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# Freestyle gymnastic exercise can be used to assess complex coordination in a variety of sports

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## ABSTRACT

**Objective:** The assessment of motor coordination is a very complex process and demonstrates a high degree of sport specificity. There are a limited number of tests, if any, where results correlate with the success rate of athletes in different sports.

**Methods:** Free style gymnastic exercise (FSGE) and coordination ball dribbling exercise (CBDE) were used to see whether the execution quality of these tests is related to the quality of athletes from team handball, water polo, kayak, rhythmical gymnastics (RG) and aerobics (222 athletes - 75 male, 147 female; 23 non-athletes - 9 male, 14 female).

**Results:** FSGE results related to the quality of performance in all sports ( $r = -0.232$ ,  $p < 0.01$  in handball, water polo, kayak and  $r = -0.26$ ,  $p < 0.05$  in aerobics and RG), while CBDE did not. Older players had higher ranking as they had more time to be successful at their sport ( $r = -0.498$ ,  $p < 0.01$  in handball, water polo, kayak;  $r = -0.298$ ,  $p < 0.05$  in aerobics and RG). The scores of FSGE were independent from the age and gender of the subjects.

**Conclusions:** The main findings were: (i) that athletes did significantly better than the controls in both tests; (ii) RG and aerobics athletes did better on the FSGE than handball, water polo players and kayakers; (iii) handball players did better than kayakers, RG and aerobics athletes on the CBDE test; and (iv) better ranked athletes performed better on the FSGE test. Therefore, FSGE test appears to be a reliable test to assess coordination in variety of sport and different levels of sport performance.

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## Introduction

There are a great number of factors which influence the development and preparation of elite athletes. An abundance of studies relates to conditional abilities (strength, endurance, speed, agility, flexibility) but there is a dearth of information on coordination abilities. Motor coordination is the combination of body movements created with the kinematic (such as spatial direction) and kinetic (force) parameters that result in intended actions. The reason behind the lack of related studies is not due to the marginal effects of coordination on sport performance but

rather to the complexity and sport specificity of motor coordination.<sup>1</sup> A high level of motor coordination is obligatory in those sports in which speed is a critical element of performance, because a proper contraction/relaxation pattern of agonist and antagonist muscles is required.<sup>2</sup> Moreover, with increasing speed of technical execution, the role and importance of coordination exponentially increases.

Fundamental movement skills, like running, jumping or throwing are not obligatory for everyday life. However, they are considered to be necessary for the development of complex, sport specific motor skills.<sup>3</sup> The assessment of fundamental movement skills has been evaluated,<sup>4</sup> but the assessment of complex motor skills is not very well defined.

Motor coordination is extremely important in high level sport. Moreover, there are sports, such as gymnastics, rhythmical gymnastics, aerobics, figure skating, and synchronized swimming,

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where artistic elements are important, and the judges directly evaluate the level of coordination by the number of points awarded. Hence, it is impossible to reach even a moderate level of sport performance with inadequate quality of coordination.<sup>5</sup>

Therefore, motor coordination is generally important in all sports, but it has significant sport specificity as well. It could be important to create general coordination tests, which could be linked to sport performance in general, and also to have highly correlative coordination tests for each sport. Coordination in sport includes balance, rhythm, rhythm-maintaining ability, controlling and orienteering abilities, among others, always remembering that coordination is strongly dependent upon kinesthesia and brain function.<sup>6,7</sup> The speed and efficiency of motor learning are also crucial for high level sport. The optimal age of motor learning is around 6–10 years, where the development of motor cortex allows very efficient learning. However, motor learning is a continuous process in most sports.<sup>8</sup> The efficiency of motor learning is also strongly dependent upon previous experiences, i.e. the similarities or differences in kinematic, spatial, rhythmical characteristics of newly learned and earlier learned movements.

The aim of our study was to develop an easy but appropriate test to assess coordination which can be used in variety of sports from beginners to professional athletes. Our hypothesis was that athletes with superior performance would do better at free style gymnastic exercise (FSGE) and coordination ball dribbling exercise (CBDE) tests. Moreover, we suggested that ball players would do better at CBDE test than those athletes who do not use ball at their sport. We did not expect gender dependent differences at the tests.

One way to create and evaluate the validity and usefulness of a general coordination test is to differentiate among athletes from different sports with different levels of success. We have created a coordination test by which we hope to test general coordination ability as well as specific coordination ability for ball games. In the test we recruited Olympic champions, members of national teams and other athletes from different sports with different levels of success, in order to measure the validity of the test. Our results revealed that the freestyle gymnastic exercise (FSGE) test has a significant relationship with sport performance ( $p < 0.05$  in handball, water polo, kayak and  $p < 0.01$  in aerobics and rhythmic gymnastics (RG)), while the ball test was not supportive enough to be linked to sport performance.

## Methods

### Subjects

We recruited 222 professional athletes and 23 untrained healthy individuals for the study. All subject voluntarily take part in the study and sign the approval form. The study was approved by the Research Ethical Committee, University of Physical Education: TE-KEB/No7/2019. We aimed to select athletes with different levels of sport performance in various sports in order to have a heterogeneous population at success levels in each sport. Subjects were asked to complete a questionnaire on their anthropometric parameters, sport carrier and training history, and descriptive data (Table 1A, B). Both professional athletes and control subjects were asked to come to the test before training (professionals) and in a physically fit condition (controls). The test was done early afternoon at the same time with all subjects, as in this period the level of physical fitness is the highest according to the daily circadian rhythm. The given load was moderate according to the Borg scale, hence the level of fatigue did not interfere with the results of the study.

### Design and methodology

Subjects were shown the free style gymnastic exercise (FSGE) and the coordination ball dribbling exercise (CBDE) three times to get accustomed them to the test. They practiced each for 1 min and then completed two test trials. Each test was carried out individually, following a warm up, which was individually selected. All tests were recorded by digital video camera (Sony DCR-SR32E, Japan). The detailed description of the coordination tests is the follows:

#### a. Freestyle gymnastic exercise (FSGE)

Subjects were asked to perform a simple FSGE-A at the first test. Then we changed the FSGE-A movements of arm and legs in the following FSGE-B, FSGE-C, and FSGE-D exercises. The freestyle gymnastic exercise is a 4-phase-skipping exercise, which could be practiced by all subjects for 1 min. The four phases of FSGE-A were the following (Fig. 1A).

1. Phase: jump to straddle stand, arm swinging to sideways position;
2. Phase: jump to starting position;
3. Phase: jump to straddle stand, arm swinging to high position;
4. Phase: jump to starting position.

