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Psychomotor Abilities, Body Composition and Training Experience of Elite and Sub-Elite Handball Players

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Abstract: Background: Handball is characterized by fast and dynamic movements requiring appropriate psychomotor abilities and body mass composition. High levels of reaction and movement time can be crucial factors influencing quick reactions and in-time decision-making at the handball court. The aim of this study was to assess psychomotor abilities among elite and sub-elite Polish and Portuguese male and female handball players at the different levels of competition. **Methods**: Computer Test2Drive systems were used to assess reaction time, movement time and percentage of correct responses of 199 handball players (60 females). **Results**: Statistically significant correlation was noted between SIRT cr and the Elite group (r = 0.44) and between the CHORT cr and all groups (r = 0.33). A statistical correlation between CHORT MT and total body water (r = 0.44) was also noted in Elite handball players. **Conclusions**: High level of psychomotor abilities and body composition seems to have impact on the competitive level in male and female handball players.

Keywords: handball; psychomotor abilities; reaction time; decision making; movement time; body composition

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1. Introduction

Modern elite handball is characterized by 60 min of repeated accelerations, sprints, jumps, shots, rapid changes of direction, and a high number of physical confrontations with opponent players [1,2]. Therefore, handball is a complex, multi factorial [3] dynamic sport discipline, where each team tries to score goals with different technical, tactical and physiological demands [4,5]. It is a kind of competitive sport that requires processing a significant amount of information at the same time [6], combined with possessing knowledge to correctly respond in a timely manner [7]. Therefore, modern handball results may depend on numerous factors [8,9] such as reaction time, movement time, decision-making or body composition [10,11]. The scientific research of Curiţianu et al. [12] can be an example showcasing that players' reaction speed has an impact on the number of effective quick attacks. Similarly, Ohnjec et al. [13] have shown, by quantifying 60 matches for the World Women's Handball Championship in 2003, that the possibility of a fast break is

determined by reaction speeds. Also Krawczyk [14] showed that top-level goalkeepers wait until the last second before reacting to the opponent's shot, which makes their decisions more effective. Moreover, high demands on the retention time and range of perception, and the multitude of visual stimuli and moving objects in the central as well as the peripheral field of vision at the same time makes handball a sport with a high need for perceptual competence in its players [15]. Approximately sixty per cent of offensive actions have a standard duration between 21 and 35 s, while seventeen per cent of them are short actions with a duration of less than twenty seconds [16,17]. Anticipation abilities and quick reaction time can be crucial in handball at different competitive levels [14,18–20]. The optimal reaction time for athletes is between 140 and 160 milliseconds [21]. This can also be used to assess psychophysical state and technical and tactical skills [22]. Although the basic physical and motor elements are important, physical training alone seems to not be enough for sporting success. So, psychomotor abilities like coordination and perception can play an important role in enabling players to successfully perform and respond to complex tasks [23]. In addition, success in motor coordination depends on individual perception (i.e., the ways in which a person perceives a given situation). Bideau [24] showed that professional handball goalkeepers' success depends on their ability to anticipate and shorten their reaction time. Related conclusions presented by Krawczyk et al. [14] show that handball goalkeepers exhibit high abilities in reaction time and motor time in terms of simple reaction time and choice reaction time. Moreover, Śliż et al. [25] showed statistically significant reaction and movement time differences between female handball players on different levels of competition. Furthermore, the female players from the Polish Women's Superliga exhibited the fastest reaction time according to the simple reaction time, choice reaction time and spatial anticipation test. Nevertheless, psychomotor abilities differentiate players by position, especially short-term memory capacity and reaction time [26]. Przednowek et al. [27] revealed that, in the majority of psychomotor tests, the first-division handball players had a shorter reaction time than players competing in lower leagues. It is also necessary to take note of the fact that appropriate anthropometric characteristics and body composition of male and female handball players at different training levels is very important in current handball [9–11,28–33]. The importance of adequate anthropometric characteristics and body composition was shown in a study by Martinez-Rodriguez et al. [34], who presented that female handball players have a proportion of fat mass of around 20%, with a slightly lower proportion in elite players. For male players, the proportion of fat mass is significant at around 14%, with a higher proportion in non-elite players.

Therefore, there are many scientific works about the relationship between body components and reaction time in team sports at the different gender, age, level of league and training competition characteristics [35–40]. A similar investigation published by Śliż et al. 2023 [9] showed that the level of selected motor abilities might be affected by some parameters of body composition.

Summarizing, a crucial matter of concern in handball can be finding a solution between body composition, training experience, reaction time, movement time and correct responses [41].

2. Aim

This study's aim was two fold: (i) to assess psychomotor abilities such as reaction time, movement time, correct responses in male and female handball players from the Elite and Sub-Elite Polish and Portuguese handball leagues during 2023/2024 season, (ii) analyze the relationship between body composition, training experience and psychomotor abilities in different levels of competition in Polish and Portuguese female and male handball players. Furthermore, the aim of this research was also to identify whether there was a correlation

between reaction time, movement time and correct response according to sex, age, body fat, body mass, fat-free mass, body height and total body water of male and female handball groups (Elite and Sub-Elite).

