

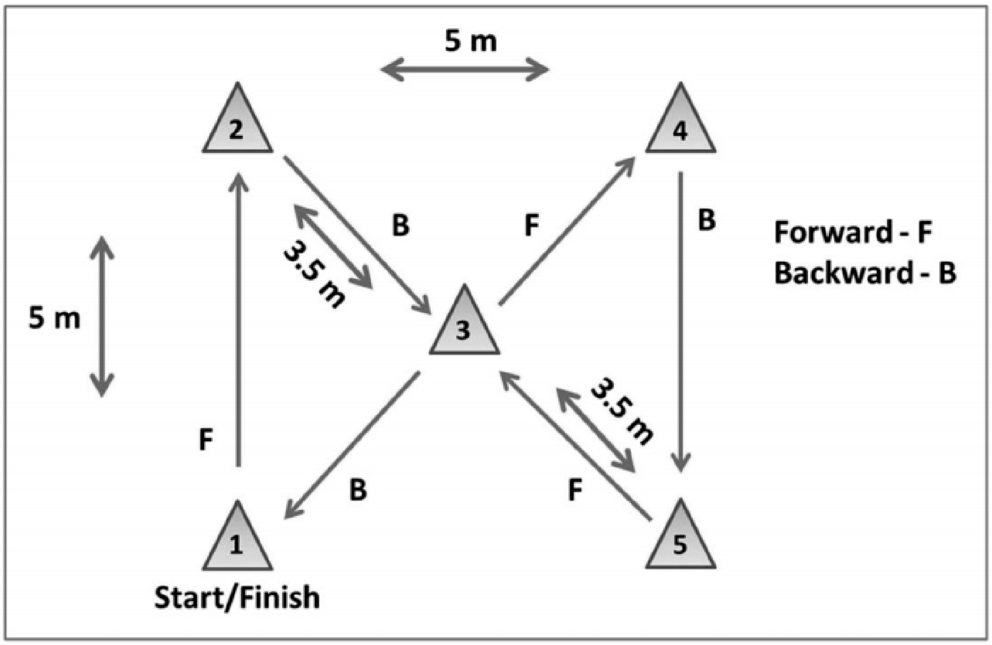

Figure 1. Presentation of the Agility Forward-Backward Test.

Zig-Zag Test

The Zig-zag test (Figure 2) evaluated running agility through direction changes. The path was divided into four 5 m segments (20 m in total) with cones at a 100° angle and two sets of photocells (Witty, Microgate, Bolzano, Italy), and participants needed to slowed down and accelerate through each cone as rapidly as they could from separate starting and ending places. The methods were reviewed with the players prior to testing. Players were asked to finish the test as soon as possible, starting from standing with their front foot 30 cm above the first pair of timed gates and crossing the second pair of photo cells. Players had a maximum of three tries with a 3-min gap. The Zig-zag test was also performed with the ball within the same conditions described earlier. The test's validity and reliability have been verified elsewhere [24,28].

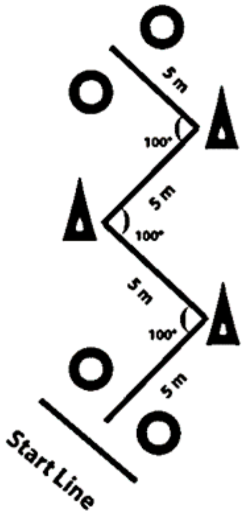

Figure 2. Presentation of the Zig-zag test.

Slalom Test

All participants began at point A with both feet (Figure 3). Six cones were placed 2 m apart, with the first cone 1 m from the starting point. Every player remained still, facing the starting line, his feet apart, the cone between his legs. He began following the signal and sprinted from point A to point B. The player at point B needed to be passed on his right side. The player proceeded to sprint as fast as possible, frequently changing directions from right to left, until he reached the player standing at the last point. After that point, the player made a 180-degree turn and continued running the slalom to the start line. The Slalom test was also performed with the ball under the earlier conditions. The test's validity and reliability have been verified elsewhere [29,30].