In the FSGE-B, only the arm movement was changed compared to the previous one, so that during the 4-phase-exercise the arm took the same positions, only the starting position was different, so after joining the arm and foot movement (Fig. 1B).

1. Phase: jump to straddle stand, arm swinging to low position;
2. Phase: jump to starting position;
3. Phase: jump to straddle stand, arm swinging to high position;
4. Phase: jump to starting position.

In the FSGE-C we changed the foot movement compared to the basic exercise. A simple variation was our choice. No new and extra tasks were given to athletes, we simply changed the beating of the basic skipping so that skipping had to be doubled in every position and hence the harmony between the arm and the foot was completely disrupted (Fig. 1C).

1. Phase: jump to straddle stand, arm swinging to sideways position;
2. Phase: jump upwards, arm swinging to low position;
3. Phase: jump to basic stand, arm swinging to high position;
4. Phase: jump upwards, arm swinging to low position.

In the FSGE-D, the arm and footwork changed in the second and third exercises were put together which resulted in a new variation compared to the basic exercise (Fig. 1D).

1. Phase: jump to straddle stand, arm swinging to low position;
2. Phase: jump upwards, arm swinging to sideways position;
3. Phase: jump to basic stand, arm swinging to high position;
4. Phase: jump upwards, arm swinging to sideways position.

#### b. Coordination Ball Dribbling Exercise (CBDE)

In the first ball exercise (CBDE-A), two size 7 basketballs of equal pressure had to be dribbled in alternate rhythm for 30 s, making sure that the rhythm is maintained and the  $2 \times 2$  meter area is not left by the athlete (Fig. 2A).

In the second variation (CBDE-B), two different balls of varying

**Table 1a**  
Descriptive data's of the participants 1, Mean ± SD.

	Gender	N		Height (cm)		Bodyweight (kg)		Age (y)	
<b>HB</b>	Female	48	85	172,7 ± 5,1	180 ± 10,4	66,6 ± 8	77,8 ± 16,2	20,3 ± 5,2	26,1 ± 4,8
	Male	37		189,4 ± 7,7		92,4 ± 11,9		26,1 ± 4,8	
<b>WP</b>	Female	27	49	176 ± 5,8	181,7 ± 8,7	70 ± 7,6	79,8 ± 13,7	22,9 ± 4,7	24,5 ± 5,8
	Male	22		188,8 ± 6,3		91,9 ± 8,8		26,5 ± 6,6	
<b>RG</b>	Female	38	38	164,9 ± 5,8	164,9 ± 5,8	48,3 ± 6,7	48,3 ± 6,7	16,6 ± 3	16,6 ± 3
	Male	0		0		0		0	
<b>KY</b>	Female	11	27	169 ± 6,1	178,4 ± 10	63,4 ± 6,4	76,5 ± 12,9	22,9 ± 6,1	22,4 ± 4,2
	Male	16		184,8 ± 6,5		85,5 ± 7		22,1 ± 2,4	
<b>AE</b>	Female	23	23	164,8 ± 3,9	164,8 ± 3,9	55,9 ± 12,9	55,9 ± 12,9	19,2 ± 3,9	19,2 ± 3,9
	Male	0		0		0		0	
<b>NA</b>	Female	14	23	168,1 ± 7,2	173,2 ± 9,2	63 ± 13,1	67,3 ± 14,6	21,1 ± 1,8	21,4 ± 2,1
	Male	9		181,1 ± 5,8		74,2 ± 14,9		22 ± 2,5	
<b>SUM</b>	Female	170	245						
	Male	75							

Abbreviations: HB: Handball, WP: Water polo, RG: Rhythmic Gymnastics, KY: Kayak, AE: Aerobic, NA: non-athletes.

**Table 1b**  
Descriptive data's of the participants 2, Mean ± SD.

	Gender	Sport age (y)		National team member		Rank	
<b>HB</b>	Female	12 ± 5,2	13,5 ± 5,3	10	15	44,6 ± 23,2	46,1 ± 19,7
	Male	15,6 ± 4,9		5		48 ± 13,9	
<b>WP</b>	Female	15,8 ± 5,1	16,9 ± 5,1	18	24	22,7 ± 24,5	26,6 ± 22,5
	Male	18,3 ± 4,9		6		31,4 ± 19,3	
<b>RG</b>	Female	10,7 ± 2,8	10,7 ± 2,8	14	14	51 ± 23,2	51 ± 23,2
	Male	0		0		0	
<b>KY</b>	Female	14 ± 5,3	13,5 ± 4	8	15	20,2 ± 11,6	25,3 ± 12,1
	Male	13,1 ± 2,9		7		28,8 ± 11,5	
<b>AE</b>	Female	11,8 ± 4,7	11,8 ± 4,7	7	7	41 ± 24,6	41 ± 24,6
	Male	0		0		0	
<b>NA</b>	Female	0	0	0	0	0	0
	Male	0		0		0	
<b>SUM</b>	Female			57	75		
	Male			18			

Abbreviation: HB: Handball, WP: Water polo, RG: Rhythmic Gymnastics, KY: Kayak, AE: Aerobics, NA: non-athletes.

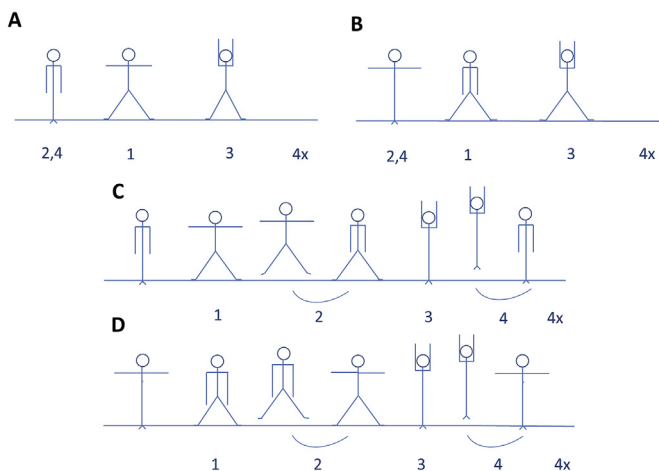
size and weight, one tennis ball and one basketball had to be dribbled under the same conditions as in the fifth exercise. Participants had an opportunity to choose in which hand they would like to use the tennis ball (Fig. 2B).

