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ASSESSING COORDINATION IN OPEN- AND CLOSED-SKILL SPORTS – MARTIAL ARTISTS AND SPRINT ATHLETES

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Abstract. *For any sporting activity to be effective, movement coordination is essential. The purpose of this research was to explore the strengths and weaknesses of male athletes practicing open- and closed-skill sports, in terms of intersegmental coordination. It also examined differences related to the type of sport and athletes' performance, based on the results for intersegmental coordination results. The study involved 49 male athletes, some practicing martial arts (boxing and jiu-jitsu) and some practicing sprinting (100 meters). The RCMV computerized test, developed by the Romanian company RQ Plus, was used to assess intersegmental coordination. First, the study highlighted strengths and weaknesses in terms of intersegmental coordination in the case of the investigated open- and closed-skills sports (using one-sample t-test). Next, sport-related differences in coordination were explored, with the Kruskal-Wallis test, and the Dwass-Steel-Critchlow-Fligner post-hoc test for multiple comparisons. Not least, the study assessed whether athletes' results for intersegmental coordination were significantly related to their sports performance. The findings revealed that boxing athletes had better scores in choice reaction time than sprint athletes, and also outperformed male jiu-jitsu athletes in terms of resistance to disruptive factors in tasks requiring coordination. However, sprint athletes made significantly fewer errors when coordinating their movements quickly and steadily, compared to both boxing and jiu-jitsu athletes. Learning capacity or the coordination of upper and lower limbs in new, unfamiliar conditions was found to be essential for martial arts athletes, aiming for high sports performances.*

Keywords: *coordination; martial arts; open-skill sports; sprint.*

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Introduction

Coordination is a fundamental aspect of human movement, a complex and multifaceted concept encompassing the harmonious interaction between the nervous system, musculoskeletal system, and cognitive processes (Kimura et al., 2021) resulting in rapid, accurate, and balanced movements (Fernandes et al., 2016).

Coordination is viewed as a complex motor quality, an individual skill that involves rapid learning and capacity to restructure movements performed at high speed and under different conditions, a process under the control of the cerebellum and sensory organs (Jafar, 2023; Iorga et al., 2023). Delignières et al. (2009) define coordination as the spatio-temporal relationships between different body parts during task performance.

According to Rosa et al. (2020), motor coordination is the set of perceptual-kinetic abilities that enable the organisation, regulation and execution of motor and sensory processes associated with certain motor actions with a specific objective. Motor coordination includes the ability to adapt movement patterns and adjust forces to complete tasks successfully (Hulteen et al., 2023). “Motor coordination (MC), at every stage of life, represents a research topic widely investigated […] since it is related to the quality and the ability level of motor skill competence and is also associated with several physical, cognitive, and emotional domains” (Giustino et al., 2023).

Adapting motor skills or creating new solutions to successfully complete a task should be a priority when learning the basics of motor coordination. Moreover, the concepts of learning and coordination are intricately connected (Herlitz, 2020). Coordination is achieved by triggering a motor program developed based on previously acquired abilities (motor learning), and when faced with a new motor task, a person acquires the new motor program as a set of generalized rules or abstract representations of fundamental movement models that can be applied in a variety of contexts (Tükel, 2020).

The ability to coordinate is governed by control processed and movement regulation, which manage both the control of predictable and unpredictable actions, according to Shumway-Cook and Woollacott (2011). The difficulties, in the case of intersegmental coordination “manifest thorough temporal discrepancies between processing the information and executing the motor act, errors of non-synchronization of individual movements, order errors (inversions or substitutions of movements) or commutative errors (persevering with the anterior movement, interferences between movements)” - Grigore et al. (2012).