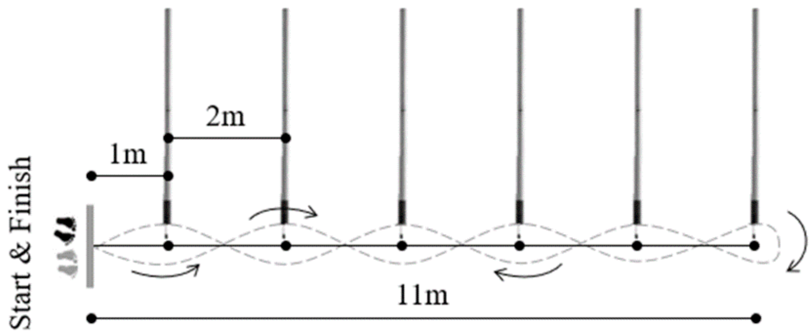

Figure 3. Presentation of the *Slalom test*.

2.4. Data Analysis

The descriptive statistics were expressed as each variable's mean and standard deviation. Differences in body composition, jump, sprint, and agility performance at five measurement points during the season were determined using a discriminatory parametric procedure with repeated measures ANOVA and Bonferroni post-hoc test, with a level of statistical significance set at $p < 0.05$. The data obtained in the research were processed using SPSS 26 software (Statistical Package for Social Sciences, v26.0, SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Body Composition

Based on repeated measures ANOVA, no significant differences in body composition parameters were found at five measurement points during the season.

3.2. Jump Performance

Based on ANOVA testing, a significant difference was found only in CMJ left between measurements ($p = 0.011$, ES = 0.703). According to Bonferroni post-hoc test, it was determined that players achieved significantly higher values in the fourth measurement compared to the first, as well as in the final (fifth) measurement compared to the first in CMJ left.

3.3. Linear Sprint Ability

Significant differences were found in measurement points during a season at 5 and 10 m ($p = 0.000$, ES = 0.904 and $p = 0.000$, ES = 0.872, respectively). It should be noted that the best time was achieved in the second measurement at 5 m (1.20 s), which was significantly better than the first and third measurements. Additionally, players achieved a better time in the fourth measurement compared to the third measurement point. There were no differences among the other measurements. For the 10-m split, the best time was also recorded in the second measurement, significantly better than the first and third measurements. The third measurement was inferior to both the first and fourth. There were no other differences in the 10-m split times. In the overall 30-m result, there were no significant differences among groups.

3.4. Agility Performance

Table 3 presents the results of agility tests at five measurement points during the season, with three agility tests performed without a ball and two with a ball. In the Slalom test without a ball, a significant difference was observed at the multivariate level ($p = 0.000$, ES = 0.939). Significantly better results were achieved in the second measurement compared to the first, third, and fourth measurements, as well as in the fifth measurement compared to the third and fourth measurements. In the Zig-Zag test without a ball, significant differences were also found at the multivariate level ($p = 0.000$, ES = 0.964). This difference was attributed to better results in the third measurement compared to all other measurements. In the third Agility test without a ball, there were no significant differences among groups.

Regarding agility tests with a ball, significant differences were observed in both tests among different measurement points, namely in the Slalom Ball ($p = 0.000$, ES = 0.936) and Zig-Zag Ball ($p = 0.000$, ES = 0.940) tests. In the Slalom Ball test, the differences were due to better results in the second measurement compared to the first, third, and fourth measurements, as well as better results in the fifth measurement compared to the first and fourth measurements, and in the fourth compared to the third measurement. In the

Zig-Zag Ball test, it was found that the players' results in the third measurement were significantly better than all other measurement points. There were no differences among other measurement points during the season.

Table 3. Parameters of body composition, jump, sprint, and agility among female handball players at five measurement points during the season; Descriptive statistics and ANOVA test.