In the next difficulty level (CBDE-C), different type of movement with two balls with different sizes had to be executed. The tennis ball had to throw up and the basketball had to be dribbled again. It was also an opportunity to choose which hand the ball was thrown

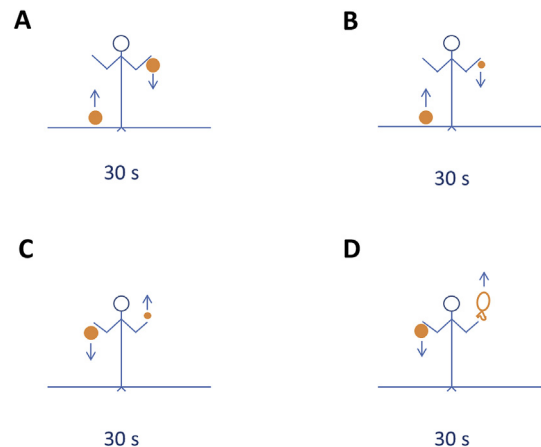
by the athletes (Fig. 2C).

In the final exercise (CBDE-D), the basketball movement was the same, while a balloon had to be kept hitting in the air. In this exercise they also had an opportunity to choose which hand they would like to use the balloon or the ball. In this test, rhythm maintenance was only a criterion for basketball (Fig. 2D).

All trials were evaluated by a highly qualified judge. Judges were former athletes and internationally qualified judges working with



**Fig. 1.** Description of the Freestyle gymnastic exercise (FSGE).



**Fig. 2.** Description of the Coordination ball dribbling exercise (CBDE).

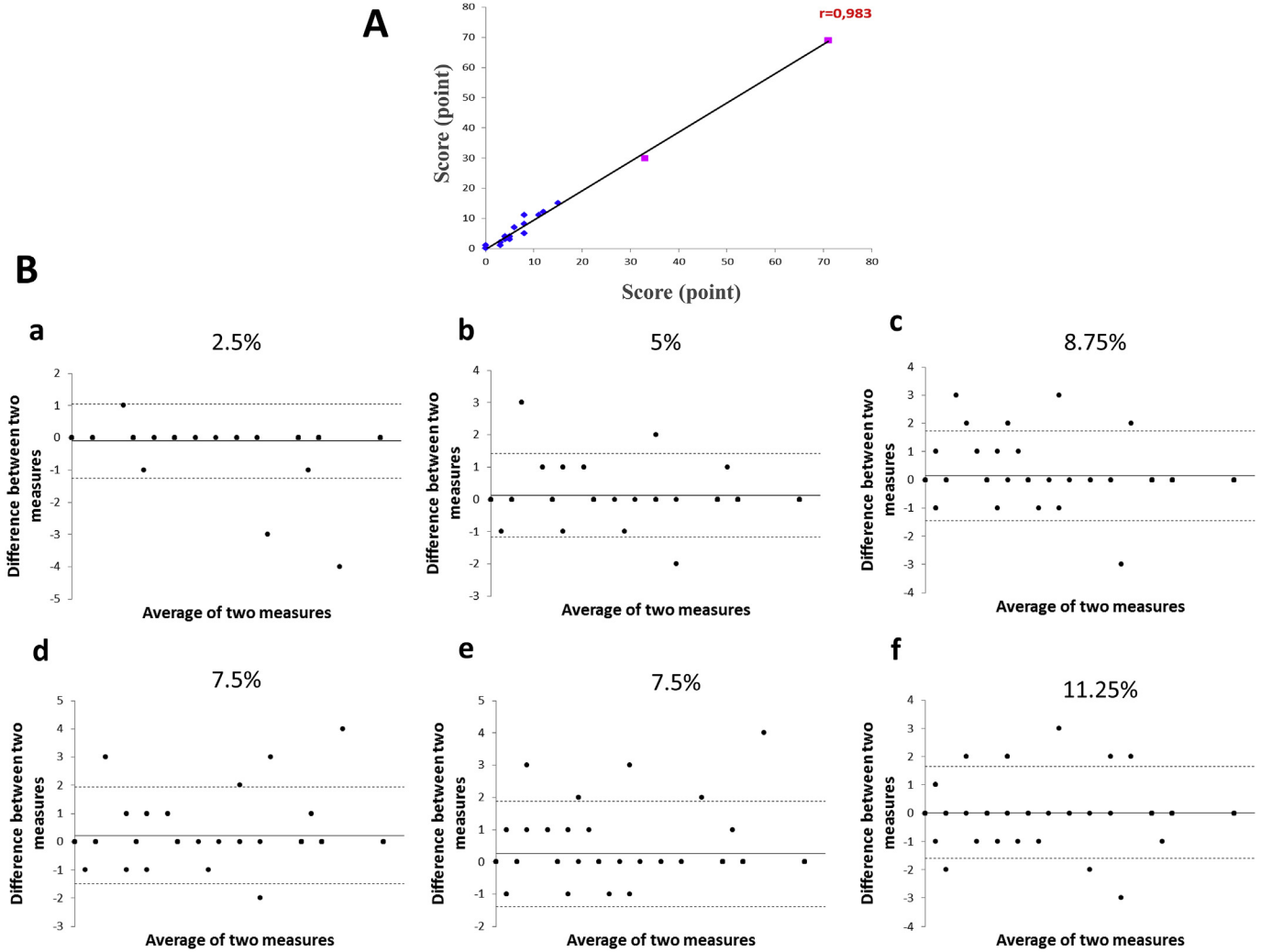


Fig. 3. Panel A: Representative correlation of the scoring of the four judges. Panel B: Comparison of the evaluation of the judges by Bland-Altman plots. Graphs show comparison of judges 1–2 (a), 1–3 (b), 1–4 (c), 2–3 (d), 2–4 (e), 3–4 (f). From 2.5% to 11.25% of the points are out of the limits of agreement.

Table 2  
Evaluation of Free style gymnastic exercises (FSGE).

Score (point)	Rate	Arms work (A)				Legs work (L)				Rhythm
		1	2	3	4	1	2	3	4	
0	0	–				–				–
1	1x4	A/L	+	–	A/L	A/L	–	+	A/L	–
2	1x4	+				+				–
3	1x4	+				+				+
+3	Trial 1 with perfect execution									

Abbreviations: A/L: successful arms or legs work, + successful execution, - unsuccessful execution.

intercontinental license of Federation Internationale de Gymnastique (FIG). Each evaluation was randomly confirmed by four judges who possessed international judge licenses for artistic sports (gymnastics, rhythmical gymnastics and aerobics). The mean of correlation between the testers evaluation was  $r = 0.983$  (Fig. 3A and B). As seen on Fig. 3B, from 2.5% to 11.25% of the points are out of the limits of agreement. This is clearly the limitation of the study, but this is the limitation of objective evaluation in all of the sports, where judges evaluate the performance by scores. The criteria for evaluation are shown at Tables 2–3. The other limitation of this study was that the judges were not completely blinded to the

Table 3  
Evaluation of Coordination ball dribbling exercises (CBDE).