Specialized literature (Christenko et al., 2020) distinguishes two categories of coordinative skills. The first category includes the ability of general coordination, which enables rapid motor acquisition and execution of complex motor tasks with precision and efficiency (Bompa & Carrera, 2005; Biino et al., 2023). The second category includes specific coordinative abilities, developed within a particular sport, allowing athletes the choice of tactical combinations specific to the respective sport (Petrariu & Leuciuc, 2022). The development of coordination abilities is a complicated process that requires deciding which skills - combining ability, balance, precision, orientation, rhythm, or reaction - should come first. There is a consensus in the specialized literature (Grigore et al., 2011; Iorga et al., 2023) regarding the fact that coordination can be educated towards improving specific abilities, like the ability to coordinate and regulate the movement of every body part, the ability to control movement in any circumstance, and the ability to switch quickly between actions and relationships without disrupting the continuity and flow of motor actions, in accordance with the ever-changing demands of the environment.

Different sports have different requirements for coordination skills. In certain sports, these skills are essential to ensure a better economy of movement, while in others they support a higher frequency of movement with high explosiveness and force application (Dubey & Choudhary, 2023). For any sporting activity to be effective, movement coordination is essential.

For this reason, a great deal of effort is put into researching and developing it. Even though many sports have similar requirements, like balance, spatial orientation, and movement differentiation, each sport has its own unique demands on motor coordination (Cazzola et al., 2016). One of the most common sports activities, running, depends on the lower leg and thigh's phase connections and synchronization in the sagittal plane to enable knee joint flexion and extension (Mullineaux & Uhl, 2010). To accomplish pronation and supination at the subtalar joint in the frontal plane, leg and foot movements must be coordinated (Stergiou et al., 2001). Examining functional coordination patterns in the lower limb and across the body is necessary for comprehending running coordination. Coordination is also necessary for the lower extremities to absorb the impact forces during running (Stergiou et al., 2001).

When talking about effective performance in sport, an appropriate level of coordination skills is high on the list, being one of the primary factors influencing an athlete's effectiveness during competition (Bojkowski et al., 2022). This statement is supported by studies indicating that increasing the level of coordination is one of the most important factors in achieving the intended performance results. For example, Grigore et al. (2016) underlined that in women's artistic gymnastics, the development of the intersegmental coordination influences the athletes' performance (e.g. the results for landing in the case of vault). Also, in tennis, at junior level, good results in terms of coordination (eye-hand coordination and intersegmental coordination) were linked with sports performance, expressed through the ranking position (Predoiu, 2015). Studies established that coordination has a great influence on sports success and performance in gymnastics, athletics, sport climbing and swimming (Stanković et al., 2023); also, in football, a multiple experience of gestures is recommended, which shortens the learning and makes the training process more efficient (Cojocaru et al., 2015). Additionally, it was found that a high level of coordination skills in a football player is one of the key factors determining the effectiveness of their actions (Bojkowski et al., 2022). The importance of a high level of coordination was, also, underlined in dance sport, the results of a study (Zahiu et al., 2019) showing that dancers have a very good development of space-time orientation ability, this being true for visual discrimination and also, regarding eye-hand coordination skills.

Sports can be classified as *open* or *closed*, depending on the temporal and spatial characteristics of the environment where a motor task is performed (Muratori et al., 2013). While closed skill sports are classified as static with predetermined conditions (e.g. running, sprint), with a minimal variation in the movements performed, open skill sports – like team or combat sports require athletes to react within continuously changing conditions, unpredictable and externally-paced environments (Campanella et al., 2024). With respect to closed skill sports, it is widely believed that the environment is more predictable, steady, and athletes go at their own pace and can plan their motor answers (Gallotta et al., 2020).

The present research addresses intersegmental coordination in open- and closed-skill sports, more precisely in martial arts (boxing and jiu-jitsu) and sprint athletes (100 m). The mentioned sports disciplines should not be considered separately, 50 m sprint training increasing the power and the speed of kicks in martial artists (e.g. taekwondo athletes) – Tsania et al. (2022).