Variables	I	II	III	IV	V	p	ES	Post-hoc
BH	173.18 ± 7.17	173.18 ± 7.17	173.18 ± 7.17	173.18 ± 7.17	173.18 ± 7.17	-	-	-
BM	66.69 ± 8.90	66.66 ± 8.42	66.70 ± 8.51	66.89 ± 8.72	68.39 ± 9.58	0.103	0.507	/
BMI	22.15 ± 1.66	21.96 ± 1.38	22.38 ± 1.36	22.01 ± 1.52	22.69 ± 1.79	0.180	0.437	/
%BF	28.16 ± 4.30	28.29 ± 5.78	28.24 ± 3.79	28.49 ± 3.72	29.41 ± 4.19	0.254	0.387	/
%MM	31.16 ± 2.28	31.79 ± 4.44	31.11 ± 2.17	30.94 ± 2.07	30.66 ± 2.23	0.351	0.333	/
SJ	24.56 ± 3.26	25.09 ± 2.74	24.79 ± 3.30	25.49 ± 2.62	25.42 ± 3.45	0.733	0.168	/
CMJ	26.93 ± 3.37	27.34 ± 3.59	26.41 ± 3.02	27.27 ± 3.18	26.82 ± 3.87	0.407	0.306	/
CMJA	31.76 ± 3.65	32.34 ± 3.67	31.11 ± 3.13	30.90 ± 3.42	31.27 ± 4.68	0.096	0.515	/
CMJ right	12.54 ± 1.96	14.00 ± 2.58	13.39 ± 1.54	14.25 ± 1.78	14.59 ± 2.35	0.084	0.530	/
CMJ left	12.76 ± 1.64	13.79 ± 2.47	13.44 ± 1.32	14.11 ± 1.56	15.15 ± 2.37	0.011 *	0.703	IV > I, V > I
5 m	1.26 ± 0.06	1.20 ± 0.07	1.32 ± 0.06	1.21 ± 0.07	1.24 ± 0.07	0.000 *	0.904	I > II, III > II, III > IV
10 m	2.09 ± 0.07	2.01 ± 0.08	2.18 ± 0.10	2.06 ± 0.10	2.08 ± 0.10	0.000 *	0.872	I > II, III > I, III > II, III > IV
30 m	4.93 ± 0.17	4.79 ± 0.16	4.97 ± 0.22	4.92 ± 0.21	4.83 ± 0.22	0.110	0.499	/
Agility	7.90 ± 0.49	7.60 ± 0.44	7.54 ± 0.40	7.69 ± 0.48	7.55 ± 0.54	0.162	0.451	/
Slalom	8.03 ± 0.33	7.25 ± 0.47	8.32 ± 0.43	8.32 ± 0.38	7.62 ± 0.54	0.000 *	0.939	I > II, III > II, III > V, IV > II, IV > V
SlalomBall	8.99 ± 0.64	8.15 ± 0.64	8.93 ± 0.45	8.96 ± 0.56	8.41 ± 0.65	0.000 *	0.936	I > II, I > V, III > II, III > IV, IV > II, IV > V
Zig-Zag	5.72 ± 0.32	5.64 ± 0.39	4.76 ± 0.18	5.45 ± 0.27	5.70 ± 0.35	0.000 *	0.964	I > III, II > III, IV > III, V > III
Zig-ZagBall	5.98 ± 0.31	5.85 ± 0.34	5.10 ± 0.38	5.86 ± 0.35	5.93 ± 0.31	0.000 *	0.940	I > III, II > III, IV > III, V > III

Legend: BH—body height; BM—body mass; BMI—body mass index; %BF—percentage of body fat; %MM—percentage of muscle mass; SJ—squat jump; CMJ—countermovement jump; CMJA: countermovement jump with arm swing; CMJright: countermovement jump on right leg; CMJleft: countermovement jump on left leg; 5 m—5-m sprint; 10 m—10-m sprint; 30 m—30-m sprint; Agility—Agility test; Slalom—Slalom agility test without a ball; SlalomBall—Slalom agility test with a ball; Zig-Zag—Zig-Zag agility test without a ball; Zig-ZagBall—Zig-Zag agility test with a ball; I—initial measurement point; II—second measurement point; III—third measurement point; IV—fourth measurement point; V—fifth measurement point (final); *p*—statistical significance; ES—partial effect size; *—denotes statistical significance.