Score (point)	Duration (sec)	Rhythm
0	0–2	–
1	3–5	–
2	3–5	+
3	6–10	–
4	6–10	+
5	11–15	–
6	11–15	+
7	16–20	–
8	16–20	+
9	21–25	–
10	21–25	+
11	26–30	–
12	26–30	+
15	26–30	+
Trial 1 with perfect execution		

Abbreviations: + successful execution, - unsuccessful execution.

athletes because some of them were known internationally, and this is a potential source of bias.

For the statistical evaluation, sport performance of the athletes was divided into 20 categories ranging from Olympic champions (ranked 1) to amateur athletes (ranked 75–80) (Table 4). In each

**Table 4**

Division of the category according to the sport quality.

Category	Competition	Results	Representatives of different sports						Ranking
			Sum	HB	WP	RG	KY	AE	
1	OG, WCh, EC	1–3	28	4	17	0	3	4	1–9
2		4–6	5	3	0	0	0	2	10–12
3		7–10	3	1	0	1	1	0	13
4	OG, WCh, EC	11–25	5	0	1	4	0	0	14–17
5	U23, U21, U18 WCh, EC	1–3	34	9	13	0	12	0	18–26
6	CL, CWC, WC, WG, AG	1–6	9	4	1	4	0	0	27–30
7	WUC, U	1–3	4	1	3	0	0	0	31–32
8	U23, U21, U18 WCh, EC	4–12	13	3	2	3	4	1	33–36
9	EHFC, YOF	1–6	4	0	0	0	4	0	37–39
10	WUC, U	4–6	1	0	0	0	1	0	40
11	CL, CWC, WC, WG,	7–10	1	0	0	1	0	0	41
12	NC, HCh, HC, HFD	1–6	47	25	5	8	2	7	42–53
13	NC, HCh, HC, HFD	7–10	1	0	0	1	0	0	54
14	HSD	1–3	6	6	0	0	0	0	55–57
15	HTD	1–3	7	2	0	0	0	5	58–59
16	OIG	4–6	2	2	0	0	0	0	60
17	HSD	1–6	22	22	0	0	0	0	61–70
18	HTD	1–6	14	0	6	4	0	4	71–73
19	HYC	1–6	12	2	0	10	0	0	74–80
20	–	–	4	1	1	2	0	0	81

Abbreviations: HB: Handball, WP: Water polo, RG: Rhythmic Gymnastics, KY: Kayak, AE: Aerobics, OG: Olympic Games, WCh: World Championship, EC: European Championship, CL: Champions League, CWC: Cup Winners Cup, WC: World Cup, WG: World Games, AG: Asian Games, WUC: World University Championship, U: Universiade, EHFC: EHF Cup, YOF: Youth Olympic Festival, NC: National Championship, HCh: Hungarian Championship, HC: Hungarian Cup, HFD: Hungarian First Division, HSD: Hungarian Second Division, HTD: Hungarian Third Division, OIG: Other International Games, HYC: Hungarian Youth Championship.

category the athletes were ranked according to their best sport performance.

We set up 20 categories to rank the sport performance in every sport, such as national and international (European-World) Championships, Olympic Games and Cups. Higher sport performance was associated with superior ranking values (Olympic Games/World Championships/European Championships 1–3 results = category 1), and all the 222 subjects were evaluated in the 20 categories (Table 4). In one category we could have number of subjects in different sport, Olympic champions in the category 1, got the rank 1 regardless of sport, if we had 2 times Olympic champion she or he got higher rank than one times Olympic champion. According to our evaluation system, category is independent from sport, while ranking is sport specific. The rank number in each category is the same as the larger number of subjects from a specific sport (if in the category 1 we have 17 water polo players and some of them have the same ranking, 3 kayak, 4 handball and 4 aerobics athletes, then at the category 1 we have 9 ranking number). The category 2 starts from the ranking number of 10 in each sport. This method prevented the jumping between categories and was independent from the number of subjects in each sport. In the present study the most successful athletes were from kayak-canoe, water polo, and team handball, while the less successful athletes were from rhythmic gymnastics.

#### Statistical analysis

According to the type of parameters, analyzing the differences between groups, statistical significance was assessed by the nonparametric Mann-Whitney U test and Kruskal-Wallis ANOVA. Spearman's rank correlation was used to evaluate the relationships between parameters. The significance level was set at  $p < 0.05$ .

#### Results

Firstly, the results of athletes and non-athletes were compared. Not surprisingly, the data clearly showed that athletes have better results in both tests than controls (Fig. 4). Next, the FSGE and CBDE

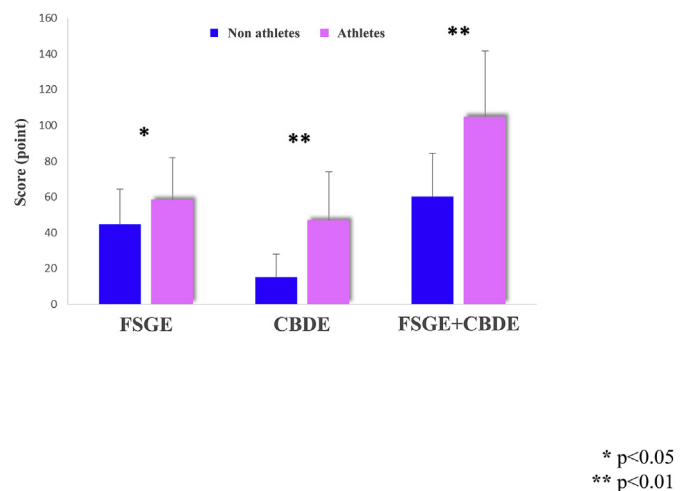


Fig. 4. Comparison of athletes and non athletes in the coordination tests.

results of different sports were compared and the data revealed, that RG and aerobics athletes had significantly better results for the FSGE than ball players (team handball and water polo) and kayak athletes (Fig. 5A). This could be due to the fact that RG and aerobics are focusing on the perfect execution of the movements, while in other measured sports not the “beauty” but the effectiveness is more important. The results of the ball test, CBDE, demonstrated that ball players, especially handball players, had higher scores than kayakers, and athletes from rhythmic gymnastics and aerobics ( $p < 0.01$ , Fig. 5B). Handball players even had better results in this test than water polo players.