Martial arts are examples of open-skill sports disciplines. The athletes are performing in a dynamic environment and are solicited to respond to external stimuli in a constantly shifting, unpredictable, and fast-paced environment (Heilmann et al., 2022). Development of motor skills, discipline, self-confidence, and socialization are benefits that martial artists develop (Patenteu et al., 2023a). Such examples of sports are boxing and jiu-jitsu, investigated in the current research. Boxing is a combat sport in which two fighters use just their fists above the waist to fight; gloves were first worn during the early 20th century. The International Boxing Association (IBA) regulates boxing competitions in the Olympics (Lee-Barron, 2012). Boxing involves the certainty of some degree of injury, possibly causing interruption in training or competition (Alberton, 2024). Throughout the history of boxing at the modern Olympic Games, athletes from as many as 77 different countries have taken home the gold medals (Bagińska et al., 2022), including Romania. Jiu-Jitsu involves a type of fighting where the opponent is taken down or projected upon, while wearing a uniform or gi. Once on the ground, the athletes must use various tactics (joint locks, chokes, and immobilizations) to try to control the opponent. The number of points won determines the winner, in the absence of submission at the end of the match (see Predoiu et al., 2022; Del Vecchio et al., 2007).

Sprint is an example of a closed skill sport, characterized by a relatively constant, predictable and self-paced environment, which requires repetitive activities and predetermined patterns (Formenti et al., 2021). Track and field events classified as sprints usually have distances of 60, 100, 200, and 400 meters. Sprinting speed refers to the ability of the human musculoskeletal system to facilitate the forward movement of the body until the point of maximum speed is reached (Bezodis et al., 2019). Speed assessments are frequently incorporated into talent identification tests (Ciacci et al., 2017; Cavedon et al., 2023), as they are recognized as a crucial factor for success in various adult (Cavedon et al., 2022) and youth sports (Gleadhill & Nagahara, 2021).

Methodology

Scope

The purpose of the research was to explore the strengths and weaknesses of male athletes practicing open- and closed-skill sports in terms of intersegmental coordination. Additionally, the study examines the differences between the investigated sports branches, and how these differences relate to the athletes' sports performances, taking into consideration the results of their intersegmental coordination.

Research questions

1) What are the strengths and weaknesses of male athletes practicing open- and closed-skill sports (specifically martial artists and sprint athletes), in terms of intersegmental coordination?
2) What are the sport-related differences concerning intersegmental coordination?
3) Are the results for intersegmental coordination significantly related to the athletes' sports performances?

Participants

Forty-nine male athletes from Romania, practicing open-skill sports (martial arts) and closed-skill sports (sprint athletes - 100 m), aged between 18 and 25, took part in the study. Athletes are members of sports clubs recognized by sports federations and have at least one year of competitive experience (minimum 18 years old and minimum 1 year of competitive experience represent inclusion criteria for the study). Participants are distributed as follows:

- By sport discipline: boxing (*N* = 17), jiu-jitsu (*N* = 18), respectively sprint athletes – 100 m (*N* = 14). Even if, at first glance, there seem to be few sprint athletes, it is worth mentioning that national competitions are generally attended by approximately 20 sprint athletes (100 m).
- By sports results: martial arts athletes (boxing and jiu-jitsu) having international and/ or national performances, *N* = 20 (top ranks at World, European and/or national competitions), respectively martial artists with regional/local sports results (*N* = 15), as in previous studies (Patenteu et al., 2023b; Predoiu et al., 2023). In the case of sprint athletes, personal best (for 100 meters) was taken into consideration.

Measures

To assess intersegmental coordination the RCMV computerized test, developed by the Romanian company RQ Plus, was used. In this test, stimuli are represented by red squares positioned up/ down and left/ right, on the computer screen. The participant holds a lever in each hand (each with a single button), and the feet are positioned on the pedals. The athlete "must respond through a motor reaction of his upper limbs (button pressing) and lower limbs (pedal pushing) […] depending on the number and position of the displayed squares" (Predoiu, 2015). During the test, 2 or 3 squares appear at the same time on the screen (never one square or all 4). If the squares appear in the top area of the screen, the athlete presses the corresponding button on the lever (left or right). If the squares appear at the bottom of the screen, the participant presses the left or right pedal (depending on the stimuli position – in the left/ right side of the screen).