3. Material

Participants

The study group consisted of 199 handball players (60 female and 139 male) (Table 1) associated in the Polish and Portuguese Handball Federation (female average age: 29.3 ± 5.4 and male average age: 24.3 ± 3.9). The group of male and female handball players was divided into Elite and Sub-Elite athletes, according to the National division in which their team compete. The Elite group of female and male handball players were professionals and competed in the top national league, while the Sub-Elite group were semi-professionals playing in the second national league. Therefore, 68 Elite and 71 Sub-Elite male handball players were examined. Also, the female handball players consisted of 21 Elite and 39 Sub-Elite handball players. All female and male handball players participated in different competitive levels (Elite and Sub-Elite competition) in Poland and Portugal. Before the beginning of the tests, we received permission from the handball clubs to allow the players to participate in the scientific research. All the male and female handball players studied were Elite and Sub-Elite group who were tested during the Portuguese (March 2024) and Polish (April 2024) national competitions.

Table 1. Characteristic of Polish and Portuguese female and male handball players.

Group	Female Handball	Male Handball
N	60	139
Age	29.3 ± 5.4	24.3 ± 3.9
Body Height (cm)	180.6 ± 6.7	186.0 ± 7.0
Body Weight (kg)	78.9 ± 9.1	103.1 ± 15.2
BMI	29.3 ± 4.6	24.2 ± 2.1

N—number of participants, BMI—Body Mass Index.

4. Methods

4.1. Psychomotor Abilities Assessment

Test2Drive is a modern device that is clear and intuitive for the test participant. The tests are conducted using an online-connecting computer equipped with a touch monitor. The use of the touchscreen monitor makes it possible to replace the elaborate traditional apparatus, which significantly reduces the examination time. The entire examination with a complete battery of tests is carried out at one station. All tests of the Test2Drive system were preceded by a practice phase after which the test participant proceeded to the main test. Immediately after the examination, the participant had access to the reports and protocols of the results. The system is standardized with tables of norms. The report includes raw scores, as well as normalized results presented on a sten scale. Figure 1 shows 6 tests assessing psychomotor ability such as reaction time, movement time and correct response in SIRT, CHORT, HECOR, SPANT, PUT and PAMT tests. The compatibility and effectiveness of Test2Drive are confirmed by previous studies, making it an effective replacement for conventional psychological tests [21,42–44]. Simple reaction time (SIRT)—in a standing position, the participant's task is to move the forefinger from one box on the screen to another in response to a stimulus. All stimuli are identical, presented at random intervals. The test measures reaction time (from the stimulus to lifting the finger from the resting field) and movement time (movement time to the reaction field). The median reaction time and median motor time are therefore evaluated. Choice reaction time (CHORT)—in a

standing position, varying responses are required of the participant—depending on the displayed pattern, the participant must touch the appropriate box or hold back from reacting. In addition to reaction and movement time, an important variable is the percentage of correct reactions, indicating the effectiveness of inhibition processes. HECOR (hand–eye coordination) measures eye–hand coordination. The participant has to press the box under the presented stimulus. The test is a development of the idea of the classic Piórkowski apparatus. The variables are reaction time and movement time. SPANT (spatial anticipation test) was also designed to measure eye–hand coordination. The SPANT test involves tapping a box at the intersection of the row and column indicated by the signal. In these tests, the variables are reaction time, movement time and the percentage of correct responses. SPANT is the most complex task testing psychomotor performance. PUT (pop-up test) is based on Anna Treismann's trait-integration concept. The task involves searching a set of elements for an object defined by a conjunction of features. It allows for the assessment of visual search speed and attentiveness. The participant was instructed to select the black triangle pointing either vertically upward or downward. If no such triangle appeared, the participant was to click the "NONE" button located in the bottom-right corner to proceed to the next stage. The perception–anticipation of movement test (PAMT) involves evaluating the movement of objects and making decisions at the right moment. The result of the test is the percentage of correctly performed tasks. The participant was required to touch an object using the index finger in such a way that it would avoid collision with other objects while moving horizontally across the board. The tests were selected to correspond to the specifics of the profession that female and male handball players face. During a handball match, handball players make a significant number of decisions in offensive and defensive actions where reaction time can be key to achieve the individual and team goal.

