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The Impact of Coordination Training on Psychomotor Abilities in Adolescent Handball Players: A Randomized Controlled Trial

Michał Spieszny [1,*], Zygmunt Kamys [2], Krzysztof Kasicki [3], Wojciech Wąsacz [1], Tadeusz Ambroży [1], Jarosław Jaszczur-Nowicki [4] and Łukasz Rydzik [1]

1 Institute of Sports Sciences, University of Physical Education, 31-571 Krakow, Poland; wojciech.wasacz@doctoral.awf.krakow.pl (W.W.); tadek@ambrozy.pl (T.A.); lukasz.rydzik@awf.krakow.pl (Ł.R.)
2 Polish Handball Federation, 02-819 Warszawa, Poland; zkamys@smskielce.pl
3 Faculty of Medicine and Health Sciences, University Andrzej Frycz-Modrzejewski Krakow, 30-705 Krakow, Poland; krzysztof.kasicki2@gmail.com
4 Department Physiotherapy, School of Public Health, Collegium Medicum, University of Warmia and Mazury, 10-719 Olsztyn, Poland; j.jaszczur-nowicki@uwm.edu.pl
* Correspondence: michal.spieszny@awf.krakow.pl

Abstract: Background: Handball requires significant psychomotor skills, especially in young athletes, to enhance performance. Coordination training is crucial but under-researched in this context. The objective of this study was to evaluate the impact of an experimental coordination training program on the psychomotor abilities of young handball players. Methods: A randomized controlled trial was conducted with 27 young handball players. Participants were divided into an experimental group (n = 15) receiving additional coordination training and a control group (n = 12) following standard training. Psychomotor skills were assessed before, during, and after the intervention by PNTR (Computer Tests of Coordination Abilities) tests. Statistical analysis included the Mann–Whitney U test for between-group differences and the Wilcoxon test for within-group comparisons, with significance set at $p < 0.05$. Results: The experimental group showed significant improvements in psychomotor performance, including reaction time and visual–motor coordination, compared to the control group. Specifically, there were statistically significant improvements in simple reaction time, visual–motor coordination, spatial orientation, attention distribution, and perception orientation. Conclusions: Coordination training effectively enhances the psychomotor abilities of young handball players, suggesting that its integration into regular training sessions can optimize performance.

Keywords: young athletes; experimental training; psychomotor performance

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1. Introduction

Handball, as one of the team sports, enjoys popularity among adults, youth, and children alike [1,2]. The interest of children and youth in handball is of great importance in the context of their development and the popularization of this sport [3]. Many countries invest in training programs aimed at nurturing a new generation of players [4]. As a result, handball not only maintains its popularity but also continues to grow and attract more enthusiasts worldwide.

The multifaceted nature of this sport requires appropriate physical preparation, both for beginners and advanced players [5]. For this reason, young athletes, even in the early years of their sports careers, focus on improving coordination as well as overall strength and speed, which are motor abilities that contribute to enhancing sports performance and results [6,7]. In handball, coordination is particularly important, as it involves a wide range of cognitive abilities, allowing the player to quickly assess a situation, make decisions, and execute motor tasks [8,9]. Hence, there is interest among researchers in training that influences the development of broadly understood cognitive abilities, especially its application in handball [10–12]. According to some authors, training that improves motor coordination optimizes motor skills, which contributes to the gradual enhancement of abilities specific to a particular type of physical activity and sport discipline [13,14].

The current literature on the subject was analyzed, which, according to the authors, revealed the need for further research to develop innovative training stimuli and to include coordination training for young individuals playing handball professionally [15–17]. At present, there is a shortage of studies that focus solely on the effects of coordination training programs on visuomotor relationships and cognitive characteristics. Future analyses should concentrate on exploring the connections between simple and complex reaction times and visuomotor coordination, as this could be a crucial aspect of understanding these effects [18–21].

It is suggested that reaction time can be a good indicator of the speed and efficiency of mental processes [22], which can be very important for handball players during match situations. This is indicated, among other things, by the results obtained by Krawczyk et al. in a publication on the psychomotor performance of handball goalkeepers, where the average reaction time in choice reaction situations was 292.67 ms, while the average motor time was 75.50 ms. These results were classified as above average compared to normative values, indicating that goalkeepers exhibit superior psychomotor skills, which are crucial for their role in handball [23]. Moreover, significant differences are observed among players of different ages concerning reaction time variability [24].