The test has 3 parts, each with its own speed. At speed one (the first part of the test) the athlete has 5 seconds to correctly press the levers and/or pedals (depending on the number of stimuli which appear on the screen, and their positioning). At speed two (the second part of the test) the athlete has 4 seconds to correctly press the levers and/or pedals, in the same time (being a coordination test). If the levers and pedals are not pressed at the same time (throughout the entire test), the participant is notified by the software that he/she has made an error. In the third part of the test, the participant is the one who controls the speed of the test – each time he/she presses the right combination of buttons and pedals, a new stimulus appears on the screen. The aim is to work as quickly and correctly as possible.

Among the ten coefficients provided by the soft, in the current study we present the following: learning capacity (LC) – "rapid adaptation of movements at new perceptual conditions" (Cojocaru et al., 2015); personal rhythm (the number of errors – in the case of this coefficient a lower score means better performance); choice reaction time (CRT) measured in milliseconds; time pressure (TP) – „the ability to perform motor tasks under stress conditions expressed by increasing the dynamic of the situations" (Predoiu, 2015); resistance to disruptive factors (RDF) – in the case of unpredictable appearance of signal-stimuli the athlete gives correct responses/ he coordinates his movements; autotempo coefficient/self-imposed tempo coefficient (AUTO) – "the time, measured in seconds, in which the task has been completed" (Teodorescu et al., 2012) taking into consideration only the third part of the test; performance coefficient (PC) – ratio of correct answers to reaction time during the first two parts of the test.

The raw scores obtained at the RCMV test divide athletes into five classes (for each coefficient): Class 5 means a very good performance; Class 4 - good result; Class 3 - average performance; Class 2 - weak result; Class 1 means a very weak result.

Procedure

The RCMV test was applied between 2023-2024. Data confidentiality was ensured throughout the study, and athletes were given the option to withdraw at any point, and they provided written informed consent before taking part in the study. The RCMV test was applied in groups of 3-6 athletes, each test lasting approximately 10 minutes.

The disruptive factors of the environment and the level of knowledge of the motor skills influence the level and quality of movement coordination. Therefore, in the hall where the computerized testing took place it was silence, and all athletes performed the computerized test for the first time. In addition, it is known that "the precision of the manipulation movements is maximum for the objects set in front and under the level of the shoulders" (see Grigore et al., 2012; Aniței, 2007). In this study, the levers and pedals used for the assessment of intersegmental coordination were positioned according to the above recommendations – in fact, the placement of the devices (in front of the participant and under the level of his/her shoulders) was pre-determined by RQ Plus, the company that developed the computerized test.

Results

First, athletes' level of performance was investigated (in terms of intersegmental coordination), for each sport discipline and for each of the coefficients (Table 1).

Table 1. *Descriptive statistics – performance (classes) in the case of intersegmental coordination (n = 17 - boxing, n = 18 - jiu-jitsu, respectively n = 14 - sprint athletes)*

	Sports branches	LC	PC	CRT	RDF	PR	TP	AUTO
Mean	1 sprint athletes	2.57	2.00	3.43	4.07	3.07	2.86	3.29
	2 boxing	2.53	2.59	3.76	3.94	2.65	2.82	3.47
	3 jiu-jitsu	2.89	2.28	3.56	3.33	3.44	3.11	3.39
SE	1 sprint athletes	0.228	0.105	0.137	0.221	0.305	0.294	0.286
	2 boxing	0.125	0.123	0.235	0.250	0.191	0.231	0.125
	3 jiu-jitsu	0.179	0.158	0.217	0.362	0.246	0.267	0.164
SD	1 sprint athletes	0.852	0.392	0.514	0.829	1.14	1.10	1.07
	2 boxing	0.514	0.507	0.970	1.03	0.786	0.951	0.514
	3 jiu-jitsu	0.758	0.669	0.922	1.53	1.04	1.13	0.698

Note. Class 5: very good performances; Class 4: good results; Class 3: average performances; Class 2: weak results; Class 1: very weak results; LC: learning capacity; CRT: choice reaction time; PC: performance coefficient; PR: personal rhythm; RDF: resistance to disruptive factors; TP: time pressure; AUTO: autotempo coefficient.