4. Discussion

The aim of the research was to determine differences in body composition, jump, sprint, and agility at five measurement points during the season among elite female handball players. Based on repeated measures ANOVA and Bonferroni post-hoc test, the key findings were as follows: (i) there were no differences in body composition parameters among the players during the season; (ii) a significant difference was found only in one (CMJ left) of the five jump performance tests; it was found that players achieved significantly higher values in the fourth and fifth measurements compared to the initial measurement in CMJ left; (iii) significant differences were found in measurement points during the season at 5 and 10 m, while there was no difference at 30 m; in the 5-m sprint, players achieved significantly better times in the second measurement compared to the first and third, as well as in the fourth measurement compared to the third; in the 10-m sprint, significantly better times were also achieved in the second measurement compared to the first and third, while weaker results were achieved in the third measurement compared to the first and fourth; (iv) in four out of five agility tests, there were differences in measurements during the season; in two agility tests (Zig-Zag agility tests), significantly better results were achieved in the third measurement compared to other measurement points, while in the other two agility tests, generally better results were achieved in the second and fifth measurements compared to other measurement points.

The present study assessed seasonal changes in body composition, jump, sprint, and agility performance in elite female handball players across five competitive season measurements. Findings show seasonally adapted adaptations for specific performance metrics and demonstrate elite handball's physical and technical demands while underscoring the need for tailored, seasonally adjusted training regimes to optimize player performance.

The results showed that body composition parameters—such as body mass, body mass index (BMI), body fat percentage, and muscle mass—remained stable across the season, with no significant changes detected at any measurement point. This stability in body composition might indicate that the training regimen, coupled with nutritional guidance [31,32], effectively sustains physical attributes necessary for high-level handball performance throughout the season [19,33,34]. These findings align with previous research that noted minimal seasonal variation in body composition among female team sport athletes, likely because handball emphasizes agility, coordination, and endurance over substantial hypertrophy or fat loss [35,36]. This consistency could emphasize maintaining an optimal physique that supports agility, speed, and endurance, which are vital in handball to perform rapid directional changes and maintain competitive intensity [37,38]. The results suggest that for elite female athletes, body composition goals may not need to vary extensively throughout the season, allowing for a more targeted focus on performance-specific conditioning, especially strength, speed, and agility.

In jump performance, a significant improvement was noted only in the left leg countermovement jump (CMJ left), particularly in the fourth and fifth measurements compared to the initial measurement. This isolated increase may highlight an adaptation related to the asymmetric demands placed on the lower limbs in handballs, where unilateral jumps and pivots often occur, especially during offensive or defensive maneuvers [39,40]. Unilateral improvements in the CMJ left could suggest that the players' training regimen, or possibly gameplay patterns, encouraged the development of explosive strength and stability on the non-dominant leg, supporting previous studies that emphasize the importance of unilateral training for enhancing functional strength and balance in handball [41,42]. This finding may indicate the benefit of incorporating plyometric and unilateral strength training exercises focusing on both legs to enhance overall jump performance and minimize strength imbalances. However, the observed improvement in jump performance of the left leg during the last two measurements of the season compared to baseline may actually be a result of specific activities performed throughout the season. Since most of the players are right-handed and execute a large number of jumps off the left take-off leg during shots on goal in both training and matches, this repetitive use could explain the enhancement in left-leg jump performance.

Significant improvements were observed in sprint performance over the 5- and 10-m distances, with optimal sprint times recorded in the second and fourth measurements. These findings indicate a potential effect of targeted speed training integrated within the team's conditioning program during these periods. Unlike the 5- and 10-m sprints, no significant change was observed in the 30-m sprint, implying that short-burst sprints may be more relevant for handball athletes than extended sprints, as the sport typically involves brief, rapid accelerations during gameplay [43,44]. These findings reinforce the role of short-distance sprint training in the conditioning of handball players, aligning with studies indicating that acceleration over the first few meters is critical for in-game activities such as breakaways, defensive pressure, and quick directional transitions [13]. Therefore, short-distance sprints and plyometric exercises focused on acceleration may be beneficial in achieving performance improvements in female handball players.

Agility performance demonstrated significant variation across the season, with marked improvements in tests performed with and without the ball. Specifically, the Zig-Zag and Zig-zag agility tests without the ball yielded better results in the third and fifth measurements. In contrast, tests performed with the ball significantly improved the second and fifth measurements. This seasonal agility pattern may reflect the technical and physiological demands associated with handball [37,45], which requires frequent changes in direction, rapid accelerations, and coordinated hand-eye movements with the ball. The improvements observed in agility without the ball, in particular, may underscore the efficacy of periodized training phases that emphasize unweighted agility exercises, especially during the off-season or preseason periods when gameplay constraints less encumber maximal agility [5,29,46]. Agility with the ball, however, may benefit from increased in-season practice, where handling skills and ball coordination are critical for gameplay effectiveness [5]. These results suggest that coaches should consider the need for sport-specific agility exercises and, based on these results, maximize player performance by alternating agility and skill-based drills during the season to maintain high levels of agility with and without ball handling. This was in line with previous research recommendations for implementing drills similar to competitive scenarios to maximize agility and situational adaptability [47,48].