It is known that, with age, from a certain point onward, the level of coordination abilities decreases [25]. To systematically shape and improve these abilities and, consequently, optimize sports performance, there is a strong need to implement new training concepts that positively affect the cognitive abilities of young handball players, which is the goal of this research study. Therefore, the aim of this study was to assess the impact of an experimental training program on changes in the psychomotor profile of a group of young handball players.

2. Materials and Methods

The study was conducted according to the Declaration of Helsinki and approved by the Bioethics Committee at the District Medical Chamber in Krakow (No. 205/KBL/OIL/2022). Participants were informed about the objectives and methods of the study, potential side effects, and the possibility of withdrawing from the study at any time without providing a reason. Written consent was obtained from the parents and legal guardians for participation in the study.

2.1. Study Design

An experimental approach with repeated measurements and a randomized controlled trial was employed. The testing procedure was conducted before, during, and after the 8-month experimental training period. For the experimental group (EXP), the intervention was integrated into their regular training program, supplemented with specific coordination exercises. The control group (CON) followed their standard program of physical and technical–tactical training.

2.2. Participants

The study was conducted with a group of 27 male professional handball players. The sample size was calculated using G*Power v 3.1.9.6 (effect size f = 0.65, α = 0.05) with an actual power of 80%. The participants were aged 14.1 $\pm$ 0.2 years. Initially, 45 competitive players were recruited. Eighteen of them were excluded from the study due to exclusion criteria (history of injuries or health status). Inclusion and exclusion criteria were adopted to ensure the selection of regularly training players with appropriate coordination skills and a high level of training experience for their age (average 3.7 $\pm$ 0.72) and competitive play time (20% of total game time in league matches, i.e., a minimum of 100 min) (Table 1).

Table 1. Inclusion and exclusion criteria for handball players.

Adolescent Handball Players (n = 45)	
Included: n = 27 Inclusion Criteria	Excluded: n = 18 Exclusion Criteria
Age > 14 years	Current injuries or conditions that may affect participation in training or studies.
>100 min time play	Lack of consent from the athlete or their legal guardians for participation in the study.
Training experience > 3 years training	Athletes with no experience in league competitions.

At this level, the recruited cohort was allocated into two groups (experimental group n = 15 and control group n = 12). The assignment was carried out randomly using a random number generator.

2.3. Methodological Characteristics of the Experimental Intervention

The research intervention involved manipulating the training process for players in the experimental group by modifying the training program according to the principles of pedagogical experiments [26,27]. Three measurements were taken over the course of one macrocycle (which was also the experimental training period), lasting 8 months, from September 2023 to April 2024. The first assessment (pre-test) was conducted before introducing the experimental training into the training program. The second assessment (post-test 1) was carried out during the training program, 4 months after the experiment began (to control the effect). The final measurement (post-test 2) was conducted one week after the conclusion of the training program. During the experimental period, both groups performed handball training sessions lasting 90 min, 5 times a week. During this time, the control group followed the standard training included in their training program, which did not incorporate the experimental stimulus of additional coordination exercises. Figure 1 presents a flowchart of the research intervention.

2.4. Characteristics of the Experimental Training Program

All tasks aimed at enhancing motor coordination were included within a 15 to 30 min segment of the 90 min training session. One of the key priorities of this program was the variety of exercises used. A wide range of training equipment was employed, and the complexity of the exercises varied and increased throughout the experiment (progressive difficulty principle). Another significant feature was the timing of the stimulus during training. The coordination exercises were not directly preceded by intense anaerobic or mixed exercises. Coordination tasks were integrated into warm-ups, technical–tactical drills, and tactical activities. The number of training units in the macrocycle that included exercises aimed at developing broadly understood motor coordination ranged from 3 to 4 sessions. The exercises were designed and implemented with the intention of targeting all muscle groups of the participants, both analytically and holistically. Detailed contents of the coordination training exercises in the experimental program are presented below.