Results in Table 1 underline good performances, generally, in the case of resistance to disruptive factors in tasks requiring intersegmental coordination, and slightly above average performances for choice reaction time and autotempo coefficient (reflecting the speed of coordinated movements). Participants had average results (generally) for personal rhythm and resistance to time pressure, respectively slightly below average performances for learning capacity. The weakest results were obtained in the case of the performance coefficient, an overall indicator reflecting the ratio between athletes' correct responses during the test and athletes' reaction time, generally.

In Table 2 one can observe the strengths and weaknesses, in terms of intersegmental coordination, in the case of the investigated open- and closed-skills sports. The Mean of all classes (for all coefficients) is: 3.01 (Sprint athletes), 3.11 (Boxing), respectively 3.14 (Jiu-jitsu), which served as the test values for the one-sample t-test.

Table 2. *One Sample t test comparing the results for each coefficient (at group level) with the mean performance (all classes and coefficients) – in descending order of mean score*

Coefficients – IC Sprint athletes	M	SD	t(13)	p
Resistance to disruptive factor	4.07	0.829	4.79	<0.001
Choice reaction time	3.43	0.514	3.05	0.009
Autotempo coefficient	3.29	1.07	0.965	0.352
Personal rhythm	3.07	1.14	-0.03	0.975
Time pressure	2.86	1.10	-0.52	0.611
Learning capacity	2.57	0.852	-1.92	0.076
Performance coefficient	2.00	0.392	-9.63	<0.001
Coefficients – IC Boxing	M	SD	t(16)	p
Resistance to disruptive factor	3.94	1.03	3.33	0.004
Choice reaction time	3.76	0.970	2.78	0.013
Autotempo coefficient	3.47	0.514	2.88	0.010
Time pressure	2.82	0.951	-1.24	0.232
Personal rhythm	2.65	0.786	-2.42	0.027
Performance coefficient	2.59	0.507	-4.24	<0.001
Learning capacity	2.53	0.514	-4.65	<0.001
Coefficients – IC Jiu-jitsu	M	SD	t(17)	p
Choice reaction time	3.56	0.922	1.91	0.072
Personal rhythm	3.44	1.04	1.24	0.231
Autotempo coefficient	3.39	0.698	1.51	0.148
Resistance to disruptive factor	3.33	1.53	0.53	0.599
Time pressure	3.11	1.13	-0.10	0.915
Learning capacity	2.89	0.758	-1.40	0.148
Performance coefficient	2.28	0.669	-5.46	<0.001

Note: IC: Intersegmental coordination; Mean (2nd column) range from 1 to 5 indicating the level of performance in terms of coordination, with 1 being a very weak performance, and 5 being a very good performance (3 represents an average result, at group level).

Significant differences ($p < 0.05$) were found for resistance to disruptive factors (in tasks requiring intersegmental coordination) and choice reaction time in boxing and sprint athletes. Also, athletes from boxing completed fast the third part of the test (autotempo coefficient, $p = 0.010$), the mean value ($M_{classes\ for\ autotempo} = 3.47$) being significantly higher than the mean performance in the case of boxing ($M = 3.11$) - when all classes were counted.

The weakest results (coefficients with significantly lower values comparing to the mean performance) were registered for: performance coefficient (sprint athletes - 100 m, boxing and jiu-jitsu, $p < 0.001$); personal rhythm (boxing, $p = 0.027$) and learning capacity (boxing, $p < 0.001$).

It is worth mentioning that in jiu-jitsu, choice reaction time represents a strength ($M_{classes\ for\ CRT} = 3.56$), the alpha significance threshold being close to 0.05, while the learning capacity (good intersegmental coordination when faced with new stimuli) is a weakness.

Next step was to verify the type of sport-related differences concerning intersegmental coordination. Kruskal-Wallis (H) nonparametric test was used, and the Dwass-Steel-Critchlow-Fligner (DSCF) post-hoc test (for multiple comparisons).