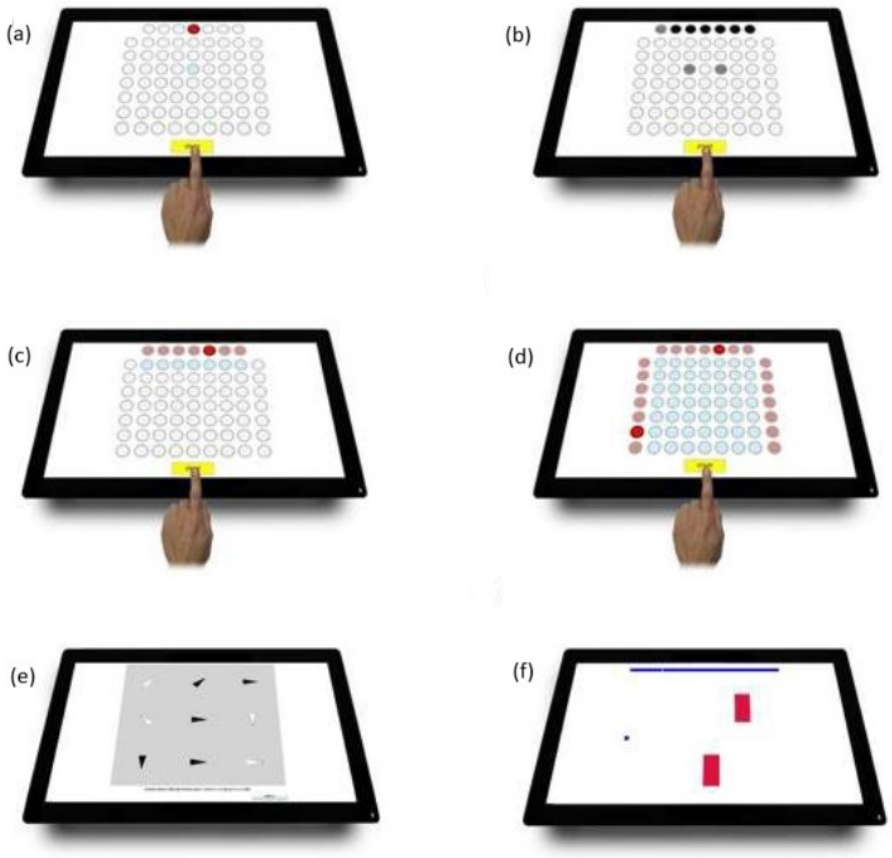

Figure 1. Reaction panel of the Test2Drive system: (**a**) SIRT, (**b**) CHORT, (**c**) HECOR, (**d**) SPANT, (**e**) PUT, (**f**) PAMT.

4.2. Statistical Analysis

Descriptive statistics were presented as mean ± standard deviation. A Shapiro–Wilk test was performed on all analyzed groups, which showed that the distribution of the data deviated from normal. Accordingly, the Mann–Whitney test was performed to identify statistically significant differences between Elite and Sub-Elite athletes. In addition, Spearman rank correlations were used to determine the relationship between the various components of body composition, experience and psychomotor performance. All statistical procedures were performed using IBM SPSS Statistics 29.0 software (SPSS Inc., Chicago, IL, USA), and the significance level was set at 5%. Scatter plots for selected variables were prepared in R Studio (version 4.3.3).

The G*Power 3.1 software was used to estimate the minimal sample size. For the Mann–Whitney test, a total number of N = 74 (37 in each group research and control) were required to detect the effect size of 0.80 at the 0.05 significance level and power 0.95.

5. Results

Table 2 presents specific selected psychomotor abilities in the group of Elite and Sub-Elite female handball players. In all tests performed, there were no statistically significant differences in reaction time and movement of players at different competitive levels. Analysis of the results obtained in the SIRT test showed that the reaction time is at a highly comparable level (Elite 333.48 ± 33.89, Sub-Elite 333.92 ± 36.23). Similar results were noted assessing correct responses in the SIRT test, in which the correct answers were Elite: 98.81 ± 2.69, Sub-Elite: 98.95 ± 2.88. Therefore, no statistically significant differences were seen in the SIRT test results obtained. However, faster reaction time in individual tests was characterized by female players. Such an example was observed in the CHORT test, in which a difference was noted between the test groups in reaction time in favor of the Elite group (658.95 ± 64.35 vs. 668.89 ± 57.38). Despite the difference in the results obtained, no statistical significance was observed. The HECOR test also showed that female handball players in the Elite group (393.14 ± 46.99) obtained shorter reaction times than the Sub-Elite group (405.58 ± 60.04). In two further tests (SPANT, PAMT) assessing reaction time, movement time and correct responses, the results obtained are at a very similar level and no statistical significance was noted between the study groups. The only statistically significant differences were observed in the PUT test, where the decisiveness of incorrect answers was assessed. The mean value for the Elite group was 95.43 ± 3.30, while the Sub-Elite group scored 94.11 ± 3.97 ($p = 0.0048$).

Table 3 presents specific selected psychomotor abilities in the group of Elite and Sub-Elite male handball players. In the group of handball players studied, in most cases no statistically significant differences were seen between the Elite and Sub-Elite male handball players. In addition, better results were observed for movement time in the SIRT, CHORT and HECOR tests. In the SIRT test, the average movement time for the Elite group was 227.24 ± 44.16 and for the Sub-Elite group it was 183.90 ± 37.87 ($p = 0.0004$). In the CHORT test, the Elite group also scored worse (239.86 ± 47.29) compared to the Sub-Elite group (197.49 ± 43.34), which was also statistically significant ($p = 0.0002$). A similar trend was also observed for the HECOR test, where the average movement time for the Elite group was 269.33 ± 51.58 versus the Sub-Elite group: 225.61 ± 35.59 ($p = 0.0001$).

Table 2. Numeral characteristics of psychomotor abilities of female handball players.