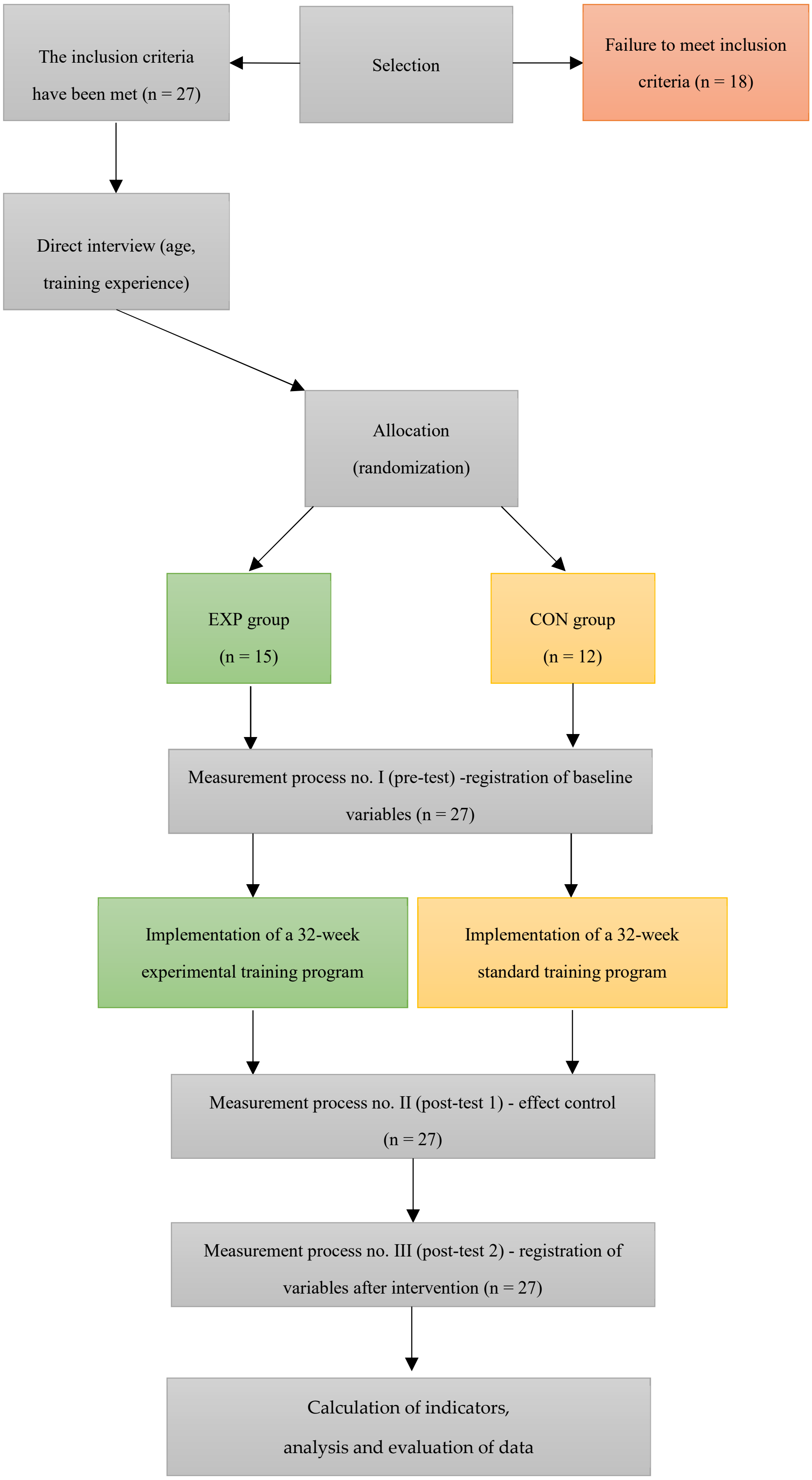

Figure 1. Flowchart of the research intervention.

The coordination exercises used in the experimental program are as follows:

1. Passes with Two Balls
Half-high passes with dribbling, half-high to half-high passes, simultaneous two-ball passes + one-handed catch, tossing one ball + two-handed pass with two balls + one-ball catch, and half-high passes with two balls, all performed in place.
2. Defensive Actions
Blocking, clinching, movement, and offensive fouls combined with passing balls of different sizes and weights (handball size 0–2, volleyball, basketball, and tennis ball).
3. Exercises with Tennis Balls
Dropping and catching a tennis ball with one hand (1/2 balls), dropping and catching preceded by hand circling over the falling ball (“spinner”), and dropping in a straight line and catching “crosswise” with 2 balls. Tossing and catching 2 balls in different directions and tossing 1/2 balls + clapping 1/2/3 times in front/behind the back.
4. Passes and Crossovers
Using two ball sizes (sizes 1 and 2), passes in place, walking, jogging, and running with direction changes, and “crossover” actions without or with exchanging balls between participants.
5. Pair Competition
Hitting the opponent on the shoulder/knee/foot while simultaneously exchanging the ball in any manner and catching a “reaction” ball in pairs while moving with step-together-step in a circle.
6. Dribbling
Using two to three balls of different sizes and weights (handball size 0–2, volleyball, basketball, and tennis ball).
7. Exercises Using Gym Benches
Two-footed/one-footed jumps on the bench (“jumping jack” legs), “scissors on the bench” left/right leg, “step up-step down” left/right leg, tossing/dribbling a ball while moving across a bench/inverted bench, two-handed/one-handed passes while standing/walking on a bench/inverted bench, and jumping from one side of the bench to the other while simultaneously dribbling the ball.
8. Exercises Using Court Lines
Sprinting preceded by jumps over the line (both feet, one foot, sideways, and forward), alternating leg jumps (left and right) “scissors”, stepping one leg over the line (left and right) “one-foot step”, “one-foot step up-step down”, and “side step up-step down” (left and right).
9. Coordination Ladder Exercises Incorporated into Warm-Up
Skipping A with one foot in one “window”—“sparse”, skipping A with both feet in one “window”—“dense”, “step up-step down” forward/left/right/backward, “scissors” left/right leg, running with retreat (two “windows” forward, one backward), and “one-foot step” left/right leg.