Table 3. *Kruskal-Wallis (H) test – differences between open- and close-skill sports (martial artists and sprint athletes)*

Intersegmental coordination - coefficients	χ^2	df	p
Learning capacity	1.479	2	0.477
Performance coeffficient	2.712	2	0.258
Choice reaction time	5.627	2	0.060
Resistance to disruptive factors	8.761	2	0.013
Personal rhythm	27.2	2	< 0.01
Time pressure	0.069	2	0.966
Autotempo coefficient	1.242	2	0.537

Table 3 emphasizes important differences between groups in the case of personal rhythm ($p < 0.01$), resistance to time pressure, $p = 0.013$ (in tasks requiring intersegmental coordination), and for choice reaction time.

Table 4. *DSCF test for multiple comparisons*

Resistance to disruptive factors (in tasks requiring IC)			
		W	p
1 sprint athletes	2 boxing	0.844	0.822
1 sprint athletes	3 jiu-jitsu	-3.014	0.084
2 boxing	3 jiu-jitsu	-3.930	0.015
Personal rhythm			
		W	p
1 sprint athletes	2 boxing	5.85	< .001
1 sprint athletes	3 jiu-jitsu	5.16	< .001
2 boxing	3 jiu-jitsu	-5.11	< .001
Choice reaction time			
		W	p
1 sprint athletes	2 boxing	-3.60	0.029
1 sprint athletes	3 jiu-jitsu	-1.40	0.584
2 boxing	3 jiu-jitsu	1.59	0.499

Note: IC: Intersegmental coordination.

Table 5. *Descriptive statistics open- and close-skill sports (martial artists and sprint athletes)*

	Sports branches	Choice reaction time	Resistance to disruptive factors	Personal rhythm
N	1 sprint athletes	14	14	14
	2 boxing	17	17	17
	3 jiu-jitsu	18	18	18
Mean	1 sprint athletes	1.67	1.06	35.1
	2 boxing	0.869	1.08	193
	3 jiu-jitsu	0.938	0.960	87.6
SE	1 sprint athletes	0.700	0.032	16.2
	2 boxing	0.051	0.026	24
	3 jiu-jitsu	0.045	0.065	11.9
Median	1 sprint athletes	1.02	1.08	17
	2 boxing	0.848	1.08	158
	3 jiu-jitsu	0.892	0.919	79
SD	1 sprint athletes	2.62	0.122	60.4
	2 boxing	0.211	0.108	98.8
	3 jiu-jitsu	0.192	0.278	50.3

Table 4 highlights significant differences between:

- boxing and jiu-jitsu (p = 0.015) for resistance to disruptive factors in tasks requiring intersegmental coordination ($M_{boxing} = 1.08$, $M_{jiu\text{-}jitsu} = 0.960$).
- sprint athletes (100 m), boxing and jiu-jitsu, for personal rhythm coefficient ($p < 0.001$), with sprint athletes realizing the fewest coordination errors in the third part of the test ($M_{sprint\ athletes\ 100\ m} = 35.1$), a part of the test where athletes have to find a fast and stable work rhythm.
- boxing and sprint athletes (p = 0.029) for choice reaction time ($M_{boxing} = 0.869$, $M_{sprint\ athletes} = 1.67$).

Not least, we checked if the results for intersegmental coordination are significantly related to athletes' sports performances.

Table 6. *Spearman correlation – personal best of sprint athletes (100 m) and coordination*

Personal best 100 m		CRT	RDF	PR	TP	AUTO	LC	PC
	r	0.413	0.296	0.126	0.370	0.336	0.409	-0.111
	p	0.142	0.303	0.667	0.193	0.240	0.146	0.706

Note. CRT: choice reaction time; RDF: resistance to disruptive factors; PR: personal rhythm; TP: time pressure; AUTO: autotempo coefficient; LC: learning capacity; PC: performance coefficient.

No significant correlations were found between variables: intersegmental coordination and sprint athletes' personal best (Table 6, $p > 0.05$). However, a moderate and positive correlation can be observed (r = 0.413 for CRT, respectively r = 0.409 for LC). This aspect is important because the sample is small ($n = 14$) and p-values are not very far from 0.05.

