SPORTS PERFORMANCE AND INTERSEGMENTAL COORDINATION VARIABILITY IN BOXING AND FENCING

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Abstract: Intersegmental coordination is particularly important in sports, where competitors must consistently coordinate their movements to attain ideal execution. This study aimed to examine the strengths and weaknesses of athletes practicing boxing and fencing, in terms of intersegmental coordination. Also, the study investigates the way athletes' coordination level vary according to their sports performances/caliber. Forty-one combat sport athletes participated in the study, 28 male athletes and 13 female athletes (M_{age} = 22.29). Athletes practice boxing (20 athletes) and fencing (21 athletes). The RCMV computerized test was used to assess hand-foot coordination, a test that generates coefficients such as: learning ability, working memory coefficient, disturbance resistance coefficient, personal best pace, self-pacing coefficient, time pressure resistance, perceptual field inspection and complex/choice reaction time. To capture the strengths and weaknesses of combat sport athletes, in terms of intersegmental coordination, the single-sample t-test was performed. To observe how athletes' results for intersegmental coordination vary according their caliber (sports performance) the Kruskall-Wallis H test and the Dwass-Steel-Critchlow-Fligner procedure (for pairwise comparisons) were used. The strengths, in terms of intersegmental coordination, specific to combat sport athletes practicing boxing and fencing and having superior results in competition (Tier 5 and 4) refer to: resistance to disruptive (visual) factors and perceptual field inspection. Data analysis showed, also, that athletes having international performances registered better results for working memory coefficient and for perceptual field inspection in tasks requiring intersegmental coordination, compared to boxers and fencers having a lower caliber.
Keywords: intersegmental coordination, combat sports, boxing, fencing, sports performance.

Introduction

Sports performance is the main motivation underlying the instructional-training process, imposing significant costs in terms of time, energy and material costs (Predoiu, 2016). Platonov (2001) considers that sports performance expresses the maximum potential of a person, in a given discipline, at a given point in his/her development. It seems that the level of sports performance increases in direct relation to the level of culture and civilization of mankind (Tüdös & Mitrache, 2011). Among the variables that condition sports performance, the following stand out (Rees et al., 2016): genetics, anthropometric and physiological factors, support provided by family, coach, sports psychologist, etc., psychological abilities and personality traits of athletes (and specialists).

The present study investigates competitive athletes practicing boxing and fencing. Although different sporting disciplines, there are certain similarities between the two Olympic combat sports. For example, athletes' upper limbs are positioned forward/ in front of the body when fighting, athletes move forward and backward to capture the right moment to trigger an attack (using the upper limbs), while athletes are not allowed to strike using the lower limbs. Also, boxing has certain similarities in terms of footwork and rhythm to fencing.

Fencing is an Olympic combat sport based on the use of weapons. The Olympic fencing competition is conducted in the disciplines of sabre, epee and foil according to the rules of the International Fencing Federation (FIE) (Łuczak, 2015). Fencing was also included by the Greeks in the first Olympic Games (776 BC) as *weapon combat* (Predoiu et al., 2022). The epee is considered to be the hardest of the three weapons specific to modern fencing, as the whole body is the valid target area (Borysiuk et al., 2018). The practice of fencing develops special perceptual skills, as fencing requires cognitive/ intellectual processes involving spatial localization, anticipation and a good ability to make appropriate and quick decisions (Feng et al., 2010).

Boxing is one of the oldest sports in the world, being known in ancient Sumer, Egypt and Crete (Parada, 1980). Boxing is a combat sport in which two contestants fight each other using only their fists above the waist. Attacks below the waist and elbow strikes are forbidden. The athlete must hit his opponent accurately while avoiding his opponent's blows. The fighter who knocks out his rival or defeats him on points is the winner (Litwic-Kaminska et al., 2023). Olympic boxing competition is conducted according to the rules of the International Boxing Association (Lee-Barron, 2012). Boxing was introduced into the program of the modern Olympic Games in Saint Louis in 1904 (Lipoński, 1987). In a boxing match not only courage, but also emotional sensitivity and responsibility for decisions are tested. The athlete is in the ring alone with his opponent, suffering pain and inevitably risking his health (Cynarski and Litwiniuk, 2006; Predoiu et al., 2024). In Romania, boxing is very popular, Romania being a constant presence at the highest level in international competitions – is among the top 10 countries in the world in terms of medals won at the Olympic Games (see Bagińska et al., 2022).

Fencing, as Olympic combat sport, according to division of the combat sports under forms of the direct confrontation (Kalina, 2000) falls under *workings of weapons* category, while boxing fall under *hits* category. The two sports disciplines will be examined, in the current study, as conventional “striking combat sports”, as in previous research (Predoiu et al., 2022; Patenteu et al., 2024; Predoiu et al., 2024).

In modern sport, performance models have come to structure the training of athletes as specialists seek to follow the best route on the *winding* road to peak sporting performance that is best suited to the demands of their sports discipline. In 2020, Santero et al. discussed about P.O.E.T. model, specific in combat sports (boxing). The model includes elements indispensable for boxers to improve their performance, related to: strategies used during the fight, physical and psychological characteristics of the athlete, environment (or context), and task. More specifically the P.O.E.T. model refers to:

o *Training and performance*: number of hours of training, technical-tactical skills, upper and lower limb technique in attack and defense, medical control, recovery.