During the macrocycle, the coordination exercises used during the training sessions were recorded, and the training schedule, along with the overall progression of the experiment, was presented (Table 2).

Table 2. Training density distribution along with the use of exercise sets in training sessions.

September		October		November		December		January		February		March		April	
1	Measure	1	W	1	1,4+5	1	1+2,4	1	W	1		1	1+2,5	1	W
2	W	2	4,5+6	2		2	W	2	W	2	1+3,9	2	W	2	2,4,9
3	W	3	7	3	7,8	3	W	3	W	3	W	3	W	3	1,6+7
4	8+9	4		4	W	4	1,3,9	4	2,3,9	4	W	4	1,5+6	4	4,8+9
5	1,3,5	5	1,3,4	5	W	5		5	1+4,6	5	1,4+7	5	2,3+8	5	2+5,8
6		6	2,5+7	6	4,5+8	6	5,7	6	W	6	3,5+6	6		6	W
7	7,8	7	W	7		7		7	W	7		7	1+3,9	7	W
8	1+9	8	W	8	1,3,6	8	3,6+9	8	1,5,6	8	1+6,9	8	2,4+6	8	2,8+9
9	W	9	3,4,5	9		9	W	9	3,4+7	9	4,7+8	9	W	9	
10	W	10		10	2,5	10	W	10		10	W	10	W	10	3,5+7
11	1,6,8	11	1,7,8	11	W	11	1,3+8	11	1+3,8	11	W	11	2+6,8	11	
12		12		12	W	12	2,6,7	12	4+5,7	12	4,6+9	12		12	1+5,8
13	2,5+7	13	2,4+6	13	5,8	13		13	W	13		13	1,4,8	13	W
14	1+6	14	W	14	2+3,9	14	1,2+7	14	W	14	1+7,8	14		14	W
15	3,8,9	15	W	15		15	3,4,9	15	3,5+9	15		15	4,6+9	15	1+6,9
16	W	16	4+6	16	6+8	16	W	16		16	2,6+7	16	W	16	3,5,9
17	W	17	2,5,8	17	3,5,9	17	W	17	1+6,7	17	W	17	W	17	
18	1+8	18	1+4	18	W	18	1,4+8	18		18	W	18	3,6+8	18	1,8+9
19		19		19	W	19		19	2+3,6	19	2,5,9	19		19	4,6+7
20	2+7	20	2+8	20	3+8	20	2,6+8	20	W	20	1+6,8	20	2,5+6	20	W
21		21	W	21		21		21	W	21		21		21	W
22	4,8+9	22	W	22	1+4,9	22	Measure	22	2+4,9	22	2,8+9	22	1,6+8	22	4,8
23	W	23	2,3+9	23	3	23	W	23	1,6+8	23	1+3,7	23	W	23	2,6+7
24	W	24		24	2,7+9	24	W	24		24	W	24	W	24	
25	5,8+9	25	5,7+8	25	W	25	W	25	2,5+8	25	W	25	1,3,8	25	3,7+9
26	3+7	26		26	W	26	W	26	1,7+9	26	1+7	26	4+6,8	26	2,5,6
27		27	2,6,9	27	2,3+5	27	W	27	W	27	3,5,6	27		27	W
28	1+9	28	W	28		28	W	28	W	28		28	1+7	28	W
29	3,6,8	29	W	29	4,6,9	29	W	29	1+5,9	29	1+3,9	29	3,4+9	29	2,8
30	W	30	4,5+9	30		30	W	30	3,6+8			30	W	30	Measure
		31	2,6			31	W	31	2,7+9			31	W		

W—indicates days falling on Saturdays, Sundays, or holidays and celebrations when training sessions were not conducted.