4.1. Practical Implications

The study's findings provide valuable insights into structuring training programs for elite female handball players. Given the stability in body composition, training emphasis might be reallocated toward skill-specific conditioning, such as short-burst sprinting and agility drills, which align with the functional movement patterns demanded by handballs. Coaches may focus on training components that address unilateral strength and plyometric drills for jump enhancement and short-distance sprint training to boost acceleration. Additionally, agility training can be optimized by balancing agility-with-ball and agility-without-ball exercises at different points in the season, enabling players to maintain agility and ball-handling performance when needed.

This highlights the importance of well-planned training periodization throughout the competitive season. Periodized training enables coaches to adjust the load, intensity, and focus areas according to the athlete's physiological readiness and the competition schedule. This tailored approach can help maintain high performance levels among handball players throughout the season and ensure peak readiness during key competitions.

4.2. Study Limits

This study, while insightful, is limited by its sample size and single-season scope, which may restrict the generalizability of the results. We encourage future research to explore further how multi-seasonal changes combine to affect performance parameters. A complete performance model over a season might be provided by considering hormonal cycles or fatigue management strategies. Such an analysis across other genders or competitive levels may also help in elucidating any specific training needs of female handball players. Such research would enhance our knowledge of the physical requirements and performance adaptations in elite female handballers and provide input for developing more accurate and efficient training programs for this gender and this subset of the athlete population. Also, future studies should investigate and isolate specific training protocols in more detail, in order to clearly determine which type of training and to what extent it influences variations in body composition and motor abilities. Finally, future research could explore the impact of other factors—such as overall training volume, number of games played, and the timing of matches (as recorded by GPS data or coaching statistics)—on the physical fitness of female athletes.

5. Conclusions

This study highlights the unique seasonal adaptations in physical performance among elite female handball players, with distinct improvements in short-distance sprinting, unilateral jump performance, and agility. The stability observed in body composition parameters underscores the effectiveness of existing training and nutritional strategies in maintaining an optimal physique for the handball's demands. However, improvement in special features like agility, with and without the ball, and short burst sprinting implies that specific training to these features via integrated programs might provide added value to maximizing players' in-game performance. These results can guide in-season training adjustments by emphasizing skill-specific and periodized approaches to conditioning. Coaches should incorporate more targeted drills for agility and sprinting to optimize performance during the season.

These results show that a periodized, skill-specific training program based on handball's physiological and technical demands is an essential component of high levels of athleticism throughout a competitive handball season, and coaches should be able to tailor their conditioning programs to sustain high levels of athleticism by these physiological and technical demands. Future research should focus on multi-season studies or intervention-based designs to further explore long-term adaptations and examine other critical factors, such as hormonal cycles and injury prevention, to provide a more comprehensive framework for supporting elite female handball athletes.

Author Contributions: Conceptualization, M.S., B.K., K.G., A.B., D.B., B.M. and I.B.; methodology, M.S., B.K., B.M. and I.B.; validation, I.B.; investigation, M.S. and I.B.; writing—original draft preparation, M.S., B.K., K.G., A.B., D.B., B.M. and I.B; writing—review and editing, A.B., D.B. and B.M.; supervision, B.K. and B.M. 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 was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board. The University of Niš (Republic of Serbia) approved this study decision (No. 04-1769/2) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets generated and analyzed during the current study are not publicly available for reasons of privacy.