- *Physical and psychological characteristics*: laterality, muscular strength, joint amplitude, quality of muscle fibers, muscular endurance, motivation, observation, personality, intelligence, will, family support.
- *Context:* size of the surface, complexity of the situations, number of fights performed.
- *Task characteristics*: attack and defense (upper and lower limbs), previous fights, video analysis of future opponents.

Considering coordination, in the last 20 years the researchers’ attention has been focused on difficulties in acquiring coordinative skills (de Castelnau et al., 2007). In 2005, Geuze addressed the issue of motor development and sensory-motor integration difficulties in children. Studies on eye-hand coordination (Kaiser et al., 2009) and intersegmental coordination (Lamoth et al., 2009) have also been conducted. Other researchers address changes in execution cues under the impact of psychophysical fatigue (Zory et al., 2009). Coordination has been investigated in combat sports, as it is necessary for the correct technique (Hartmann & Fetz-Hartmann, 2012; Starosta & Fostiak, 2013). Thus, the execution of techniques with maximal precision and efficiency at the opportune moment exemplifies well-developed coordination, a quality deeply intertwined with the central nervous system's functionality (Breaz, 2019).

The efficiency of intersegmental coordination directly impacts an athlete's ability to generate power, maintain balance, and execute complex skills with precision (Mańkowska et al., 2015). Motor coordination, which involves the harmonious interaction of the nervous and musculoskeletal systems, is crucial for producing quick, precise, and well-balanced motor responses (Fernandes et al., 2016). But the importance of coordination extends beyond mere physical execution; it encompasses the cognitive processes involved in anticipating an opponent's movements, reacting swiftly to changing circumstances, and adapting strategies on the fly, especially in heuristic sports such as boxing and fencing when under uncertainty athletes need to be inventive "in their quest to find the best solutions to achieve their performance goals" (Predoiu et al., 2018).

Materials and method

Scope

The aim of the research is to examine the strengths and weaknesses of athletes practicing boxing and fencing, in terms of intersegmental coordination. Moreover, the study investigates the way athletes' intersegmental coordination levels vary according to their sport results.

Research questions

1) What are the strengths and weaknesses of athletes practicing boxing and fencing, in terms of intersegmental coordination?

2) How do combat sport athletes' results for intersegmental coordination vary taking into consideration their caliber (Tier)?

Participants

Forty-one senior combat sport athletes participated in the study, 28 male athletes and 13 female athletes, aged between 18-30 years: M_{age} = 22.29, SD = 4.05. A minimum of two years of competitive experience was set as an inclusion criterion – $M_{competitive\ experience}$ = 4.70, SD = 2.66 (in the entire sample). Martial arts athletes are affiliated to different sports clubs in Romania, recognized by national federations.

Athletes in the current study practice boxing (20 athletes - 18 M and 2 F) and fencing (21 athletes - 10 M and 11 F). According to The Participant Classification Framework (McKay et al., 2022) the investigated combat sport athletes are classified as Tier 5 (World class, *N* = 4), Tier 4 (Elite/International level, *N* = 9), Tier 3 (Highly trained/National level, *N* = 14), respectively Tier 2 (Trained/Developmental, *N* = 14). No participant in this research is classified under Tier 1 (recreationally active). Due to very small sample size in the case of World class athletes, Tier 5 and Tier 4 participants formed a single group in this study (*N* = 13).

Measures

The RCMV computerized test (created by RQ Plus company, Romania) was used to assess intersegmental coordination. "RCMV assesses motor coordination through bi-segmental and multi-segmental responses" (Vicol et al., 2025). The test was used in different studies with athletes (Dumitru et al., 2024; Cojocaru et al., 2015; Grigore et al., 2011), and automatically generates coefficients such as: learning ability (how the athlete coordinates when faced with new stimuli); working memory coefficient (athletes' ability to operate promptly with procedural knowledge – which move to make in a specific situation); general performance coefficient (the ratio between accuracy and response time during the computerized test); disturbance resistance coefficient (how well the athlete coordinates his/her movements in the presence of disturbing visual stimuli); personal best pace coefficient (only the accuracy of movements and only in the most dynamic part of the computerized test); self-pacing coefficient (only the speed of movements and only in the most dynamic part of the test); time pressure resistance coefficient (how well the athlete coordinates when the stimuli come in quick succession); perceptual field inspection coefficient (a good result means a good attentional set-up that involves awareness of significant stimuli in the environment, locating them correctly in space, and a good speed of correctly coordinated movements); complex reaction time (the interval of time between the appearance of a non-anticipated stimuli and the onset of athletes' response (Schmidt & Wrisberg, 2000).

How RCMV test works – "at variable time intervals and in a randomized order, square-shaped centrally-left/-right, upward/downward positioned relevant stimuli" (Predoiu, 2015) appear on the computer screen. Athletes hold a lever in each hand, while feet are placed on pedals. The participant "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" (Teodorescu et al., 2011). Two or three red squares are visible on the screen in the same time. The computerized test assumes the existence of 6 possible stimuli which require six different coordinated

movements. RCMV test lasts approximately 10 minutes.
The raw scores registered (for each coefficient) divide combat sport athletes into five classes, where Class/level 5 = very good performance, while Class/level 1 = very weak result (Predoiu et al., 2024).