2.5. Testing Procedure

To assess the training effects, the PNTR Computerized Coordination Ability Test System [28] was used, which included measurements of simple reaction time to a visual stimulus, complex reaction time to visual stimuli, visual–motor coordination (orientation ability)—a modified test using the Piórkowski apparatus, spatial orientation (orientation ability)—a modified test using the cross apparatus, divided attention (adjustment ability), and orientation–perception (orientation ability).

The tests were conducted using a computer keyboard, with an active key procedure for both right-handed and left-handed participants. The examiner demonstrated each test according to the procedure and then provided instructions and explanations. The participant immediately performed a preliminary shortened trial and then proceeded to the actual assessed test. Each test trial was repeated twice, and the better result was considered for evaluation. Breaks of at least 5 min were maintained between tests. The testing room contained only the participant and the examiner to ensure full concentration on the test.

2.6. Statistical Analysis

In the analysis of the research results, basic statistical methods were used, including the calculation of the arithmetic mean, median, standard deviation, minimum and maximum values, and the coefficient of variation. To assess the significance of differences between groups, the non-parametric Mann–Whitney U test was applied. For evaluating the significance of changes within a group, differences in progression were analyzed using the non-parametric Wilcoxon signed-rank test for paired observations. The threshold for statistical significance was set at $p < 0.05$. The choice of tests was preceded by checking the normality of variable distributions using the Shapiro–Wilk test, which indicated significant deviation from normal distribution. The degree of homogeneity within each group was assessed by interpreting the coefficient of variation values according to the following classification: CV < 25% indicates low variability; 25–45% indicates moderate variability; 45–100% indicates high variability; and >100% indicates very high variability [29]. The collected data were analyzed using Statistica software, version 13.3 (Statsoft, Krakow, Poland). The significance level for statistical differences was set at $p < 0.05$.

3. Results

Table 3 presents the test results of the participants and their intergroup variability (groups: EXP vs. CON).

Regarding the baseline assessment (I measurement—pre-test), more favorable test results were observed for reaction time, visual–motor coordination, spatial orientation, divided attention, and perception orientation in the CON group, although the differences were not statistically significant ($p > 0.05$). Conversely, an opposite trend was noted only for complex reaction time, favoring the EXP group, with the differences also being non-significant ($p > 0.05$).

After 13 weeks of applying the experimental stimulus and standard training (II measurement—post-test 1), the CON group showed better results in divided attention and perception orientation. In contrast, the EXP group outperformed in tests of simple and complex reaction time, as well as spatial orientation. For visual–motor coordination, both groups exhibited the same average score. No significant differences between variables in the tested groups were found for this measurement ($p > 0.05$).

After 32 weeks of the training period (experimental vs. standard training), the final measurement (III measurement—post-test 2) revealed significant differences in the perception orientation test ($p < 0.05$), with better results in the CON group. This group also showed more favorable outcomes for simple and complex reaction time and divided attention. However, these differences did not reach statistical significance ($p > 0.05$). The EXP group achieved better results in visual–motor coordination and spatial orientation, without significant differences ($p > 0.05$).

The coefficients of variation indicate that the internal variability of the test variables was very low in both groups (EXP vs. CON) (V = 5–23%). For the trials of divided attention (II measurement) in the EXP group (V = 27%) and complex reaction time (II measurement) in the CON group (V = 28%), moderate internal variability was observed.

Table 4 presents the range of progression in psychomotor skill components and the degree of intra-group variability in the studied handball players (EXP vs. CON).

Table 3. Statistical characteristics of psychomotor test results and their intergroup variability in the studied groups (EXP vs. CON) of handball players (n=27).