Looking at the sport quality ranks of athletes in different sports, water polo players and kayakers had the lowest scores (=highest efficiency) (medalist at Olympic or world championships), while ranking of handball players, RG and subjects from aerobics were similar.

Importantly we tried to explore the link between the quality (based on the top results of the athletes) and the results in our

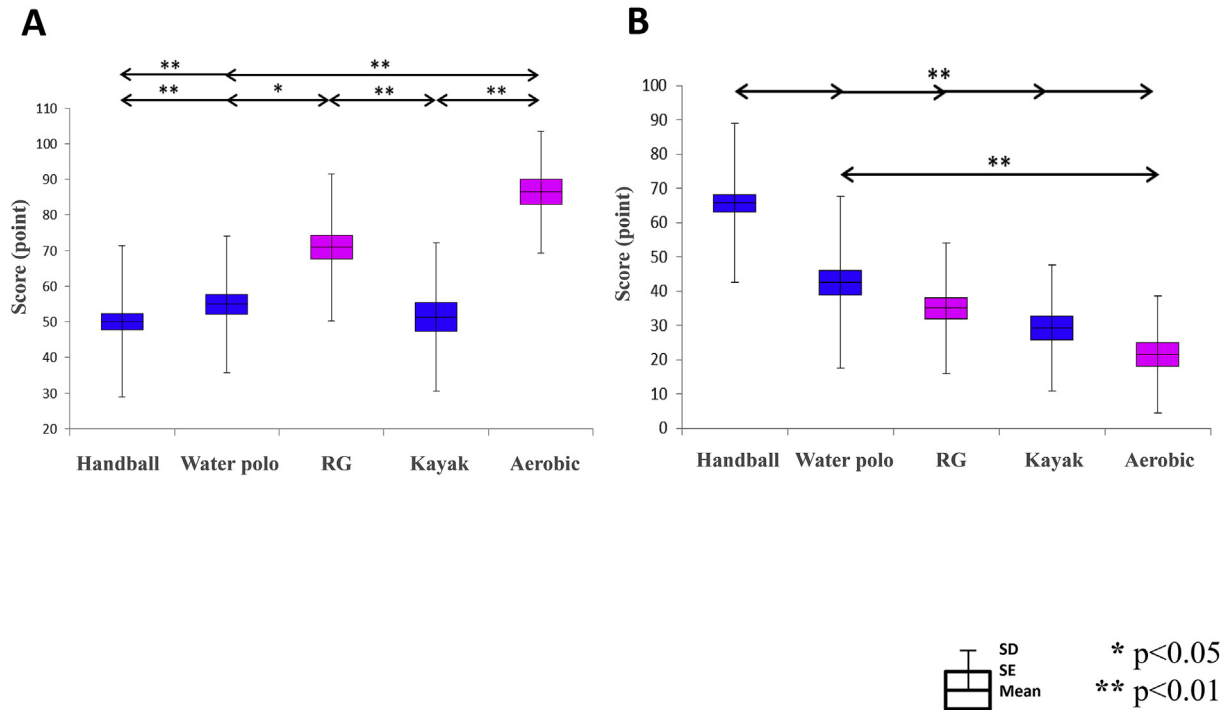


Fig. 5. Scores of FSGE (A) and CBDE (B) at different sports.

applied coordination tests. It is important to note, that due to robust differences in the characteristics of sports and biological parameters (age, body mass, height), between athletes from RG, aerobics and other subjects, significant correlations were looked for aerobic-RG and handball-water polo-kayak subgroups separately. The ranking and the scores of FSGE correlated significantly ( $r = -0.232$ ,  $p < 0.01$  in handball, water polo, kayak and  $r = -0.26$ ,  $p < 0.05$  in aerobics and rhythmic gymnastics), so superior rank showed higher score of this coordination test, parallel in both subgroups, which represent better performance at FSGE (Fig. 6A). On the other hand, there is not any significant link between the results of CBDE and ranking ( $p > 0.05$ , Fig. 6B).

On the other hand, gender specific significant differences were not found between female and male subjects in the coordination tests (Fig. 7A) and sport ranking (Fig. 7B). The effects of age on the results of FSGE and ranking in sports (Fig. 8) were also calculated. Overall, significant relationships were found between age and ranking ( $r = -0.498$ ,  $p < 0.01$  in handball, water polo, kayak and  $r = -0.298$ ,  $p < 0.05$  in aerobics and rhythmic gymnastics, Fig. 8A2, 8B2). Older players had superior ranking as they had more time to be successful at their sport. Nevertheless, in the case of ball players and kayakers, where the average age is around 23 years, the score on the FSGE test was not correlated with age ( $p > 0.05$ , Fig. 8A1). Therefore, the results of this coordination task represent the level of coordination skills in all probability. Age does not correlate with better coordination in adulthood. In contrast, testing the rhythmic gymnastics and aerobics subgroups, where the majority of the examined subjects were younger than 18 years, positive correlation was found between the FSGE scores and age ( $r = 0.391$ ,  $p < 0.01$ , Fig. 8B1), thus demonstrating advanced coordination through the period of biological maturation.

We also examined the relationship between weekly training hours and the results of FSGE and ranking (Fig. 9). In the cases of handball, water polo and kayak, higher FSGE scores related to greater weekly training hours ( $r = 0.163$ ,  $p < 0.05$ , Fig. 9A1) which

was linked to greater success (superior ranking) in sport ( $r = -0.522$ ,  $p < 0.01$ , Fig. 9A2). In the case of RG/aerobics athletes, probably because of the extremely high weekly training hours, no significant correlation was observed between the coordination test results or sport ranking ( $p > 0.05$ , Fig. 9B1, 2).

The results obtained for the CBDE test were not significantly correlated with ranking, age, or training hours ( $p > 0.05$ ).