Procedure

The RCMV test was applied in the experimenter's presence between 2023-2024. Data confidentiality was ensured, and combat sport athletes provided their written informed consent to take part in the study. Athletes performed the RCMV test for the first time, being known that the quality of coordinated movements can be influenced by the previous experience with a specific task.

Results

In a first phase, martial arts athletes' performance in terms of intersegmental coordination was examined (Table 1).

Table 1. Intersegmental coordination – performance level (classes) in the case of all coefficients of the RCMV test

	TIER	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Mean	TIER 5 and 4	3.38	3.46	2.46	3.46	4.23	3.31	3.69	4.54	3.23
	TIER 3	3.00	3.00	2.50	3.64	4.21	3.14	3.50	4.64	3.43
	TIER 2	2.64	2.64	2.43	4.00	4.00	2.79	3.00	3.50	3.57
	Overall score	3.00	3.02	2.46	3.7	4.15	3.07	3.39	4.22	3.41
Std. error	TIER 5 and 4	0.290	0.291	0.183	0.243	0.122	0.208	0.308	0.243	0.257
	TIER 3	0.257	0.148	0.139	0.199	0.239	0.294	0.228	0.169	0.228
	TIER 2	0.133	0.169	0.137	0.148	0.314	0.214	0.210	0.251	0.137
SD	TIER 5 and 4	1.04	1.05	0.660	0.877	0.439	0.751	1.11	0.877	0.927
	TIER 3	0.961	0.555	0.519	0.745	0.893	1.10	0.855	0.633	0.852
	TIER 2	0.497	0.633	0.514	0.555	1.18	0.802	0.784	0.941	0.514

Note. Class 5: very good performances, Class 3: average performances, Class 1: very weak, A: learning ability, B: working memory coefficient,
C: general performance (during the computerized test), D: complex reaction time, E: disturbance resistance coefficient, F: personal best pace,
G: time pressure resistance coefficient, H: perceptual field inspection, I: self-pacing coefficient.

Data in Table 1 highlight that combat sport athletes with higher caliber (Tier 5, 4 and 3) registered better values for intersegmental coordination, compared to athletes having regional/local sports results (Tier 2). Athletes obtained (generally) above-average results for intersegmental coordination (> class/level 3), with the highest values for disturbance resistance coefficient (E) and perceptual field inspection coefficient (H).
To capture the strengths and weaknesses of combat sport athletes, in terms of intersegmental coordination, the one-sample t-test was performed. The Mean of all classes and for all coefficients generated by the RCMV test (which served as the test value) is 3.38 (calculated based on the overall score, Table 1). Athletes' strengths and weaknesses are presented (separately) for each group/ Tier.

Table 2. Single sample t test – results in descending order of mean score

Coefficients – TIER 5 and 4	**t(12)**	**p**
A	0.015	0.987
B	0.28	0.784
C	-5.01	< 0.01 (Mean = 2.46)
D	0.33	0.743
E	6.99	< 0.01 (Mean = 4.23)
F	-0.34	0.734
G	1.015	0.330
H	4.76	< 0.01 (Mean = 4.54)
I	-0.58	0.572
Coefficients – TIER 3	**t(13)**	**p**

A	-1.47	0.162
B	-2.56	0.023 (Mean = 3.00)
C	-6.34	< 0.01 (Mean = 2.50)
D	1.32	0.209
E	3.49	0.003 (Mean = 4.21)
F	-0.807	0.434
G	-0.525	0.608
H	7.46	< 0.01 (Mean = 4.64)
I	0.213	0.834
Coefficients – TIER 2	**t(13)**	**p**
A	-5.54	< 0.01 (Mean = 2.64)
B	-4.35	< 0.01 (Mean = 2.65)
C	-6.93	< 0.01 (Mean = 2.42)
D	4.18	< 0.01 (Mean = 4.00)
E	1.97	0.070
F	-2.77	0.015 (Mean = 2.78)
G	-1.81	0.093
H	0.477	0.641
I	1.39	0.186

Note. A: learning ability, B: working memory coefficient, C: general performance (during the test), D: complex reaction time, E: disturbance resistance coefficient, F: personal best pace coefficient, G: time pressure resistance, H: perceptual field inspection, I: self-pacing coefficient.

Significant differences ($p < 0.05$) were observed for various coefficients automatically generated by the RCMV test. Investigated athletes (boxers and fencers) obtained the following strengths and weaknesses in the case of intersegmental coordination.

TIER 5 and 4

- ***Strengths:*** disturbance resistance coefficient (the athlete coordinates his/her movements well in the presence of disturbing visual stimuli) and perceptual field inspection (the athlete has a good attentional set-up that involves rapid shifting of gaze fixation points, awareness of the occurrence of relevant information, rapid localization of information, and a good speed of motor response in task requiring intersegmental coordination).
- ***Weaknesses:*** general performance coefficient (the ratio between accuracy and response time, in general, during the RCMV test).