Variable		Total			Elite			Sub-Elite			e.s	*p*
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max		
SIRT	RT [ms]	333.76 ± 35.12	262.00	451.00	333.48 ± 33.89	262.00	383.00	333.92 ± 36.23	272.00	451.00	−0.05	0.3382
	MT [ms]	221.29 ± 35.16	162.00	331.00	227.24 ± 44.16	162.00	331.00	218.00 ± 29.19	166.00	283.00	−0.08	0.6123
	cr [%]	98.90 ± 2.80	85.00	100.00	98.81 ± 2.69	90.00	100.00	98.95 ± 2.88	85.00	100.00	0.03	0.8724
CHORT	RT [ms]	665.36 ± 59.60	509.00	793.00	658.95 ± 64.35	509.00	779.00	668.89 ± 57.38	577.00	793.00	0.10	0.5245
	MT [ms]	238.66 ± 42.01	161.00	382.00	239.86 ± 47.29	190.00	382.00	238.00 ± 39.44	161.00	305.00	0.05	0.7595
	cr [%]	94.59 ± 5.03	79.00	100.00	94.62 ± 4.20	83.00	100.00	94.58 ± 5.50	79.00	100.00	0.05	0.7357
HECOR	RT [ms]	401.15 ± 55.65	306.00	671.00	393.14 ± 46.99	306.00	486.00	405.58 ± 60.04	332.00	671.00	0.08	0.5988
	MT [ms]	261.31 ± 39.48	199.00	413.00	269.33 ± 51.58	214.00	413.00	256.87 ± 30.80	199.00	314.00	−0.08	0.2490
	cr [%]	99.32 ± 1.73	95.00	100.00	99.29 ± 1.79	95.00	100.00	99.34 ± 1.71	95.00	100.00	0.01	0.9437
SPANT	RT [ms]	614.20 ± 94.50	433.00	893.00	615.86 ± 113.46	433.00	893.00	613.29 ± 83.89	448.00	809.00	0.01	0.9312
	MT [ms]	293.80 ± 69.53	178.00	552.00	299.29 ± 90.76	193.00	552.00	290.76 ± 55.66	178.00	406.00	0.06	0.6561
	cr [%]	89.07 ± 10.40	40.00	100.00	88.81 ± 13.41	40.00	100.00	89.21 ± 8.50	65.00	100.00	−0.08	0.6319
PUT	cr [%]	94.58 ± 3.77	88.00	100.00	95.43 ± 3.30	88.00	100.00	94.11 ± 3.97	88.00	100.00	−0.19	0.2341
	cr [%] avr RT	1915.07 ± 384.46	1341.00	3120.00	2046.14 ± 473.76	1384.00	3120.00	1842.63 ± 308.60	1341.00	3021.00	−0.24	0.1273
	cr % inr RT	1335.76 ± 191.20	986.00	1868.00	1424.14 ± 199.43	986.00	1868.00	1286.92 ± 170.07	1024.00	1859.00	−0.44	0.0048 *
PAMT	cr [%]	87.73 ± 8.14	67.00	100.00	85.43 ± 9.01	67.00	100.00	89.00 ± 7.44	72.00	100.00	0.22	0.1574

SIRT—Simple Reaction Time, CHORT—Choice Reaction Time, HECOR—Hand–Eye Coordination Test, SPANT—Spatial Anticipation Test, PUT—Perception and Attention test, PAMT—Anticipation test, RT—reaction time, MT—movement time, cr—correct response, *p*—probability of testing, *—statistical significance.

Table 3. Numeral characteristics of psychomotor abilities of male handball players.

Variable		Total			Elite			Sub-Elite			e.s	*p*
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max		
SIRT	RT [ms]	337.73 ± 36.43	199.00	503.00	333.48 ± 33.89	262.00	383.00	334.24 ± 36.66	199.00	447.00	−0.05	0.2493
	MT [ms]	197.35 ± 43.61	111.00	345.00	227.24 ± 44.16	162.00	331.00	183.90 ± 37.87	111.00	319.00	−0.34	0.0004 *
	cr [%]	99.21 ± 2.11	90.00	100.00	98.81 ± 2.69	90.00	100.00	99.30 ± 1.94	90.00	100.00	0.02	0.8255
CHORT	RT [ms]	658.61 ± 82.06	238.00	886.00	658.95 ± 64.35	509.00	779.00	652.61 ± 81.27	238.00	811.00	−0.08	0.3888
	MT [ms]	212.49 ± 48.94	96.00	367.00	239.86 ± 47.29	190.00	382.00	197.49 ± 43.34	100.00	315.00	−0.36	0.0002 *
	cr [%]	94.87 ± 7.52	46.00	100.00	94.62 ± 4.20	83.00	100.00	94.79 ± 6.56	62.00	100.00	−0.08	0.4234
HECOR	RT [ms]	403.97 ± 38.48	262.00	529.00	393.14 ± 46.99	306.00	486.00	406.24 ± 34.78	316.00	483.00	0.10	0.3263
	MT [ms]	243.33 ± 48.30	147.00	432.00	269.33 ± 51.58	214.00	413.00	225.61 ± 35.59	147.00	302.00	−0.42	0.0001 *
	cr [%]	97.34 ± 13.78	0.00	100.00	99.29 ± 1.79	95.00	100.00	98.24 ± 9.82	20.00	100.00	0.07	0.4532
SPANT	RT [ms]	607.63 ± 91.23	421.00	818.00	615.86 ± 113.46	433.00	893.00	606.45 ± 90.38	438.00	812.00	−0.01	0.8773
	MT [ms]	249.76 ± 67.22	135.00	564.00	299.29 ± 90.76	193.00	552.00	238.63 ± 56.71	135.00	505.00	−0.19	0.0532
	cr [%]	92.30 ± 10.82	10.00	100.00	88.81 ± 13.41	40.00	100.00	91.62 ± 12.56	10.00	100.00	−0.03	0.7480
PUT	cr [%]	95.71 ± 4.10	69.00	100.00	95.43 ± 3.30	88.00	100.00	95.65 ± 3.90	81.00	100.00	−0.03	0.44123
	cr [%] avr RT	1909.64 ± 388.21	1106.00	3164.00	2046.14 ± 473.76	1384.00	3120.00	1884.72 ± 353.44	1118.00	3164.00	−0.05	0.1559
	cr [%] inr RT	1263.96 ± 176.98	925.00	1895.00	1424.14 ± 199.43	986.00	1868.00	1243.08 ± 148.20	925.00	1631.00	−0.07	0.4685
PAMT	cr [%]	84.09 ± 8.21	61.00	100.00	85.43 ± 9.01	67.00	100.00	84.01 ± 8.67	61.00	100.00	0.01	0.9180