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

References

1. Florin, T.D.; Adrian, G.; Marco, C.; Daniele, S.; Sara, B.; Christina, T.; Panos, P. Strategies and best practices for international handball development. *Ovidius Univ. Ann. Ser. Phys. Educ. Sport/Sci. Mov. Health* **2023**, *23*, 515–520.
2. Granli, A. Optimizing Physical Performance During the Competitive Season for Female Handball Players: A Comparative Study on the Effects of High-Load Strength Training Versus Power and Plyometric Training. Master's Thesis, University of Agder, Kristiansand, Norway, 2023.
3. Wagner, H.; Fuchs, P.; Fusco, A.; Fuchs, P.; Bell, J.W.; von Duvillard, S.P. Physical performance in elite male and female team-handball players. *Int. J. Sports Physiol. Perform.* **2019**, *14*, 60–67. [CrossRef]
4. Stankovic, M.; Djordjevic, D.; Trajkovic, N.; Milanovic, Z. Effects of high-intensity interval training (HIIT) on physical performance in female team sports: A systematic review. *Sports Med. Open.* **2023**, *9*, 78. [CrossRef]
5. Hammami, M.; Gaamouri, N.; Cherni, Y.; Gaied, S.; Chelly, M.S.; Hill, L.; Knechtle, B. Effects of complex strength training with elastic band program on repeated change of direction in young female handball players: Randomized control trial. *Int. J. Sports Sci. Coach.* **2022**, *17*, 1396–1407. [CrossRef]
6. Jeličić, M.; Jelaska, G.; Stanković, M.; Čaprić, I. Exploring interactions between performance and efficiency among junior female basketball players: A canonical analysis approach. *J. Phys. Educ. Sport* **2023**, *23*, 2246–2251. [CrossRef]