TIER 3

- ***Strengths:*** disturbance resistance coefficient and perceptual field inspection (the same as athletes having Tier 5 and 4).
- ***Weaknesses:*** general performance coefficient (the same as athletes having Tier 5 and 4), and working memory coefficient (reflects athletes' ability to remember and operate promptly with procedural knowledge, for example knowledge of action, procedures in performing a task).

TIER 2

- ***Strengths:*** complex reaction time (expresses athletes' ability to initiate and execute fast motor operations).
- ***Weaknesses:*** general performance coefficient, working memory coefficient (the same as athletes having Tier 3), but, also, learning ability (the correctness of the athlete's movements when faced with new situations/stimuli - it refers only to the first part of the test) and personal best pace coefficient (the accuracy in the case of intersegmental coordination in the last part of the RCMV test).

Next, we were interested about how athletes' results for intersegmental coordination vary according their caliber (sports performance). To achieve this goal we used the Kruskall-Wallis H test, and then the Dwass-Steel-Critchlow-Fligner procedure (for pairwise comparisons). Tables 3-5, respectively Tables 7-9 contain (mainly) the significant differences found.

Table 3. Kruskal-Wallis test – results at RCMV test (working memory coefficient) according to athletes' caliber

	χ^2	df	p	ε^2
Working memory coefficient (raw score)	7.03	2	0.030	0.176
Working memory (classes/level)	5.21	2	0.074	0.130

Table 4. Dwass-Steel-Critchlow-Fligner procedure – working memory coefficient (raw score)

		W	p
TIER 5 and 4	TIER 3	-1.42	0.576
TIER 5 and 4	TIER 2	-3.34	0.048
TIER 3	TIER 2	-2.81	0.116

Table 5. Dwass-Steel-Critchlow-Fligner procedure – working memory coefficient (classes/level)

		W	p
TIER 5 and 4	TIER 3	-1.63	0.484
TIER 5 and 4	TIER 2	-2.94	0.094
TIER 3	TIER 2	-2.05	0.317

A significant difference was found for working memory coefficient (raw scores, $p = 0.048$), between athletes having Tier 5 and 4 (international performances), and combat sport athletes having Tier 2 (regional/local results), but not for classes (when the raw scores are grouped into level of performances). Even if the difference is not significant, athletes having Tier 3 (national results) registered better scores for the ability to remember and operate fast with procedural knowledge (in tasks requiring intersegmental coordination), compared to Tier 2 athletes (Table 6).

Table 6. RCMV test – working memory coefficient (raw score and classes/level)

Item	TIER	Working memory coefficient (raw scores)	Classes (level)
N	TIER 5 and 4	13	13
	TIER 3	14	14
	TIER 2	14	14
Mean	TIER 5 and 4	935	3.46
	TIER 3	924	3.00
	TIER 2	888	2.64
Median	TIER 5 and 4	947	3
	TIER 3	935	3.00
	TIER 2	912	3.00
Standard deviation	TIER 5 and 4	43.6	1.05
	TIER 3	33.9	0.555
	TIER 2	58.9	0.633

Note. Class (level) 5: very good performances, Class 3: average performances, Class 1: very weak scores.

Table 7. Kruskal-Wallis test – results for perceptual field inspection coefficient according to athletes' caliber

Item	χ^2	df	p	ε^2
Perceptual field inspection coefficient (raw score)	12.0	2	0.003	0.299
Perceptual field inspection (classes/level)	11.7	2	0.003	0.293

Note. χ^2= chi-square, df= degrees of freedom, p= significance threshold, ε^2 = effects size (epsilon squared)

Table 8. Dwass-Steel-Critchlow-Fligner procedure – perceptual field inspection coefficient (raw scores)

Item		W	p
TIER 5 and 4	TIER 3	-0.178	0.991
TIER 5 and 4	TIER 2	-3.953	0.014
TIER 3	TIER 2	-4.137	0.010

Table 9. Dwass-Steel-Critchlow-Fligner procedure – perceptual field inspection (classes/level)

Item		W	p
TIER 5 and 4	TIER 3	-0.0447	0.999
TIER 5 and 4	TIER 2	-3.7102	0.024
TIER 3	TIER 2	-4.3391	0.006

Significant differences were found for perceptual field inspection in tasks requiring intersegmental coordination, between athletes having a higher caliber (Tier 5, 4 and 3), and combat sport athletes having Tier 2 (a lower caliber), for the raw scores and classes/level of performance. Table 10 presents the results at descriptive level.

Table 10. RCMV test – perceptual field inspection (raw scores and classes/level)

Item	TIER	Perceptual field inspection coefficient (raw scores)	Classes/level
Mean	TIER 5 and 4	969	4.54
	TIER 3	971	4.64
	TIER 2	848	3.50
Median	TIER 5 and 4	1000	5
	TIER 3	1000	5.00
	TIER 2	867	3.00
Standard deviation	TIER 5 and 4	58.3	0.877
	TIER 3	56.8	0.633
	TIER 2	168	0.941

Discussion

Intersegmental coordination, a cornerstone of human movement, refers to the intricate orchestration of multiple body segments to produce efficient motor actions. Intersegmental coordination is especially paramount in sports, where athletes must seamlessly integrate the movements of their limbs and trunk, to achieve optimal performance (Shirota et al., 2016). In combat sports, a good coordination of movements is essential for success, influencing a competitor's offensive, counteroffensive, and defensive capabilities (Atan & İmamoğlu, 2005).