SIRT—Simple Reaction Time, CHORT—Choice Reaction Time, HECOR—Hand–Eye Coordination Test, SPANT—Spatial Anticipation Test, PUT—Perception and attention test, PAMT—Anticipation test, RT—reaction time, MT—movement time, cr—correct response, *p*—probability of testing, *—statistical significance.

Table 4 presents correlation between specific selected psychomotor abilities, body composition components and training experience in the group of Elite and Sub-Elite male handball players. All statistically significant results are marked with an asterisk, and the numbers represent Spearman's rank correlation coefficients (r). It was observed that correct answers in the HECOR cr positively correlated (r = 0.27) with body mass and body height (r = 0.31) in the Sub-Elite group. In addition, a negative correlation coefficient was observed in HECOR cr with training experience in all the groups (r = −0.23), whereas SPANT cr showed a correlation with training experience in the Elite group (r = −0.30). A statistical significance was also noted in the male study group between PUT cr and fat-free mass (kg) (r = 0.18), and also between PAMT cr and body height (r = 0.19). No statistically significant correlations were observed for the SIRT and CHORT test.

Table 4. Correlation analysis between body composition, body height, training experience and correct answers among male handball players.

Variable	Group	SIRT cr [%]	CHORT cr [%]	HECOR cr [%]	SPANT cr [%]	PUT cr [%]	PAMT cr [%]
Body Fat [%]	Total	NS	NS	NS	NS	NS	NS
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Body mass [kg]	Total	NS	NS	NS	NS	NS	NS
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	0.27 *	NS	NS	NS
Fat-Free Mass [kg]	Total	NS	NS	NS	NS	0.18*	NS
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Body Height	Total	NS	NS	NS	NS	NS	0.19 *
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	0.31 *	NS	NS	NS
Total Body Water [L]	Total	NS	NS	NS	NS	NS	NS
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Training Experience [years]	Total	NS	NS	−0.23 *	NS	NS	NS
	Elite	NS	NS	NS	−0.30*	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS

cr—correct response; *—statistical significance ($p < 0.05$); NS—not statistically significant; Values represent Spearman's rank correlation coefficient (r).

Table 5 shows the correlation analysis between body composition, body height, training experience and correct response. Correlations of moderate strength were noted between the SIRT cr and Elite group (r = 0.44) and between CHORT cr and all the groups (r = 0.33). In most cases, a negative correlation was also observed in SIRT cr with body height in all the groups (r = −0.26) and the Elite group (r = −0.38), as well as in SIRT cr with total body water in all the groups (r = −0.26). Correlation of high strength, however, was observed between SPANT cr and body fat percentage in the Elite group (r = −0.58) and in the whole group (r = −0.37). Comparable occurrence was observed between SPANT cr and body mass (kg) and fat-free mass (kg) with strong correlation. Moreover, a statistical significance in PAMT cr it was also observed with body mass (kg) and fat-free mass (kg) and training experience in all groups (r = −0.38). No statistically significant correlations were observed for the HECOR and PUT tests.

Table 5. Correlation analysis between body composition, body height, training experience and correct answers among female handball players.

Variable	Group	SIRT cr [%]	CHORT cr [%]	HECOR cr [%]	SPANT cr [%]	PUT cr [%]	PAMT cr [%]
Body Fat [%]	Total	NS	0.33 *	NS	−0.37 *	NS	NS
	Elite	NS	NS	NS	−0.58 *	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Body Mass [kg]	Total	NS	NS	NS	−0.54 *	NS	−0.48 *
	Elite	NS	NS	NS	−0.78 *	NS	−0.54 *
	Sub-Elite	NS	NS	NS	NS	NS	NS
Fat-Free Mass [kg]	Total	NS	NS	NS	−0.46 *	NS	−0.56 *
	Elite	NS	NS	NS	−0.66 *	NS	−0.58 *
	Sub-Elite	NS	NS	NS	NS	NS	−0.49 *
Body Height	Total	−0.26 *	NS	NS	NS	NS	NS
	Elite	−0.38 *	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Total Body Water [L]	Total	−0.26 *	NS	NS	NS	NS	NS
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Training Experience [years]	Total	NS	NS	NS	NS	NS	−0.38 *
	Elite	0.44 *	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS

cr—correct answers; *—statistical significance ($p < 0.05$); NS—not statistically significant; Values represent Spearman's rank correlation coefficient (r).