7. Bojić, I.; Pavlović, L. Correlation between coordination and situational-motor abilities of young female handball players. *Res. Phys. Educ. Sport Health* **2015**, *4*, 110–114.
8. Śliż, M.; França, C.; Martins, F.; Marszałek, P.; Gouveia, É.R.; Przednowek, K. Psychomotor abilities, body composition and training experience of elite and sub-elite handball players. *Appl. Sci.* **2025**, *15*, 176. [CrossRef]
9. Luteberget, L.S.; Trollerud, H.P.; Spencer, M. Physical demands of game-based training drills in women's team handball. *J. Sports Sci.* **2018**, *36*, 592–598. [CrossRef]
10. Kolodziej, M.; Schmidt, M.; Jaitner, T. Seasonal variations of performance parameters in female elite handball. In Proceedings of the 21st Annual Congress of the European College of Sport Science (ECSS), Vienna, Austria, 6–9 July 2016.
11. 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*, 149. [CrossRef]
12. Fristrup, B.; Krustrup, P.; Petz, A.K.; Bencke, J.; Zebis, M.K.; Aagaard, P. Effects of off-season heavy-load resistance training on lower limb mechanical muscle function and physical performance in elite female team handball players. *J. Funct. Morphol. Kinesiol.* **2024**, *9*, 268. [CrossRef]
13. Stanković, M.; Đorđević, D.; Aleksić, A.; Lazić, A.; Lilić, A.; Čaprić, I.; Trajković, N. The relationship between jump performance, speed and COD speed in elite female soccer players. *Facta Univ. Ser. Phys. Educ. Sport* **2022**, *20*, 47–59. [CrossRef]
14. Chirosa-Ríos, L.J.; Chirosa-Ríos, I.J.; Martínez-Marín, I.; Román-Montoya, Y.; Vera-Vera, J.F. The role of the specific strength test in handball performance: Exploring differences across competitive levels and age groups. *Sensors* **2023**, *23*, 5178. [CrossRef]
15. Papaevangelou, E.; Papadopoulou, Z.; Mandroukas, A.; Michaildis, Y.; Nikolaidis, P.T.; Margaritelis, N.V.; Metaxas, T.I. Changes in Anthropometric Characteristics and Isokinetic Muscle Strength in Elite Team Sport Players during an Annual Training Cycle. *Sci* **2023**, *5*, 43. [CrossRef]
16. Cavedon, V.; Zancanaro, C.; Milanese, C. Anthropometric prediction of DXA-measured body composition in female team handball players. *PeerJ* **2018**, *6*, e5913. [CrossRef] [PubMed]
17. Bojić, I.; Živković, M.; Kocić, M.; Veličković, M.; Milenković, D. Differences in explosive strength of elite female handball players during the competition season. *Facta Univ. Ser. Phys. Educ. Sport* **2020**, *17*, 601–608. [CrossRef]
18. Bojić, I.; Stojiljković, N.; Valdevit, Z.; Veličković, M.; Nikolić, D. Change in speed, agility and body composition of top-ranked female handball players during the playing season. *Facta Univ. Ser. Phys. Educ. Sport* **2020**, *17*, 515–522. [CrossRef]
19. Milanese, C.; Piscitelli, F.; Lampis, C.; Zancanaro, C. Effect of a competitive season on anthropometry and three-compartment body composition in female handball players. *Biol. Sport* **2012**, *29*, 199–204. [CrossRef]
20. Karcher, C.; Buchheit, M. On-court demands of elite handball, with special reference to playing positions. *Sports Med.* **2014**, *44*, 797–814. [CrossRef]
21. García-Sánchez, C.; Navarro, R.M.; Karcher, C.; de la Rubia, A. Physical demands during official competitions in elite handball: A systematic review. *Int. J. Environ. Res. Public Health* **2023**, *20*, 3353. [CrossRef]
22. Gorostiaga, E.M.; Granados, C.; Ibañez, J.; González-Badillo, J.J.; Izquierdo, M. Effects of an entire season on physical fitness changes in elite male handball players. *Med. Sci. Sports Exerc.* **2006**, *38*, 357–366. [CrossRef]
23. Parpa, K.; Katanic, B.; Michaelides, M. Seasonal variation and the effect of the transition period on physical fitness parameters in youth female soccer players. *Sports* **2024**, *12*, 84. [CrossRef] [PubMed]
24. Stanković, M.; Trajković, N.; Mačak, D.; Đorđević, D.; Lazić, A.; Milanović, Z. Effects of linear and change of direction high-intensity interval training on physical performance of elite female soccer players. *Biol. Sport* **2024**, *41*, 31–39. [CrossRef] [PubMed]
25. Markovic, G.; Dizdar, D.; Jukic, I.; Cardinale, M. Reliability and factorial validity of squat and countermovement jump tests. *J. Strength Cond. Res.* **2004**, *18*, 551–555. [PubMed]
26. Darrall-Jones, J.D.; Jones, B.; Roe, G.; Till, K. Reliability and usefulness of linear sprint testing in adolescent rugby union and league players. *J. Strength Cond. Res.* **2016**, *30*, 1359–1364. [CrossRef]
27. Vieira, F.; Veiga, V.; Carita, A.I.; Petroski, E.L. Morphological and physical fitness characteristics of under-16 Portuguese male handball players with different levels of practice. *J. Sports Med. Phys. Fit.* **2013**, *53*, 169–176.
28. Lockie, R.G.; Schultz, A.B.; Callaghan, S.J.; Jeffriess, M.D.; Berry, S.P. Reliability and validity of a new test of change-of-direction speed for field-based sports: The change-of-direction and acceleration test (CODAT). *J. Sports Sci. Med.* **2013**, *12*, 88–94.
29. Sporiš, G.; Milanović, L.; Jukić, I.; Omrčen, D.; Molinuevo, J.S. The effect of agility training on athletic power performance. *Kinesiology* **2010**, *41*, 65–72.
30. Sporis, G.; Jukic, I.; Milanovic, L.; Vucetic, V. Reliability and factorial validity of agility tests for soccer players. *J. Strength Cond. Res.* **2010**, *24*, 679–686. [CrossRef]
31. Clauss, M.; Gérard, P.; Mosca, A.; Leclerc, M. Interplay between exercise and gut microbiome in the context of human health and performance. *Front. Nutr.* **2021**, *8*, 637010. [CrossRef]
32. Holmes, C.J.; Racette, S.B. The utility of body composition assessment in nutrition and clinical practice: An overview of current methodology. *Nutrients* **2021**, *13*, 2493. [CrossRef]