Coordination in combat sports manifests through a myriad of specific skills, each requiring a unique blend of agility, balance, and timing. Considering the footwork of a boxer, or the striking combinations of a fencer, each of these actions necessitates a high degree of coordination to be executed effectively under the duress of competition. The complexity of coordination is further amplified by the dynamic and unpredictable nature of combat situations, where athletes must constantly adjust their movements and strategies in response to their opponent's actions. The development of coordination and learning sensorimotor abilities represent a multifaceted process that involves both innate abilities and learned skills (Rao et al., 2018). While some individuals may possess a natural aptitude for movement coordination, consistent and targeted training is essential for maximizing an athlete's potential.

The current study investigated the strengths and weaknesses of athletes practicing boxing and fencing, in terms of intersegmental coordination, and, also, examined the way combat sport athletes' coordination level vary according to their sports caliber. As strengths, specific to athletes having higher caliber, we observed disturbance resistance coefficient and perceptual field inspection in task requiring intersegmental coordination. Specifically, athletes practicing boxing and fencing (Tiers, 5, 4 and 3) coordinate their movements well in the presence of disturbing visual stimuli and have a good attentional set-up that involves rapid shifting of gaze fixation points, rapid localization of relevant information, and a good speed of motor answer (in task requiring intersegmental coordination). Previous studies underlined the important role of the disturbance resistance coefficient when performing intersegmental movements, this indicator (specific to the RCMV test) being linked to a better ranking position of athletes (Predoiu, 2015).

As weaknesses (regardless of athletes' caliber) the general performance coefficient stands out (slightly below average results were obtained). Therefore, a better balance between accuracy and response time in tasks requiring intersegmental coordination should be a priority for specialists in the training process. Moreover, in the case of Tier 2 athletes one can observe the best results for complex/choice reaction time (Table 1). These combat sport athletes have clearly valorized speed (during the RCMV test) over accuracy (coordinated movements). Investigating Romanian freestyle and Greco-Roman wrestlers, members of the Olympic team (Predoiu et al., 2018), the following results for intersegmental coordination were obtained (the same RCMV test was applied): good values for perceptual field inspection coefficient; very good scores (for girls) and good results (for boys) in the case of resistance to disruptive (visual) factors coefficient; above average or slightly above average results in the case of working memory coefficient, learning ability, complex/choice reaction time and resistance to time pressure coefficient.

With respect to athletes' coordination level and combat sport athletes' sports performances, a significant difference was found for working memory coefficient, between athletes having Tier 5 and 4 (international performances) and combat sport athletes having a lower caliber (Tier 2). Also, it is worth mentioning that athletes having national sport results (Tier 3) registered better values for the ability to remember and operate fast with procedural knowledge (in tasks requiring intersegmental coordination), compared to Tier 2 athletes (even if the differences were not significant). Furthermore, a significant difference was found for perceptual field inspection coefficient between boxers and fencers having a higher caliber (Tier 5, 4 and 3), and combat sport athletes having a lower caliber (Tier 2). When ready to coordinate their movements, athletes with international and/or national sports performances demonstrated a better attentional set-up, a rapid shift of gaze fixation points and a rapid localization of relevant stimuli in the environment, compared to athletes with regional/local sport results. These data are especially important for coaches and sport psychologists, to scientifically conduct the training process.

The development of coordination abilities is very important, as it determines human motor fitness (Chovanová, 2019), which is crucial for athletes seeking to attain technical mastery (Mańkowska et al., 2015). To improve combat sport athletes' sports performances, coordination and reaction time are psychomotor dimensions which need to be addressed, especially as they can be improved through training (Proctor & Schneider, 2018). Sensory stimulation (Wilimzig et al., 2012) can be used, or computer-based training programs (Simpson et al., 2012) and not least, strobe training, "a form of cognitive-motor training where the vision is impaired intermittently" (see Vasile & Stănescu, 2023), information processing speed being stimulated. Also, optimal movement patterns may be enhanced by augmenting exercises with additional loads, thus amplifying proprioceptive feedback mechanisms (Forte & Teixeira, 2023). Mastering sports techniques requires, therefore, a comprehensive understanding of the role and importance of motor actions within the game, with training outcomes closely tied to motor skills (Naumchuk, 2019).

The development of technology has enabled the exploration of intersegmental coordination increasingly analytical. For example, different athletes may register nearly identical reaction times when performing a coordinated movement in sport, but important differences can be observed when visual perception and motor function are examined (using EMG) (see Hülsdünker et al., 2018).

In the current work we identify with the views of scientists and recognized experts who promote the new applied science INNOAGON – *Innovative agonology*, an applied science dedicated to promotion, prevention and therapy related to all dimensions of health and regarding the optimization of activities that increase the ability to survive from micro to macro scales (Kalina, 2023). Previously published works pre-dedicated 'agonology' are the basis for understanding this science, a perspective of interdisciplinary research (Krzemieniecki & Kalina, 2011), the prospect of an effective defence of peace (Kalina, 2016), promoting (among other aspects) positive cooperation, negative cooperation (the necessary defence, as a part of struggle), and, also, concluding compromises, teaching respect for rules and own or the opponent's body.