## Discussion

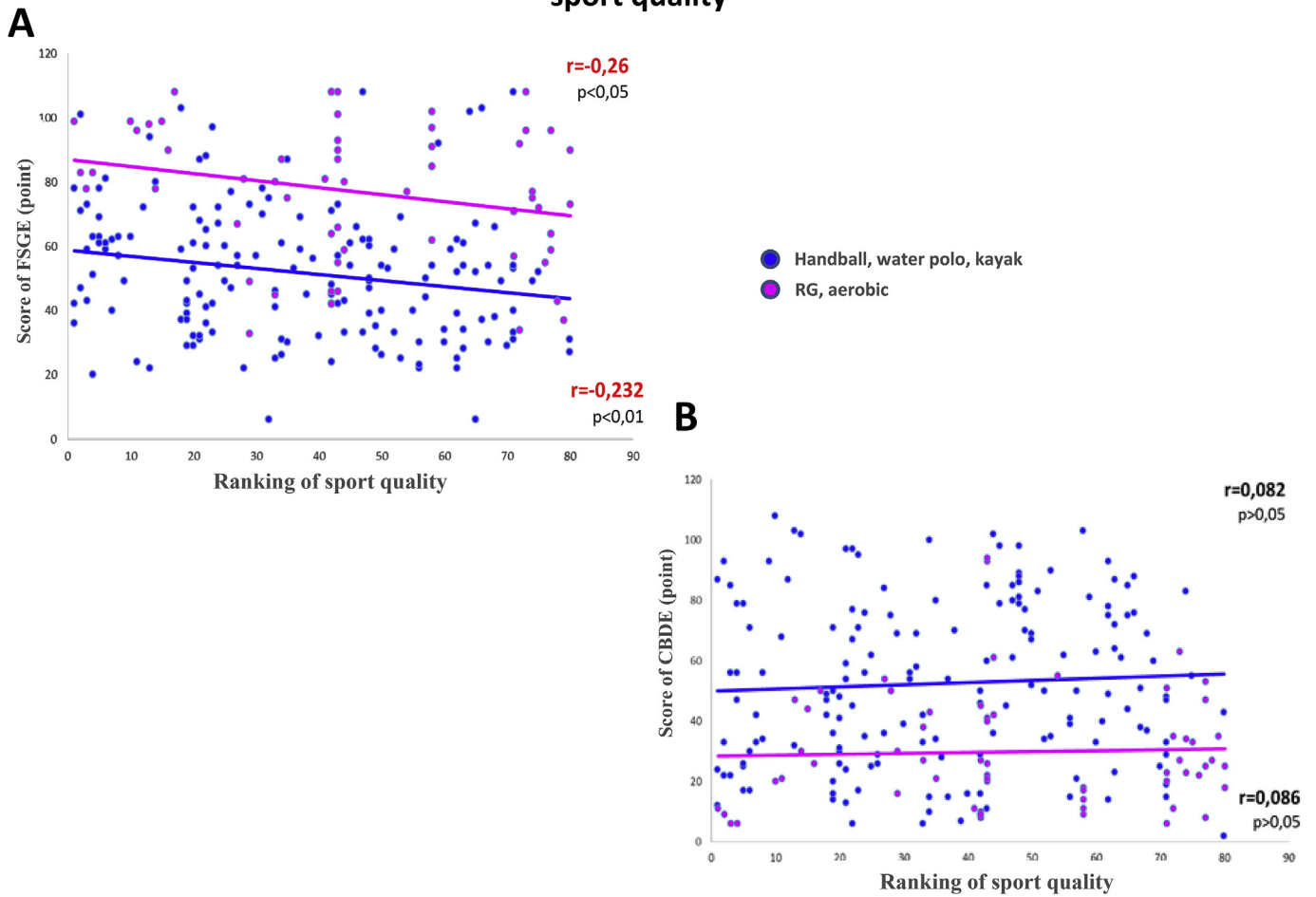
There is a great need to assess the level of complex motor coordination, involving orientation, differentiation, balance, rhythm, and learning capacity, which correlates with sport performance. To establish such a method is risky due to the extreme complexity of sport.<sup>9</sup> FSGE and CBDE tests were utilized to seek relationship with sport performance, age, gender, training history and sport specificity. The data revealed that the performance in the FSGE correlated with sport performance of the subjects who were recruited from water polo, team handball, kayak-canoe, rhythmical gymnastics and aerobics. To the good performance at FSGE, high levels of kinesthesia is necessary which is ability is one of the basis for motor learning.<sup>10</sup> Moreover, kinesthesia is linked to sensorimotor rhythms in which trained and untrained individuals differ significantly.<sup>11</sup>

Taken into account the diversity of the sports and the diversity of subjects which ranged from Olympic champions to the untrained, it is suggested that the FSGE test can be used to assess complex coordination ability in a variety of sports. The FSGE shows sport specificity, since RG and aerobics athletes have higher scores, but in all sports higher scores were associated with higher levels of sport performance. These data are in accordance with the observations of Kioumourtoglou et al. (1997) who suggested that higher levels of kinesthesia are sport specific.

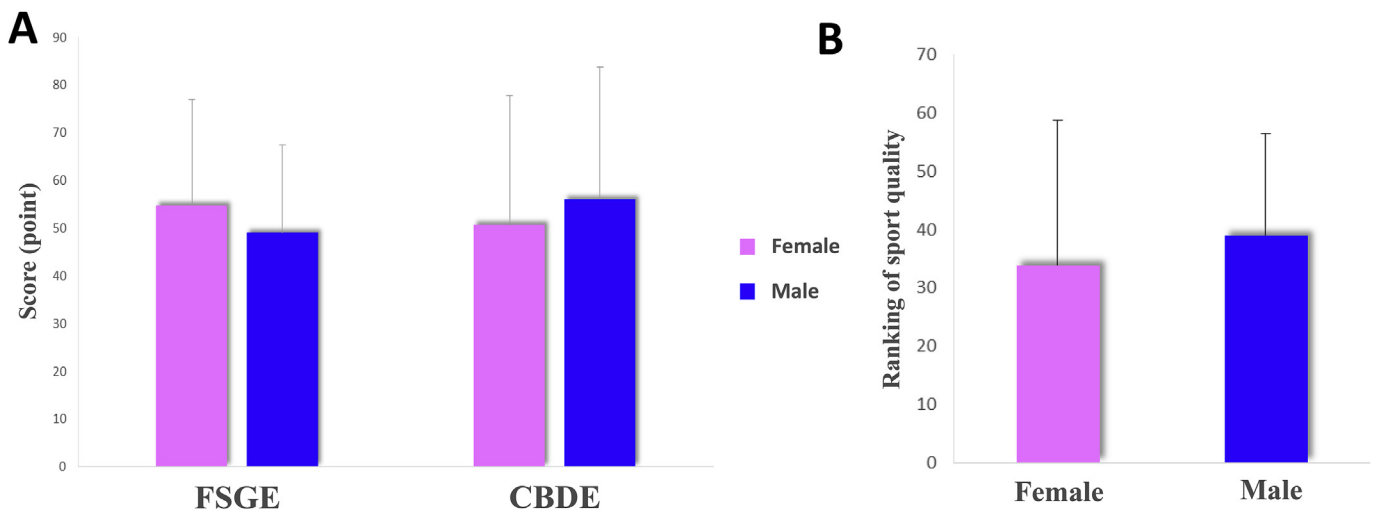
Interestingly, the results of the CBDE test did not show a statistical correlation. However, the inclusion of water polo and