Table 7. *Mann-Whitney (U) test: I/N (n = 20) vs. R/L (n = 15) – martial arts athletes*

		Statistic	p
Choice-reaction time	Mann-Whitney U	118.0	0.293
Resistance to disruptive factor	Mann-Whitney U	117.0	0.278
Personal rhythm	Mann-Whitney U	113.0	0.213
Time pressure	Mann-Whitney U	143.5	0.840
Autotempo coefficient	Mann-Whitney U	110.0	0.187
Learning capacity	Mann-Whitney U	91.0	0.048
Performance coefficient	Mann-Whitney U	132.5	0.569

Note. I/N: International/ National sports performances; R/L: Regional/Local sports results.

Data in Table 7 emphasize that martial arts athletes (boxing and jiu-jitsu) having international and/ or national performances (top ranks at World, European and/or national competitions) have significantly better results (p = 0.048) in the case of learning capacity (they showed better intersegmental coordination in new, unfamiliar tasks), compared to martial artists with regional/local sports results ($M_{I/N\ performances} = 74.8$, $SD = 15.7$; $M_{R/L\ sport\ results} = 65.7$, $SD = 9.66$).

Discussions

Coordination is considered to be the ability to perform a sequence of tasks consistently in a smooth and precise manner (Dubey & Choudhary, 2023). A high degree of perception, anticipation and focus are also involved in coordinated movements, which are defined by appropriate rhythm, direction, speed, and muscle tension (Raj, 2006). Better and more efficient execution of a series of moves is the outcome of the athletes' ability to coordinate their movements (Pramanick, 2011). "Coordination is a complex psychomotor skill with an essential role in adaptation, which involves synergistic action of sensory functions (exteroceptive and interoceptive) and motor function, resulting in providing informational and energy parameters of the movement" (Grigore et al., 2012).

Coordinated movements represent a distinct category of *instrumental movements* – movements linked with device manipulation, tools (Aniței, 2007), which can be carried out at superior precision indices, timing and dexterity. In the present research, athletes' level of coordination (intersegmental coordination) was assessed with a computerized test involving levers and pedals manipulation.

In a first phase, athletes' level of performance was examined, in terms of intersegmental coordination. The strengths and weaknesses were, therefore, highlighted. In boxing and sprint (100m) the results for resistance to disruptive factors in tasks requiring intersegmental coordination (when unpredictable stimuli appear the athlete gives correct responses) and for choice reaction time (measures the speed of nerve impulse transmission and the time required for the mental operations of stimuli identification and selection of the appropriate psychomotor response – see Predoiu et al., 2016 for the mental operations of identification and selection) represent athletes' strengths. Also, athletes from boxing completed fast the third part of the test (autotempo coefficient), meaning fast reactions when they have to find a stable rhythm and coordinate their movements. However, even if the speed of the movements was good, the accuracy in terms of intersegmental coordination (meaning the personal rhythm coefficient) represents a weakness for boxing athletes. Other weaknesses observed: performance coefficient and learning capacity in the case of sprint athletes, boxing and jiu-jitsu. Athletes from the sports disciplines investigated need to develop the general ability of intersegmental coordination, both in terms of speed of execution and precision of movements (referring to performance coefficient, an overall indicator). Also, all athletes need to develop the ability to coordinate correctly with the upper and lower limbs in new circumstances (that require intersegmental coordination), when faced with new stimuli in the environment. It is worth mentioning, also, that in jiu-jitsu, choice reaction time represents a strength, the results being better than those obtained for other test coefficients.