The present study is not without limits. Taking into consideration that visuomotor reaction time refers, also, to the time between stimulus onset and initial muscular activation - when using EMG onset (Hülsdünker & Mierau, 2021), further studies could use EMG, and not button pressing (as in the current study) to investigate reaction times when performing a coordinated movement. The samples of athletes practicing boxing and fencing are gender unbalanced, further studies being necessary to investigate intersegmental coordination according, also, to gender. Therefore, different results could be obtained if only male or only female athletes would be explored, on larger samples and from various combat sports disciplines (striking combat sports – e.g., karate, taekwondo, or grappling combat sports such as judo and wrestling).

Conclusions

The strengths, in terms of intersegmental coordination, specific to combat sport athletes practicing boxing and fencing and having better sports performances (Tier 5 and 4) refer to: resistance to disruptive (visual) factors and perceptual field inspection. More weaknesses were observed in the case of Tier 2 athletes, such as: general performance (during the RCMV test), working memory coefficient, learning ability and personal best pace coefficient. Our findings revealed, also, that athletes having Tier 5 and 4 (international performances) registered better results for working memory coefficient and for perceptual field inspection in tasks requiring intersegmental coordination, compared to boxers and fencers having a lower caliber.

References

Atan, T., & İmamoğlu, O. (2005). Competition analysis of World Greco-Roman and World free-style wrestling championships. *International Journal of Performance Analysis in Sport,* *5*(1): 31. https://doi.org/10.1080/24748668.2005.11868313

Bagińska, J., Piepiora, P., Piepiora, Z., & Witkowski, K. (2022). The geography of Olympic combat sports – part two: boxing, fencing, modern pentathlon, wrestling. *Archives of Budo, 18*, 327-340.

Borysiuk, Z., Czyz, S., Markowska, N., Konieczny, M., & Pakosz, P. (2018). Fencing fleche performed by elite and novice epeeists depending on type of perception. Archives of Budo, 14, 179-187.

Breaz, P. C. (2019). Study on the development of coordinating capacities in gymnasium education students. *Bulletin of the Transilvania University of Braşov Series IX Sciences of Human Kinetics*, *12*, 87-96. https://doi.org/10.31926/but.shk.2019.12.61.2.43

de Castelnau, P., Albaret, J. M., Chaix, Y., & Zanone, P. G. (2007). Developmental coordination disorder pertains to a deficit in perceptuo-motor synchronization independent of attentional capacities. *Human movement science*, *26*(3), 477–490. https://doi.org/10.1016/j.humov.2007.03.001

Chovanová, E. (2019). The development of coordination abilities in non-integrated students and correction of behavior disorders in integrated students through engaging in movement games. *Physical Activity Review, 7*, 209. https://doi.org/10.16926/par.2019.07.25

Cojocaru, V., Tüdös, Ş., Predoiu, R., Coliţă, E., & Coliţă, D. (2015). Study regarding the impact of trait anxiety on intersegmental coordination and topographical memory in junior football players. *Procedia-Social and Behavioral Sciences*, *187*, 124-129. https://doi.org/10.1016/j.sbspro.2015.03.024

Cynarski, W. J., & Litwiniuk, A. (2006). The violence in boxing. *Archives of Budo, 2*, 1-10.

Dumitru, E., Tudor, V., Dumitru, N., Stănescu, M., & Dina, L. (2024). The role of street dance in developing psychomotor skills and creativity of students. *Discobolul – Physical Education, Sport and Kinetotherapy Journal, 63*(1), 1-14. https://doi.org/10.35189/dpeskj.2024.63.1.1

Feng, Y., Zhou, C., & Zhang, T. M. (2010). Neural mechanisms of intuitive tactical decision-making predominance of high-level fencing athletes. *Journal of Medical and Biological Engineering, 30*(1), 47-56.

Fernandes, V. R., Ribeiro, M. L. S., Melo, T., de Tarso Maciel-Pinheiro, P., Guimarães, T. T., Araújo, N. B., de Ribeiro, S., & Deslandes, A. C. (2016). Motor coordination correlates with academic achievement and cognitive function in children. *Frontiers in psychology, 7:* 318. https://doi.org/10.3389/fpsyg.2016.00318

Forte, P., & Teixeira, J. E. (2023). Exercise Biomechanics for Health: Evaluating Lifelong Activities for Well-Being. *Healthcare, 11*(6): 900. https://doi.org/10.3390/healthcare11060900

Geuze, R. H. (2005). *Le Trouble de l'Acquisition et de la Coordination. Evaluation et rééducation de la maladresse chez l'enfant*. Solal.