**Fig 6. Correlation between coordination tests (FSGE – A, CBDE – B) and ranking of sport quality**

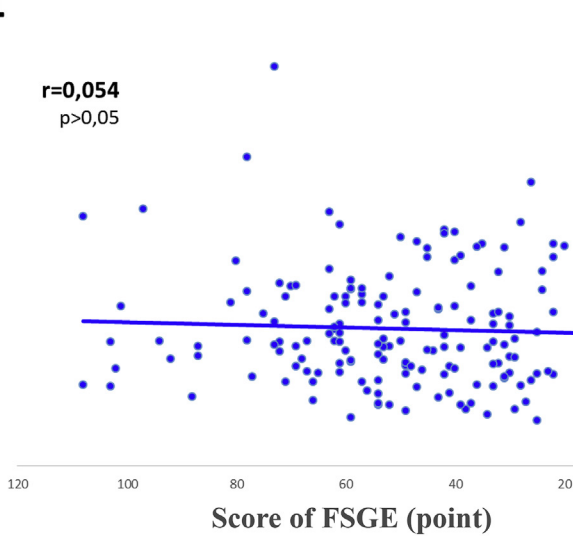


**Fig. 6.** Correlation between coordination tests (FSGE – A, CBDE – B) and ranking of sport quality.

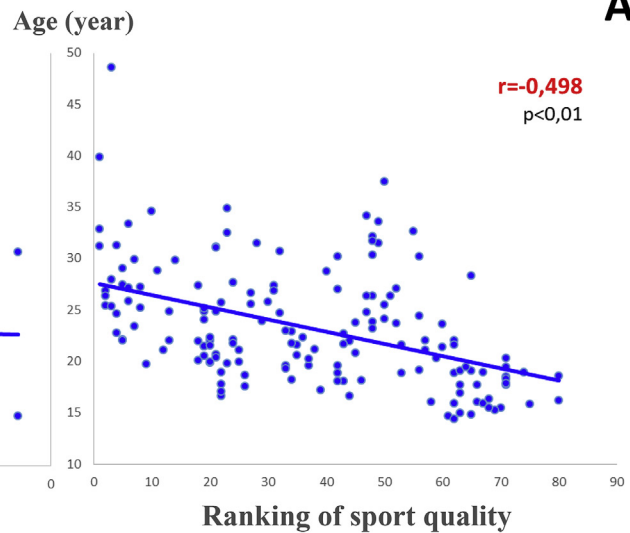


**Fig. 7.** Results of coordination tests (A) and sport ranking (B) depending on gender (Sports with both gender only, 161 participants).

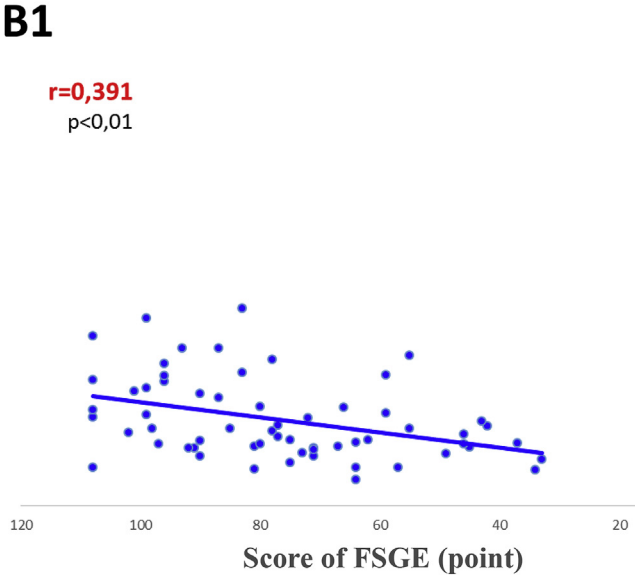
A1



A2



B1



B2

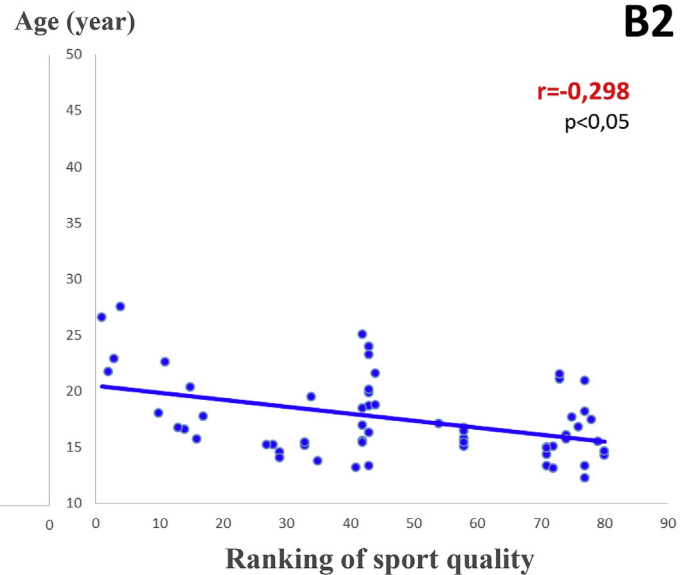


Fig. 8. Relationships of FSGE and sport quality ranking with age (Handball, water polo, kayak (A) and RG, aerobics (B)).

handball players among the subjects skewed the data. According to our hypothesis, ball players achieved higher scores in the CBDE tests, revealing expected sport specificity.

The data showed no gender dependent differences in the performance of the applied tests. Findings point out that although there are significant differences in conditional abilities between males and females (strength, endurance and speed),<sup>12</sup> but this existing difference does not interact with the performance of the applied coordination tests. This is an important point, which nicely distinguishes the different backgrounds of conditional and coordination abilities. We are not questioning the importance of conditional abilities on the development of techniques in different sports, but merely emphasizing the fundamental differences in these abilities.