Measurement	Group EXP (n = 15)						Group CON (n = 12)						d	p
	x̃	sd	Me	min	max	V (%)	x̃	sd	Me	min	max	V (%)		
Simple Reaction Time [ms]														
I	308	30	305	261	358	10	306	34	314	256	348	11	2.0	1.000
II	303	34	300	239	355	11	304	22	308	267	338	7	−1.0	0.961
III	287	25	290	221	319	9	285	25	290	224	327	9	2.0	0.608
Complex Reaction Time [ms]														
I	473	72	464	316	611	15	487	107	467	365	723	22	−14	0.981
II	479	88	461	348	687	18	539	151	476	407	936	28	−60	0.393
III	447	59	438	331	531	13	427	79	428	303	540	19	20	0.526
Visual–Motor Coordination [ms]														
I	81	4.4	81	72	88	5	80	6.7	81	71	92	8	1.0	0.755
II	77	5.1	77	68	88	7	77	6.2	76	68	87	8	0.0	0.961
III	74	5.5	75	66	86	7	76	5.1	76	65	85	7	−2.0	0.456
Spatial Orientation [ms]														
I	101	12	105	85	122	12	100	14.4	97	84	135	14	1.0	0.719
II	94	12	94	75	119	12	96	9.8	93	80	112	10	−2.0	0.829
III	91	11	92	75	110	12	93	9.7	92	78	110	10	−2.0	0.829
Divided Attention [points]														
I	53	12	52	28	77	23	54	10.2	54	38	76	19	−1.0	0.750
II	59	16	54	34	85	27	60	11.9	60	44	77	20	−1.0	0.883
III	61	12	60	45	88	20	64	9.7	65	47	79	15	−3.0	0.379
Perception Orientation [points]														
I	50	9.8	51	32	65	19	51	6.2	48	43	63	12	−1.0	0.903
II	51	8.9	52	37	67	18	56	8.6	59	42	70	15	−5.0	0.075
III	55	7.9	54	43	73	14	62	7.4	62	52	70	12	−7.0	0.033

x̃—arithmetic mean, Me—median; sd—standard deviation, min—minimum value, max—maximum value, V (%)—coefficient of variation; I—first measurement period (pre-test); II—second measurement period (post-test 1); III—third measurement period (post-test 2); d—difference between means (delta); *p*—level of significance; ms—milliseconds.

In the EXP group, after a 32-week period of experimental training (first measurement period—pre-test vs. third measurement period—post-test 2), there was a statistically significant improvement in test effectiveness for the following: simple reaction time ($p < 0.05$), visual–motor coordination ($p < 0.001$), spatial orientation ($p < 0.05$), divided attention ($p < 0.05$), and perception orientation ($p < 0.05$). Additionally, significant progress in visual–motor coordination and perception orientation was observed after 13 weeks of intervention (first measurement period vs. second measurement period). Continued improvements in visual–motor coordination and perception orientation were detected during the second half of the experiment (second measurement period vs. third measurement period), with statistical significance ($p < 0.05$).

In the CON group, after 13 weeks of standard training, a trend of significant improvement was noted for visual–motor coordination, spatial orientation, divided attention, and perception orientation ($p < 0.05$). Furthermore, significant increases were observed for complex reaction time during the second 19 weeks of training (second measurement period vs. third measurement period) and visual–motor coordination during the first 13 weeks of training (first measurement period vs. second measurement period).

Table 4. Statistical characteristics of psychomotor skill progressions and their intra-group variability in the studied groups (EXP vs. CON) of handball players (n = 27).

Variable	Measurement	Group EXP (n = 15)			Group CON (n = 12)		
		x̃	sd	*p*	x̃	sd	*p*
Simple Reaction Time [ms]	I–II	−5.47	33.95	0.348	−2.58	29.28	0.666
	II–III	−15.93	31.51	0.069	−19.25	35.41	0.109
	I–III	−21,4	32.36	0.035	−21.83	35.54	0.092
Complex Reaction Time [ms]	I–II	5.53	104.73	0.570	52.75	83.81	0.060
	II–III	−31.6	93.80	0.222	−112.75	146.90	0.016
	I–III	−26.07	89.96	0.349	−60.00	126.29	0.151
Visual–Motor Coordination [ms]	I–II	−4.2	2.81	<0.001	−3.24	2.50	0.002
	II–III	−2.3	2.99	0.012	−1.07	4.03	0.424
	I–III	−6.5	2.84	<0.001	−4.31	3.73	0.013
Spatial Orientation [ms]	I–II	−6.4	7.41	0.008	−4.85	8.61	0.129
	II–III	−2.87	7.9	0.187	−2.37	5.28	0.176
	I–III	−9.27	9.92	0.004	−7.23	7.6	0.003
Divided Attention [points]	I–II	5.67	10.08	0.059	6.33	9.76	0.077
	II–III	2.53	9.52	0.394	4.00	10.67	0.230
	I–III	8.2	11.66	0.013	10.33	8.45	0.008
Perception Orientation [points]	I–II	0.37	3.72	0.700	5.77	9.74	0.071
	II–III	3.89	5.89	0.017	5.18	8.61	0.071
	I–III	4.25	7.02	0.036	10.95	9.63	0.003

x̃—arithmetic mean; sd—standard deviation; I—first measurement period (pre-test); II—second measurement period (post-test 1); III—third measurement period (post-test 2); *p*—level of significance; ms—milliseconds.