Table 6 shows the correlations analysis between body composition, body height, age and movement time in male handball players. A weak to moderate correlation was observed in CHORT MT (r = −0.30) and SPANT MT (r = −0.26) with age in the Sub-Elite group. While the HECOR MT test showed a statistically significant correlation with body fat % (r = −0.20) in all the groups of players, fat-free mass (kg) also saw a significant correlation (r = −0.26) in the Sub-Elite group.Moreover, in the same test, there was also a moderate correlation with total body water (r = −0.37). No statistically significant correlations were observed for the SIRT test.

Table 6. Correlation analysis between body composition, body height, age and movement time among male handball players.

Variable	Group	SIRT MT [ms]	CHORT MT [ms]	HECOR MT [ms]	SPANT MT [ms]
Body Fat [%]	Total	NS	NS	−0.20 *	NS
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS
Body Mass [kg]	Total	NS	NS	NS	NS
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS
Fat-Free Mass [kg]	Total	NS	NS	NS	NS
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	NS	−0.26 *	NS
Body Height	Total	NS	NS	NS	NS
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS
Total Body Water [L]	Total	NS	NS	−0.19 *	−0.18 *
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	NS	−0.37 *	NS
Age [years]	Total	NS	NS	NS	NS
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	−0.30 *	NS	−0.26 *

MT—movement time; *—statistical significance ($p < 0.05$); NS—not statistically significant; Values represent Spearman's rank correlation coefficient (r).

Table 7 shows the correlation analysis between body composition, body height, age and movement time in female handball players. A moderate correlation was observed between CHORT MT and total body water (r = 0.44) in Elite handball players. Meanwhile, HECOR MT correlated with age in the Sub-Elite group (r = −0.39). Moreover, SPANT MT showed a correlation with fat-free mass (r = −0.30) and total body water (r = −0.30) in all the groups. No significant relationships were shown for the SIRT test.

Table 7. Correlation analysis between body composition, body height, age and movement time among female handball players.

Variable	Group	SIRT MT [ms]	CHORT MT [ms]	HECOR MT [ms]	SPANT MT [ms]
Body Fat [%]	Total	NS	NS	NS	NS
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS
Body Mass [kg]	Total	NS	NS	NS	NS
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS
Fat-Free Mass [kg]	Total	NS	NS	NS	−0.30 *
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS
Body Height	Total	NS	NS	NS	NS
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS
Total Body Water [L]	Total	NS	NS	NS	−0.30 *
	Elite	NS	0.44 *	NS	NS
	Sub-Elite	NS	NS	NS	NS
Age [years]	Total	NS	NS	NS	NS
	Elite	NS	NS	NS	NS
	Sub-Elite	NS	NS	−0.39 *	NS

MT—movement time; *—statistical significance ($p < 0.05$); NS—not statistically significant; Values represent Spearman's rank correlation coefficient (r).

The correlation analysis between body composition, body height, age and reaction time in male handball players was presented in Table 8. A weak-to-moderate correlation was observed between SIRT reaction time and body mass (r = 0.32), fat-free mass (r = 0.28) and total body water (r = 0.31) in the Sub-Elite group. Meanwhile, SIRT reaction time correlated in the Elite group with total body water (r = 0.24). It is noteworthy that, in the HECOR test in relation to the Sub-Elite group, the highest values for correlation were determined with fat-free mass and total body water in all the groups as well as in the Sub-Elite group. A correlation was also observed with body fat (r = 0.28) in the Elite group.Moreover, a weak correlation was observed in PUT reaction time with body height (r = −0.14) in all groups. No meaningful relationship were observed for the CHORT reaction time, SPANT reaction time and PUT reaction time tests.

Table 9 shows the correlation analysis between body composition, body height, age and reaction time in female handball players. A weak-to-moderate correlation was observed in CHORT reaction time with body mass (r = 0.27) and age (r = 0.27) in all handball groups and in PUT reaction time with body fat percentage (r = 0.59) in the Elite group, as also with age (r = 0.30) in all groups. Moreover, in PUT k reaction time, a correlation was observed with fat-free mass in the Elite group (r = 0.52) and in all the groups (r = 0.33). Furthermore, a correlation was also observed for total body water in the Elite group (r = 0.56) and all the groups (r = 0.36), as well as for age (r = 0.32) in all the groups. No relationships were observed for the SIRT reaction time, HECOR reaction time and SPANT reaction time tests.

Table 8. Correlation analysis between body composition, body height, training experience and reaction time among male handball players.