The finding that those athletes with more recorded training hours have better performance on the FSGE test is not surprising. Indeed, this is an encouraging observation which reflects the importance of practice on the development of coordination. Here again, we are not questioning the possible importance of genetic effects on coordination, which still has yet to be shown, but

highlighting the importance of training.

Interestingly enough, contrary to our expectation, the ball test used to assess coordination, CBDE, did not show significant relationships with ranking, age, or training hours. A recent study using male and female handball players as subjects, showed that, although males are faster, females do better at handball specific tests than males.<sup>13</sup> Indeed, it would be surprising if ball game players had not done better than kayakers on ball tests, but our current test was not adequate to show a significant relationship with ranking in sport. Indeed, it has been shown that elite male basketball players scored higher on hand coordination and lower on dynamic balance.<sup>14</sup>

#### Practical applications

The applied FSGE could be very helpful to test the general progress in coordination tasks during preparation. One of the novelty of our findings are the discovery the relationships between FSGE and sport ranking in various sports, therefore general comparison would be possible. It can be suggested that someone with



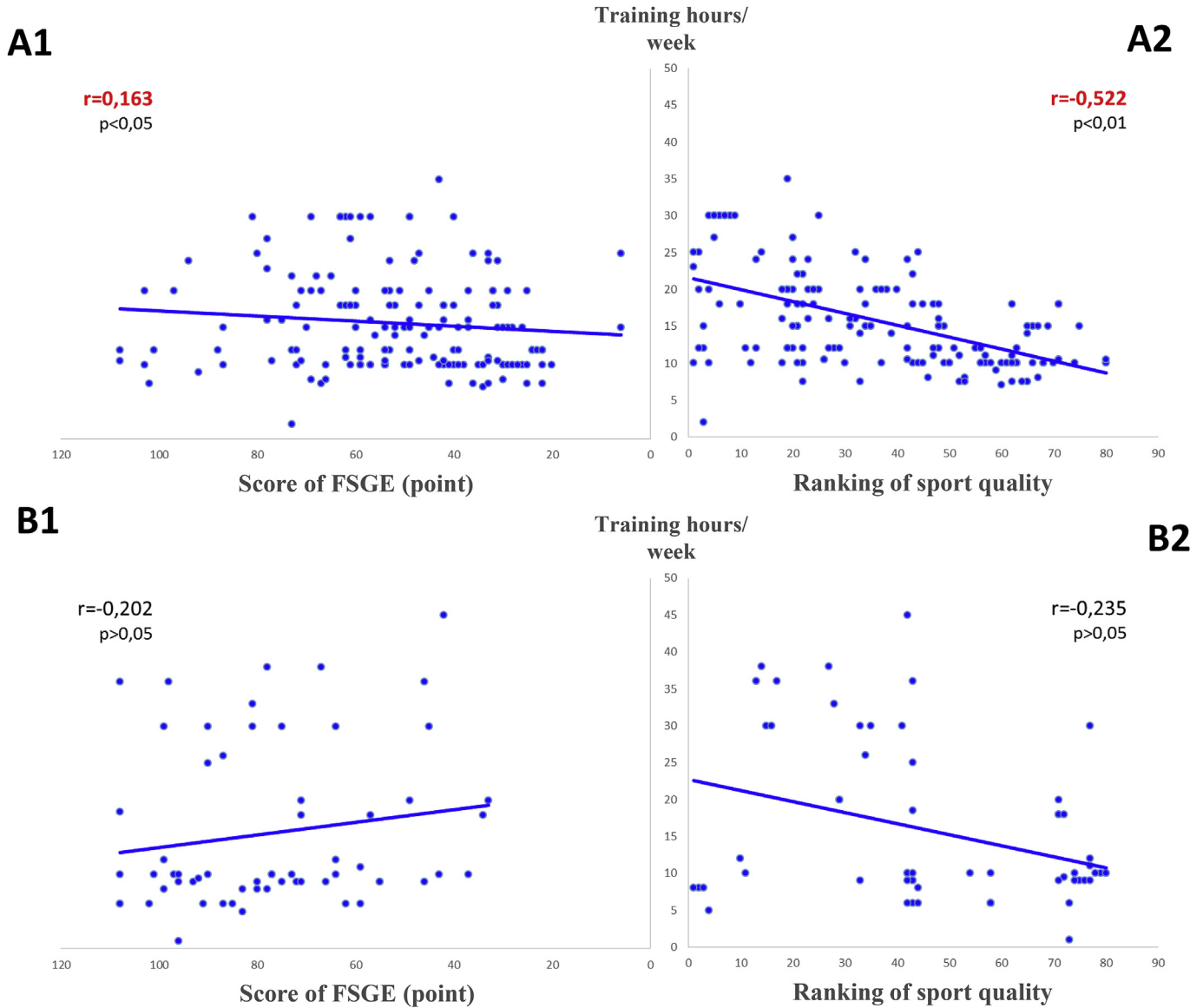


Fig. 9. Relationships of FSGE and sport quality ranking with training hours (Handball, water polo, kayak (A), RG, aerobics (B)).

excellent FSGE results has a coordination bases to be successful athlete.

Even low correlation coefficients showed significant relationships, which might suggest that sport performance is a very complex ability, which only in a certain degree is dependent on coordination. The contribution of coordination in sport performance can be quite different in rhythmical gymnastics and kayaking, as an example, but this does not mean that coordination is not important in both of them.

The aim of the study was to create a general test for assessing the level of coordination, which itself is a very complex ability. Coordination is important in all sport, however in different degree and can be a limitation of the development of sport performance. If this can be used to assess the level of coordination, as was expected based on our results, than coaches can use it to find out the level of coordination. Without knowing the limiting factors of further development, it is difficult to design training plan which is based on scientific knowledge. Therefore, our study could be a useful tool for the development of sport performance. It can be also used for talent

identification, but additional studies are important to clarify this.

One of the limitations of the current investigation is that our data are cross-sectional results and it would be very exciting to see the validity of FSGE testing in the talent selection in different sports. Currently we are working the set this test in the athlete selection protocol and check the long term validity of this test.

### Conclusions

The execution of free style gymnastic exercises, after a short period of learning, is an effective test to assess complex coordination ability. The rate of the execution is related to the quality of sport performance in a variety of sports with athletes ranging from Olympic champions to untrained individuals. It would be worthwhile to investigate whether this freestyle gymnastic exercise could be used as a tool to select children for various sports, and to test how the quality of this exercise is changing during the preparation for competition.

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## Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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