4. Discussion

The aim of the study was to determine the impact of an 8-month targeted training program, intended to optimize coordination ability, which utilized exercise content specific to handball. According to theorists and discussions within the practical sports community, the topic of coordination training's influence on the psychomotor abilities of young handball players is gaining importance in the context of optimizing training processes and developing sports talent. Through a thorough literature analysis, a gap was identified in studies attempting to evaluate the effectiveness of coordination programs for longer than a 3-month period in team sports [30–32].

Our own research addressed this cognitive–practical gap, including both a local analytical approach and a global holistic perspective concerning the stimulated group. The research aimed for the longest possible training period, accompanied by the application of the experimental stimulus. The program was based on exercise sets consisting of motor tasks focusing on attention division, orientation and perception, visual–motor coordination, and reducing the response time of the players. Our findings showed that this approach was effective in significantly improving reaction time, visual–motor coordination, spatial orientation, attention division, and perception orientation in the EXP group. Other psychomotor components also showed progression, although not as pronounced. Furthermore, it is noteworthy that selected variables showed improvement after just 13 weeks of intervention (Table 4). The component tested, visual–motor coordination, was particularly responsive to the intervention, leading to more pronounced changes than those observed in the CON group (despite a less favorable baseline level). These results highlight the potential of such innovative training stimuli.

In the literature, there are publications indicating a significant impact of specific psychomotor abilities on the performance of handball players and other team sports [33–35]. As suggested by the authors of one publication, the main prognostic factors for visual–motor performance may include sex and age [36]. Additionally, comparisons of psychomotor ability levels take into account differences between players in various competition categories and the level of developed reaction time and other indicators [37]. For this reason, our publication focused on players competing at the same level of competition. Nevertheless, as Chouhan et al. report, there may be differences in visual–motor coordination indicators depending on the player's sport level, such as their position in the team—e.g., first or second team [38]. This situation could reflect more favorable test results in the CON group compared to the EXP group during pre-tests, although this relationship was not statistically significant. Moving to the results obtained after 13 weeks of intervention, significant progress was demonstrated compared to the pre-test 1 of the EXP group, which may be a result of manipulating the training process through a high rotation of utilized exercises during training sessions and consequently manipulating the volume and intensity of the conducted training [39]. It is worth noting that most studies used training programs based on linear periodization without significant variability in training parameters and in a much shorter time frame [31,32]. The literature includes studies considering longer time frames for applied training interventions based on coordination exercises, but so far, they have been used in sports related to handball, such as soccer and volleyball [40–42]. Finally, in the second part of the training program, significant growth was also observed for psychomotor ability indicators (II measurement vs. III measurement), which may occur due to a longer training period compared to the first measurement, as well as a break in training due to occasional holidays and celebrations, during which stronger neuronal adaptations might have occurred [43].

Psychomotor abilities vary by age range, as noted by Orhan et al., who found no significant differences between genders in visual–motor coordination in their study involving school-age children [44]. However, for motor abilities and balance, differences between genders were noted, although not statistically significant [44]. Such results in the mentioned study might be due to the small sample size; therefore, for the needs of this publication, the research group consisted exclusively of male adolescents [44]. Regarding simple and complex reaction times, significant improvements were noted for the former and non-significant improvements for the latter, which may be directly related to the age of the participants. As Bucsuházy and Semela indicate, the age range of 15 to 18 years did not show significant differences in reaction time indicators compared to the 20 to 30 years age range [45]. However, significant differences were observed in the 10 to 14 years age range, which may relate to the developmental stage of adolescents and the lack of competitive physical activity [45]. Utilizing findings on adolescent development stages, where multisensory integration will likely continue into late childhood, one might hypothesize that the 14–15 years age range may be optimal for developing psychomotor skills in adolescents participating in team sports [44–46]. It would be valuable to continue our research direction and extend the intervention to other age groups of handball players, where one of the research goals could be to verify the mentioned sensitive periods (most advantageous in ontogeny) for developing coordination ability.