Variable	Group	SIRT RT [ms]	CHORT RT [ms]	HECOR RT [ms]	SPANT RT [ms]	PUT RT [ms]	PUT k RT [ms]
Body Fat [%]	Total	NS	NS	NS	NS	NS	NS
	Elite	NS	NS	0.28 *	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Body Mass [kg]	Total	0.16 *	NS	NS	NS	NS	NS
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	0.32 *	NS	0.25 *	NS	NS	NS
Fat-Free Mass [kg]	Total	NS	NS	0.22 *	NS	NS	NS
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	0.28 *	NS	0.43 *	NS	NS	NS
Body Height	Total	NS	NS	NS	NS	NS	−0.14 *
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Total Body Water [L]	Total	NS	NS	0.21 *	NS	NS	NS
	Elite	0.24 *	NS	NS	NS	NS	NS
	Sub-Elite	0.31 *	NS	0.43 *	NS	NS	NS
Age [years]	Total	NS	NS	NS	NS	NS	NS
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS

RT—reaction time; *—statistical significance ($p < 0.05$); NS—no statistical significance; Values represent Spearman's rank correlation coefficient (r).

Table 9. Correlation analysis between body composition, body height, training experience and reaction time among female handball players.

Variable	Group	SIRT RT [ms]	CHORT RT [ms]	HECOR RT [ms]	SPANT RT [ms]	PUT RT [ms]	PUT k RT [ms]
Body Fat [%]	Total	NS	NS	NS	NS	0.33 *	NS
	Elite	NS	NS	NS	NS	0.59 *	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Body Mass [kg]	Total	NS	0.27 *	NS	NS	NS	NS
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Fat-Free Mass [kg]	Total	NS	NS	NS	NS	NS	0.33 *
	Elite	NS	NS	NS	NS	NS	0.52 *
	Sub-Elite	NS	NS	NS	NS	NS	NS
Body Height	Total	NS	NS	NS	NS	NS	NS
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS
Total Body Water [L]	Total	NS	NS	NS	NS	NS	0.36 *
	Elite	NS	NS	NS	NS	NS	0.56 *
	Sub-Elite	NS	NS	NS	NS	NS	NS
Age [years]	Total	NS	0.27 *	NS	NS	0.30 *	0.32 *
	Elite	NS	NS	NS	NS	NS	NS
	Sub-Elite	NS	NS	NS	NS	NS	NS

RT—reaction time; *—statistical significance ($p < 0.05$); NS—not statistically significant; Values represent Spearman's rank correlation coefficient (r).

Figure 2 presents the correlations between body mass [kg], body fat [%] and percentage of correct answers in the SPANT Cr [%] test. The blue dots on the chart illustrate the individual results of the athletes, while the red line represents the overall trend line, showing the general tendency. Among elite female athletes, a statistically significant negative correlation ($p < 0.05$) was observed for both of the above cases. High strength correlations, for body mass (r = −0.78) and body fat (r = −0.58), indicate that an increase in body mass and body fat content decreases the number of correct answers on the SPANT cr test.

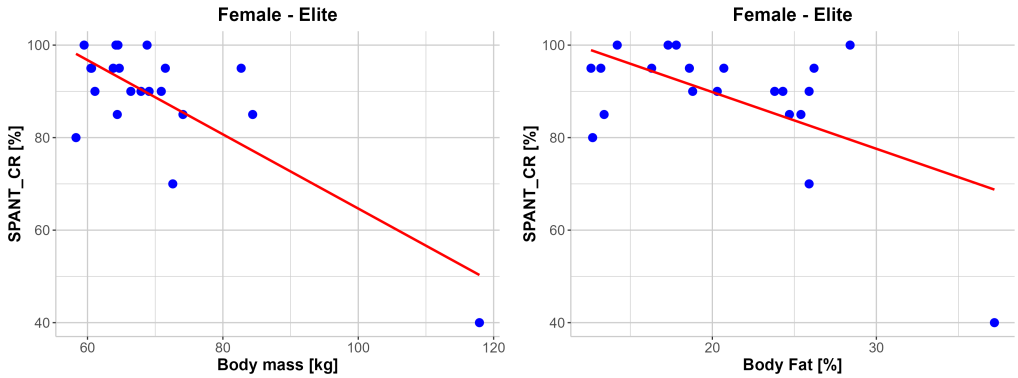

Figure 2. Scatter plot of SPANT test results in a group of professional female players: relationship between body fat, body mass, and the number of correct answers (CR). Blue dots represent individual results of the athletes, while the red line indicates the overall trend line showing the general tendency.

6. Discussion

The purpose of this study was to assess psychomotor abilities in male and female handball players from the Elite and Sub-Elite Polish and Portuguese handball leagues during the 2023/2024 season. Moreover, the aim of this evaluation was to analyze the relationship between body composition, training experience and psychomotor abilities at different levels of competition in Polish and Portuguese male and female handball players. Additionally, this study sought to identify potential correlations between reaction time, movement time and correct responses across male and female handball players in both Elite and Sub-Elite groups, with respect to variables such as sex, age, body fat percentage, body mass, fat-free mass, body height and total body water. Handball is considered to be a sport that requires the player to be constantly ready and maintain attention during offensive and defensive actions [5], even though there are shorter or longer breaks, as the sport is dominated by sudden and rapid changes in the direction and position of the players [1,2,15,45]. Therefore, appropriate development of psychomotor abilities in combination with appropriate physique and body composition of male and female handball players seems to be important in this competitive team sport.

In recent years, the problem of psychomotor abilities in team games of professional and amateur sport in the wide sense has been repeatedly undertaken by scientists all over the world. There are scientific investigations in the literature related to the assessment of reaction time, movement time, eye–hand coordination and anticipation in team sports [9,20,26,27]. Furthermore, there are also scientific publications in the literature connected to the relationship between body components and reaction time in the different level of competition [25,27,46]. Therefore, the aim of this study was to investigate the relationship between body composition, training experience and psychomotor abilities among female and male handball players of different competitive levels.