33. Banjevic, B.; Zarkovic, B.; Katanic, B.; Jabucanin, B.; Popovic, S.; Masanovic, B. Morphological characteristics and situational precision of U15 and U16 elite male players from Al-Ahli Handball Club (Bahrein). *Sports* **2022**, *10*, 108. [CrossRef] [PubMed]
34. Molina-López, J.; Planells, E. Nutrition and hydration for handball. In *Handball Sports Medicine*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 81–101. [CrossRef]
35. Alcaraz, P.E.; Marín-Cascales, E.; Blazevich, A.J.; Freitas, T.T.; Donti, O.; Spyrou, K.; Bogdanis, G.C. SCS 6th Annual Meeting—EEVFA—11th International Congress of Biochemistry and Physiology of Exercise, Athens, Greece, 2023. *Sports* **2024**, *12*, 126. [CrossRef] [PubMed]
36. Darragi, M.; Zouhal, H.; Bousselmi, M.; Karamti, H.M.; Clark, C.C.T.; Laher, I.; Hackney, A.C.; Granacher, U.; Zouita, A.B.M. Effects of in-season strength training on physical fitness and injury prevention in North African elite young female soccer players. *Sports Med.-Open* **2024**, *10*, 94. [CrossRef]
37. Akbar, S.; Kim Geok, S.; Bashir, M.; Jazaily Bin Mohd, N.N.; Luo, S.; He, S. Effects of different exercise training on physical fitness and technical skills in handball players: A systematic review. *J. Strength Cond. Res.* **2024**, *38*, e695–e705. [CrossRef] [PubMed]
38. Aouichaoui, C.; Krichen, S.; Tounsi, M.; Ammar, A.; Tabka, O.; Chatti, S.; Zaouali, M.; Zouch, M.; Trabelsi, Y. Reference values of physical performance in handball players aged 13–19 years: Taking into account their biological maturity. *Clin. Pract.* **2024**, *14*, 305–326. [CrossRef]
39. Harper, D.J.; McBurnie, A.J.; Santos, T.D.; Eriksrud, O.; Evans, M.; Cohen, D.D.; Rhodes, D.; Carling, C.; Kiely, J. Biomechanical and neuromuscular performance requirements of horizontal deceleration: A review with implications for random intermittent multi-directional sports. *Sports Med.* **2022**, *52*, 2321–2354. [CrossRef]
40. Taberner, M.; Spencer, N.; Murphy, B.; Antflick, J.; Cohen, D.D. Progressing on-court rehabilitation after injury: The control-chaos continuum adapted to basketball. *J. Orthop. Sports Phys. Ther.* **2023**, *53*, 498–509. [CrossRef]
41. Lijewski, M.; Burdukiewicz, A.; Pietraszewska, J.; Andrzejewska, J.; Stachoń, A. Asymmetry of Muscle Mass Distribution and Grip Strength in Professional Handball Players. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1913. [CrossRef]
42. Zemková, E.; Zapletalová, L. The role of neuromuscular control of postural and core stability in functional movement and athlete performance. *Front. Physiol.* **2022**, *13*, 796097. [CrossRef]
43. Lara-Cobos, D.; Martínez-Aranda, L.M.; Sanz-Matesanz, M.; Cuadrado-Peñafiel, V.; Ortega-Becerra, M. Effects of the surface type on the sprint force–velocity–power profile of female beach handball top-level players. *Appl. Sci.* **2024**, *14*, 2952. [CrossRef]
44. Mikalonytė, R.; Paulauskas, R.; Abade, E.; Figueira, B. Correction: Effects of small-sided games vs. simulated match training on physical performance of youth female handball players. *PLoS ONE* **2024**, *19*, e0316740. [CrossRef] [PubMed]
45. Farley, J.B.; Stein, J.; Keogh, J.W.L.; Woods, C.T.; Milne, N. The relationship between physical fitness qualities and sport-specific technical skills in female, team-based ball players: A systematic review. *Sports Med.-Open* **2020**, *6*, 18. [CrossRef] [PubMed]
46. Hammami, M.; Gaamouri, N.; Aloui, G.; Shephard, R.J.; Chelly, M.S. Effects of a complex strength-training program on athletic performance of junior female handball players. *Int. J. Sports Physiol. Perform.* **2019**, *14*, 163–169. [CrossRef] [PubMed]
47. Dos'Santos, T.; McBurnie, A.; Thomas, C.; Jones, P.A.; Harper, D. Attacking agility actions: Match play contextual applications with coaching and technique guidelines. *Strength Cond. J.* **2022**, *44*, 102–118. [CrossRef]
48. Kovacikova, Z.; Zemková, E. The effect of agility training performed in the form of competitive exercising on agility performance. *Res. Q. Exerc. Sport* **2020**, *92*, 271–278. [CrossRef]