Spatial orientation, according to some authors, can be developed through appropriate physical exercises in children and adolescents [47]. Both after 13 and 32 weeks of training, the EXP group showed better results compared to the CON group, with a note of less favorable baseline levels in the former. Interestingly, some authors observed significant improvements in test efficiency after 8 or 6 weeks of experimental program duration [48,49]. Such differences might be due to the age of the participants, where in the case of the 6-week training period publication, the subjects were children with an average age of 11 years, while for the 8-week experimental period publication, it could be due to the specific nature of the sport in which the participants were involved [48,49]. In our study, a further progression of this variable with statistical significance was observed after 32 weeks of training in the EXP group, supporting the hypothesis that coordination exercises are a key tool for developing spatial orientation in adolescent handball players in this age range. Although our study reported improvements in both the experimental and control groups, the magnitude and consistency of these gains differed. The experimental group, which received additional coordination training, consistently outperformed the control group in several key areas, including reaction times and visual–motor coordination. While both groups showed progress, the experimental group's more significant improvements highlight the added value of incorporating specific coordination training into the athletes' regular routines.

These findings underscore the importance of targeted training interventions. In the control group, improvements might be attributed to general physical training and the inherent developmental progress of young athletes. However, the experimental group's enhanced outcomes suggest that coordination training offers additional benefits beyond standard training practices.

A critical component of our study was the management of variability in training exercises. The experimental group followed a diverse training regimen designed to enhance various aspects of coordination. By regularly varying the types of exercises, we aimed to prevent adaptation plateaus and continuously challenge the athletes' coordination abilities. This approach likely contributed to the consistent improvements observed in the experimental group, as variability in training has been shown to enhance neural adaptation and prevent overuse injuries. The inclusion of exercises targeting different coordination aspects, such as balance, reaction time, and spatial awareness, helped to create a holistic improvement in psychomotor skills. This variability not only kept the training engaging but also ensured that different cognitive and motor skills were developed simultaneously, leading to a more robust improvement across all measured areas.

An important aspect that may explain the following results is the phenomenon of supercompensation, which plays a key role in sports training, leading to improvements in motor abilities after periods of intense effort [50]. Looking at the training distribution in our research, a longer break after the second post-test can be noticed, which might have contributed to positive adaptations to the applied training. According to the literature, to utilize supercompensation, it is crucial to manage training intensity and recovery time appropriately [51]. In a systematic review by Symons et al., a link between overtraining and a decline in cognitive abilities in athletes was found [51]. However, the review included studies on adult athletes, which further supports the hypothesis of differences between age ranges in psychomotor abilities [45]. Therefore, it is essential to consider that intensive training sessions must be appropriately balanced with periods of rest to allow the body full recovery and adaptation, which, as indicated by the final tests, may contribute to the development of expected psychomotor abilities.

It should be noted that the CON group players also showed progress, with significant results for selected components in four PTNR tests. The CON group had a more favorable baseline level of the analyzed variables. Interestingly, this group showed a significant increase in the effect for complex reaction time after 13 weeks of training, which was not observed in the EXP group. This indicates that the structure of handball training and the complexity of conducting sports battles in this discipline determine the development of psychomotor traits.

Limitations of the Study

This study has several limitations. Firstly, there is significant variability in the coordination exercises used and in the duration of the training period, making it challenging to pinpoint the optimal duration and selection of specific coordination exercises that most effectively enhance psychomotor abilities. Additionally, the maturation processes in individuals within this age range may play a crucial role in adapting to the training program.

Moreover, greater individualization of training related to the players' positions on the field and tailored coordination exercises might contribute to new scientific findings, presenting a considerable methodological challenge for future research. Finally, the sample consisted exclusively of male adolescent players. Therefore, future studies should aim to validate these findings with more diverse samples, including different age groups, genders, and other team sports.

5. Conclusions

The experimental coordination training program positively impacted the psychomotor abilities of young handball players, particularly in simple reaction time, visual–motor coordination, spatial orientation, attention distribution, and perception orientation. Notably, improvements in visual–motor coordination and spatial orientation were observed after just 13 weeks of intervention.

These findings suggest that longer training programs, such as the 32-week duration used in this study, are highly effective in achieving significant enhancements in psychomotor skills.

This approach highlights the benefit of extended, comprehensive training over shorter programs seen in previous research, emphasizing the importance of sustained training interventions for optimizing the psychomotor profile of young athletes.

Practical Implications

A 32-week coordination training program can be considered an effective practical approach for shaping and improving the psychomotor profile of adolescent handball players. It is recommended for use in training practices and should be tested in other age groups and female athletes. Additionally, there is potential for adapting the modified training program to other team sports where multidimensional motor coordination (including information processing, faster game perception and decision making, timing, reacting, and others) is essential and determines athletic performance.

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