Through the analysis of the psychomotor performance assessment tests, it can be seen that the group of Elite male handball players with more training experience achieved a better result in the SPANT cr ($r = -0.30$) psychomotor test. This shows that, the more experience athletes have, the better percentage of correct answers handball players achieve. Similar results were presented by Jackson and Mogan [47], in which their analysis showed that players at a higher level of competition are characterized by a greater level of anticipation as compared to amateurs. The same conclusions were also presented in a study by Przednowek et al. [27], where the fastest reaction time occurred among those practicing sport with the longest seniority (more than 14 years), while better performance in movement time (MT) was seen among the study group with a seniority of 10–14 years. These results raise the hypothesis that more experienced handball players should have greater an-

ticipatory abilities and correct response than the group with lower seniority. However, in a study of Shelton et al. [48] on female handball players, the authors investigated differences in reaction speed to situations depending on the sporting level represented. Furthermore, Ando et al. [49] showed that reaction time decreased with repeated exercise, which suggests that, the more experienced the player, the shorter the reaction time is.

As already mentioned, many scientific publications aimed to evaluate the relationship between reaction time and movement time with body composition parameters [1,9,37,39,46,50,51]. The results of the handball players showed a statistically significant relationship between the SPANT cr test and selected body mass components ($p < 0.05$). A negative correlation was observed with the body fat percentage in the Elite group (r = −0.58), in the whole group of female athletes (r = −0.37), as well as with body weight (kg) and lean body mass (kg). Studies have shown that, the lower the level of body fat, the higher the number of observed and correct answers. This suggests that body fat level may affect correct decision-making during a handball match. A parallel situation took place in the test in PAMT cr with body mass (kg) and fat-free mass (kg) in all the groups. This shows that, the higher the body mass, the fatter, the lower the number of correct responses.

Moreover, in HECOR MT test was observed a statistical correlation with body fat percentage in all male groups, as well as a correlation with fat-free mass and total body water (kg) in the Sub-Elite group. Meanwhile, in the group of female handball players, SPANT MT correlated with fat-free mass and total body water. Such conclusions are confirmed by the studies of other researchers. Skurvydas et al. [46] observed that the group of participants with a higher level of BMI had a significantly longer reaction time. Moreover, they noticed significant differences between the reaction time of the mid- and high-BMI groups [46]. Meanwhile, in the research of Arabaci et al. [50], the authors noticed that lower leg fat percentages and fat mass in taekwondo athletes affected the reaction time in a positive way. Moreover, Poliszczuk et al. [51], in their research on reaction time and body tissue composition of upper limbs in young female basketball players, found a correlation between movement time and the FFM [kg] (r = −0.62), as with PMM [kg] (r = −0.63) parameters.

Referring to the results obtained in a group of female and male handball players at the different levels of competition, it should be concluded that even small differences in body mass composition can have a substantial influence on the speed of in-time decision-making on the pitch, anticipation of the opponent's movement and reaction time and movement time during each offensive and defensive action in handball.

This scientific study has some limitations that need to be taken into account during its interpretation. The number of male handball players is very similar, but only 60 were tested in the female group, divided into Elite and Sub-Elite groups. We also did not have a balanced number between male and female handball players. A larger sample would have ensured greater consistency and range of results presented.

Regarding the female sample size in this study, it is important to note that the relatively small number of female participants could impact the broader applicability of the results. Therefore, future research with a larger and more diverse sample of female participants is necessary to enhance the generalizability of the results and provide more comprehensive insights into the psychomotor abilities, body composition and training experience of female handball players across various levels of competition.

The findings of this study on psychomotor abilities, body composition and training experience of Elite and Sub-Elite handball players have several practical implications for handball coaches, particularly in the context of optimizing player performance. For example, this study suggests that body fat percentage, fat-free mass and total body water may influence reaction time, movement time and correct responses. Coaches can use this infor-

mation to identify players who may benefit from adjustments in their body composition, such as implementing specific conditioning training to reduce body fat or increase lean muscle mass. Elite players, who have accumulated more years of experience, may demonstrate superior reaction time and movement efficiency compared to Sub-Elite players. Therefore, training programs for Sub-Elite players could focus on accelerating the development of these psychomotor abilities, with an emphasis on speed and decision-making under pressure. Lastly, by systematically tracking changes in body composition and their potential impact on psychomotor performance, coaches can refine training system, providing athletes with individualized feedback to optimize their physical and mental capabilities.

7. Conclusions

Based on the analysis of the data, the following hypotheses were formulated:

1. The results seems to indicate that, the higher the level of body mass, body fat and total body water, the lower the level of correct responses in psychomotor performance assessment tests.
2. There is a relationship between SPANT cr and training seniority among the male handball Elite group. This demonstrates that, the greater the level of experience of the players, the lower the percentage of correct responses of the male handball players.
3. A statistical correlation was observed between movement time in the HECOR test and body fat in the Elite and Sub-Elite male handball players; moreover, fat-free mass and total body water (kg) correlated in the Sub-Elite group.

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Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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