Grigore, V., Predoiu, R., & Mitrache, G. (2011). Study Concerning the Psycho-Motor Coordination-Differences Between Sports. *Procedia-Social and Behavioral Sciences, 30*, 1995-2000. https://doi.org/10.1016/j.sbspro.2011.10.388

Hartmann, B., & Fetz-Hartmann, A. (2012). The importance of coordination in freestyle wrestling. *International Journal of Wrestling Science, 2*(1), 48-52. https://doi.org/10.1080/21615667.2012.10878944

Hülsdünker, T., & Mierau, A. (2021). Visual Perception and Visuomotor Reaction Speed Are Independent of the Individual Alpha Frequency. *Frontiers in neuroscience, 15*, 620266. https://doi.org/10.3389/fnins.2021.620266

Hülsdünker, T., Strüder, H. K., & Mierau, A. (2018). Visual but not motor processes predict simple visuomotor reaction time of badminton players. *European journal of sport science, 18*(2), 190–200. https://doi.org/10.1080/17461391.2017.1395912

Kaiser, M. L., Albaret, J. M., & Doudin, P. A. (2009). Relationship between visual-motor integration, eye-hand coordination, and quality of handwriting. *Journal of Occupational Therapy, Schools, & Early Intervention, 2*(2), 87-95. https://doi.org/10.1080/19411240903146228

Kalina, R. M. (2000). *Teoria sportów walki* [Theory of combat sports]. COS.

Kalina, R. M. (2016). Agonology – the prospect of an effective defence of peace and unrestricted freedom of scientists. *Archives of Budo, 12*, 1-13.

Kalina, R. M. (2023). Innovative Agonology – Definition, Detailed Theories, Laws, and General Rule of Struggle. *Healthcare and Medical Devices, 79*, 272-279 http://doi.org/10.54941/ahfe1003497

Krzemieniecki, L. A., & Kalina, R. M. (2011). Agon – a term connecting the theory of struggle with belles-lettres. A perspective of inter-disciplinary research. *Archives of Budo, 7*(4), 255-265.

Lamoth, C. J., Daffertshofer, A., Huys, R., & Beek, P. J. (2009). Steady and transient coordination structures of walking and running. *Human movement science, 28*(3), 371–386. https://doi.org/10.1016/j.humov.2008.10.001

Lee-Barron, J. R. (2012). The martial science of boxing and its contribution to military close combat. *Ido Movement for Culture. Journal of Martial Arts Anthropology, 12*(4), 20-25.

Lipoński, W. (1987). *Humanistyczna Encyklopedia Sportu* [The Humanist Encyclopedia of Sports]. Sport i Turystyka.

Litwic-Kaminska, K., Brzezińska, P., Waldziński, T., Durzyńska, A., Stankiewicz, B., Bartík, P., Kochanowicz, A., & Mieszkowski, J. (2023). Affective temperament, coping styles and frontal functions among elite boxing and karate athletes. *Archives of Budo, 19*, 309-317.

Łuczak, M. (2015). A review of major polish scholarly studies on fencing in the 21st century. *Ido Movement for Culture. Journal of Martial Arts Anthropology, 2*(15), 1-9.

Mańkowska, M., Poliszczuk, T., Poliszczuk, D., & Johne, M. (2015). Visual Perception and its Effect on Reaction Time and Time-Movement Anticipation in Elite Female Basketball Players. *Polish Journal of Sport and Tourism, 22*(1), 3-8. https://doi.org/10.1515/pjst-2015-0008

McKay, A. K. A., Stellingwerff, T., Smith, E. S., Martin, D. T., Mujika, I., Goosey-Tolfrey, V. L., Sheppard, J., & Burke, L. M. (2022). Defining Training and Performance Caliber: A Participant Classification Framework. *International journal of sports physiology and performance, 17*(2), 317–331. https://doi.org/10.1123/ijspp.2021-0451

Naumchuk, V. (2019). Characterization of the Four-Stage Structure of the Process of Learning Motor Actions in Sports Games. *International Journal of Human Movement and Sports Sciences, 7*(4): 81. https://doi.org/10.13189/saj.2019.070403

Parada, Z. (1980). *Starożytne i nowożytne igrzyska olimpijskie* [Ancient and modern Olympic games]. Krajowa Agencja Wydawnicza.

Patenteu, I., Gawrych, R., Bratu, M., Vasile, L., Makarowski, R., Bitang, A., & Nica, S. A. (2024). The role of psychological resilience and aggression in injury prevention among martial arts athletes. *Frontiers in psychology, 15*: 1433835. https://doi.org/10.3389/fpsyg.2024.1433835

Platonov, V. N. (2001). *Teoría General del Entrenamiento Deportivo Olímpico* [General Theory of Olympic Sports Training]. Editorial Paidotribo.

Predoiu, R. (2015). Intersegmental and eye-hand coordination in elite junior tennis players. *Procedia-Social and Behavioral Sciences, 187*, 107-112. https://doi.org/10.1016/j.sbspro.2015.03.021

Predoiu, A., Predoiu, R., Pelin, F., Mitrache, G., Grigore, V., & Ozarchevici, C. (2018). Intellectual and psychomotor strengths and weaknesses in the case of athletes – members of the Romanian greco-roman and freestyle wrestling Olympic team. *Discobolul – Physical Education, Sport & Kinetotherapy Journal, 54*, 11-17.

Predoiu, R. (2016). *Psihologia sportului. Maximizarea performanței sportive* [Sport psychology. Maximizing sports performance]. Polirom.