The next step was to examine the type of sport-related differences in intersegmental coordination. Statistical data analysis revealed significant differences in the following areas: boxing and jiu-jitsu for resistance to disruptive factors in tasks requiring intersegmental coordination (boxing athletes obtaining a better score); boxing and sprint athletes for choice reaction time (boxing athletes obtaining a better result); sprint athletes (100 m), boxing and jiu-jitsu for personal rhythm coefficient (sprint athletes obtaining better results/fewer errors in the third part of the test – athletes were required to find a fast and stable work rhythm). These findings may be explained by the specific nature of boxing, an Olympic sport often performed under the scrutiny of large audiences, which could enhance athlete's ability to maintain coordination under pressure. Boxing as an Olympic sport is more mediatized (than jiu-jitsu), the noise is higher in the arena, and there are generally more spectators and thus more potentially disturbing factors. In this context, boxing athletes could have developed the ability to coordinate better in the presence of disturbing environmental factors. Regarding the choice reaction time, boxing is a heuristic sport, an open-skill sport, with an active and creative opponent that can force the athlete to re-evaluate tactics, to constantly analyse the movements (his/her own and the opponent's), to identify the weaknesses and to select the most appropriate movements with arms and legs in order to win. Sprint (e.g. 100 m) is an algorithmic sport, a close-skill sport, where the environment is more predictable and athletes go at their own pace. In this context, it is perhaps not by chance that sprint athletes obtained better results for the personal rhythm coefficient of the RCMV test.

The results of a previous research (Grigore et al., 2012) showed that athletes practicing sports with direct contact – karate, handball, basketball (open skill sports) have a significantly better eye-hand coordination (under slow speed and fast speed conditions) than those practicing sports without direct contact with the opponent – gymnastics, dance, athletics (jumps, running), swimming (close skill sports in this case) - both for male and female athletes. However, research regarding intersegmental coordination has demonstrated in a study (Teodorescu et al., 2012) that the recorded values for the performance coefficient of the RCMV test (providing information about the self-control capacity, the task adaptation, reaction time and the effective task-solving) were significantly better for participants competing in individual sports (gymnastics, track and field, swimming, tennis) than for those competing in team sports - basketball, handball, football (however, no martial arts athletes were investigated). The same study (Teodorescu et al., 2012) underlined that in the case of personal rhythm coefficient „athletes performing technical individual events registered a smaller number of errors as compared to the subjects practicing team sports" (track and field athletes were included in the sample). In the current study, sprint athletes obtained the best results for the personal rhythm coefficient/ fewest errors in terms of intersegmental coordination.

Not least, we explored if athletes' results for intersegmental coordination are significantly related to athletes' sports performances. No significant correlations were found between intersegmental coordination and sprint athletes' personal best. However, a moderate and positive correlation was observed for CRT and LC coefficient. Therefore, further studies should investigate more the link between learning capacity in new tasks requiring intersegmental coordination, choice reaction time and sprint athletes' personal best.

In the case of martial artists (boxing and jiu-jitsu), athletes having international and/ or national performances obtained significantly better results for learning capacity (they showed better intersegmental coordination in new tasks), compared to martial artists having regional/local sports results. Learning capacity is, therefore, an important dimension for martial artists. Acquiring a faster learning ability about how to correctly coordinate the upper and lower limbs in new, unfamiliar conditions may facilitate sport performance.

The limits of the research refer mainly to the small sample of participants in each sport. Also, different settings must be addressed, considering country, athletes' age and gender (results could be different if female athletes would be examined). Further research should explore other open- and close-skill sports in order to capture more and more clearly the differences in intersegmental coordination.

Conclusion

In both boxing and sprinting (100 metres) the results for resistance to disruptive factors in tasks, requiring intersegmental coordination and choice reaction time were identified as strengths for the athletes. Also, even if the speed of the movements was good in boxing athletes (autotempo coefficient), their accuracy in terms of intersegmental coordination (personal rhythm coefficient) represents a weakness. Other weaknesses observed among all athletes, including those in sprinting, boxing, and jiu-jitsu, were related to learning capacity and performance coefficient,

Boxing athletes outperformed male jiu-jitsu athletes in terms of resistance to disruptive factors in tasks requiring intersegmental coordination, and achieved better results in choice reaction time compared to sprint athletes. However, sprint athletes scored higher in personal rhythm, making fewer errors when required to find a fast and stable way to coordinate their movements, compared to both boxing and jiu-jitsu athletes. Learning capacity (correct coordination of upper and lower limbs in new perceptual conditions) was found to be a crucial variable for martial artists' sport performance.

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