Predoiu, R., Dințică, G., Zdanovschi, A. M., Hatuel Czuckermann, L., Predoiu, A., & Tătăran, A. (2022). The flow state in elite Romanian fencers. *Discobolul – Physical Education, Sport & Kinetotherapy Journal, 61*(3), 307-318. https://doi.org/10.35189/dpeskj.2022.61.3.4

Predoiu, R., Makarowski, R., Piotrowski, A., Görner, K., Predoiu, A., Malinauskas, R., ... & Rawat, S. (2022). Experienced stress among martial arts athletes from selected European Union countries during the 4th wave of the covid-19 pandemic and the frequency of using coping strategies. *Archives of Budo, 18*, 211-226.

Predoiu, R., Piotrowski, A., Stan, E. A., Ciolacu, M. V., Bitang, A., Croitoru, D., & Cosma, G. (2024). Explicit and indirect, latency-based measure of aggression in striking combat sports. *Frontiers in Psychology, 15:* 1451244. https://doi.org/10.3389/fpsyg.2024.1451244

Predoiu, R., Stănescu, R., Alberton, M., Lixandru, V., Ciudoiu, I. A., Marica, A. V., Ion, A. D., & Cosma, G. (2024). Assessing coordination in open-and closed-skill sports – martial artists and sprint athletes. *Discobolul – Physical Education, Sport and Kinetotherapy Journal, 63*(2), 127-141. https://doi.org/10.35189/dpeskj.2024.63.2.4

Proctor, R. W., & Schneider, D. W. (2018). Hick's law for choice reaction time: A review. *Quarterly Journal of Experimental Psychology, 71*(6), 1281-1299.

Rao, H. M., Khanna, R., Zielinski, D. J., Lu, Y., Clements, J. M., Potter, N. D., Sommer, M. A., Kopper, R., & Appelbaum, L. G. (2018). Sensorimotor Learning during a Marksmanship Task in Immersive Virtual Reality. *Frontiers in Psychology, 9*: 58. https://doi.org/10.3389/fpsyg.2018.00058

Rees, T., Hardy, L., Güllich, A., Abernethy, B., Côté, J., Woodman, T., Montgomery, H., Laing, S., & Warr, C. (2016). The Great British Medalists Project: A Review of Current Knowledge on the Development of the World's Best Sporting Talent. *Sports medicine (Auckland, N.Z.), 46*(8), 1041–1058. https://doi.org/10.1007/s40279-016-0476-2

Santero, P. P., Cazorla, G., Deliac, P., & Poisson, P. (2020). À propos des modèles de performance: le cas spécifique des boxes pieds-poings. *Reflexion Sport, 25*, 4-25.

Schmidt, R. A., & Wrisberg, C. A. (2000). *Motor learning and performance: A problem-based learning approach.* Human Kinetics.

Shirota, C., Janša, J., Díaz, J., Balasubramanian, S., Mazzoleni, S., Borghese, N. A., & Melendez-Calderon, A. (2016). On the assessment of coordination between upper extremities: towards a common language between rehabilitation engineers, clinicians and neuroscientists. *Journal of NeuroEngineering and Rehabilitation, 13*: 80. https://doi.org/10.1186/s12984-016-0186-x

Simpson, T., Camfield, D., Pipingas, A., Macpherson, H., & Stough, C. (2012). Improved processing speed: Online computer-based cognitive training in older adults. *Educational gerontology, 38*(7), 445-458.

Starosta, W., & Fostiak, D. (2013). Levels of Movement Coordination in Elite Freestyle and Classical Style Wrestlers of Different Ages. *International Journal of Wrestling Science, 3*(1), 134-147. https://doi.org/10.1080/21615667.2013.10878977

Teodorescu, S., Bota, A., Mitrache, G., & Predoiu, R. (2012). Study about the computer-imposed time and the self-imposed tempo coefficients in determining intersegmental coordination – implications for individual and team sports. *Procedia-Social and Behavioral Sciences, 33*, 45-49. https://doi.org/10.1016/j.sbspro.2012.01.080

Tüdös, Ș., & Mitrache, G. (2011). *Optimizarea capacității de performanță – Note de curs* [Optimizing performance capacity - Course notes]. National University of Physical Education and Sports, Bucharest.

Vasile, A. I., & Stănescu, M. (2023). Application of strobe training as motor-cognitive strategy in sport climbing. *Journal of Educational Sciences & Psychology, 13*, 131-138.

Vicol, S. I., Teodorescu, S., Roșca, R., & Predoiu, R. (2025). Psychomotor and cognitive abilities in U14 football players: a comparative analysis across playing positions. *Discobolul – Physical Education, Sport & Kinetotherapy Journal, 64*(1), 27-40. https://doi.org/10.35189/dpeskj.2025.64.1.3

Wilimzig, C., Ragert, P., & Dinse, H. R. (2012). Cortical topography of intracortical inhibition influences the speed of decision making. *Proceedings of the National Academy of Sciences*, *109*(8), 3107-3112.

Zory, R., Vuillerme, N., Pellegrini, B., Schena, F., & Rouard, A. (2009). Effect of fatigue on double pole kinematics in sprint cross-country skiing. *Human movement science*, *28*(1), 85–98. https://doi.org/10.1016/j.humov.2008.05.002