LATERALITY ASSESSMENT IN MARTIAL ARTISTS THROUGH KINEMATIC ANALYSIS OF STRIKING TECHNIQUES

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Abstract. *The purpose of this study was to objectively measure and highlight laterality differences in striking techniques between elite martial artists and to compare the results achieved by each athlete. The research hypothesis is that the kinematic analysis of both fighting stances (dominant and non-dominant sides) can reveal laterality differences for each athlete. We used an inertial measurement unit system based on 17 motion trackers consisting of 3D gyroscopes, 3D accelerometers and 3D magnetometers, namely the Xsens MVN Awinda system. We collected data on the striking techniques of 8 elite martial artists. The kinematic parameters were calculated and analysed for some of the most commonly used techniques in martial arts, more specifically, straight and roundhouse punches. In order to obtain information about the laterality levels of the monitored athletes, we compared the values of these parameters for technical execution on the dominant and non-dominant sides and highlighted significant differences through the non-parametric Wilcoxon Signed-Ranks Test of significance. To facilitate comparisons between athletes in terms of laterality, we designed an original rating scale and created diagrams based on their scores. The assessments carried out will contribute to both the management and individualisation of training and the choice of combat tactics in a much more informed way.*

Keywords: *martial arts, kinematic analysis, laterality, Xsens MVN Awinda.*

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Introduction

Technology has undergone major developments in all fields of activity over the last century. Such improvements are reflected not only in everyday life but also in sport. We believe that these innovative solutions are necessary and opportune in Romanian martial arts as well.

There are two types of competitions in martial arts (as sports disciplines): one that involves direct confrontation between athletes, with the fight respecting the specific rules of each style, and another one in which the ranking of athletes is based on the points awarded by judges for their individual or team performance without an active opponent. More specifically, the latter case refers to kata, a Japanese word meaning "form" and involving an imaginary fight. Some katas have remained unchanged since their creation by the founder of

the style, while others are created by coaches and athletes based on personal skills and preferences (Deliu, 2008).

Both offensive and defensive techniques in martial arts need to be performed using a set of motor skills, with the most important being speed, precision (in all styles) and strength (in full contact styles). As a consequence, performance-oriented techniques are trained to achieve the highest levels of speed and strength in the shortest possible time (James et al., 2017).

Fighting an imaginary partner/target or "shadow combat" is a very popular part of martial arts training. In this type of training, athletes try to perform the techniques as quickly and correctly as possible in terms of form (Galan, 2005).

Due to the very high execution speed of specific martial arts techniques, we consider it impossible for coaches to make a totally objective and complete analysis, given that many of the execution details are beyond human perception. In order to increase the chances of winning in competitive fights, the athletes' arsenal must be as rich as possible. This is achieved by both increasing the number of known techniques and combinations and performing them bilaterally, which equally involves the hands and the feet (Deliu, 2008).

Therefore, a very useful quality of fighters is bilaterality, which is targeted in their training from the beginning of their sports careers (Pătru, 2018).

Laterality can be considered an advantage that is used in the choice of fighting tactics (Dopico-Calvo et al., 2016). An athlete who performs the same techniques as well as possible on the non-dominant side too can easily surprise their opponents, can adapt to various opponents and can find solutions more easily even after the occurrence of injuries caused by the fight itself or fatigue (Deliu, 2008).

For this reason, we believe that the possibility to objectively know the levels of technical correctness and bilateral execution for each athlete is essential for both the individualisation of training and the choice of optimal tactics.

Although laterality has been of major interest to neuroscientists over time, studies on the laterality of martial artists are more recent (Okubo, 2022; Băițel & Pătru, 2016; Pătru et al., 2015).

Given that we aimed to examine laterality in martial artists based on the kinematic analysis of their techniques, we started from the study of specialised research in the national and international literature, which focused on both kinematics and laterality in this field but also on different methods of data collection in the field concerned.

Mikheev et al. (2002) investigated differences in hemispheric specialisation between elite judo athletes and a control group with no experience in sport. Their conclusion was that the examined athletes also performed tasks with their non-dominant hand and did this more often than the control group. The higher the technical level, the more the non-dominant side is used, and the above authors attribute this behaviour to neuroplasticity.

Gursoy (2009) analysed the number of defeats in relation to the total number of fights for 22 boxers with 4 to 15 years of experience, who were divided according to their left- or right-hand preference. The research results showed that left-handed boxers had a defeat percentage of 19.32 in 120.6 matches, while the defeat percentage of right-handed boxers was 42.25 in 127.8 matches; in statistical terms, left-handed boxers were more successful.

Sterkowicz et al. (2010) demonstrated that a "high level of skills in athletes with left-hand dominance allows them to have a tactical advantage over the opponents and to increase their

chances of success" (p. 173). The authors concluded that laterality of upper and lower limbs was significantly correlated with the choice of dominant directions of attack in judo fights.

Baker and Schorer (2013) investigated whether combat stance orientation was related to skill and success in MMA (Mixed Martial Arts) fighters. They studied 1468 athletes, extracting their data from a reliable online database. The authors took into consideration not only the fighting stance and winning percentage but also the number of fights, and concluded that the proportion of mixed martial artists using a southpaw stance was higher than that of left-handed individuals in the general population (17% versus 10-12%). No statistically significant relationship was found between laterality and winning percentage or between stance and hand preference. Mixed Martial Arts are very complex, and the database on this topic is relatively limited, which is why it is difficult to correlate success with a single factor.

The study conducted by Băițel and Pătru (2019) highlighted the influence of sport on children. The research participants were divided into two groups (athletes and non-athletes), and the Ruler Test and Touch the Plates Test were used to measure their reaction times to visual and auditory stimuli. Athletes recorded better results than non-athletes, in the sense that both their reaction times and laterality differences were lower.

Witte et al. (2007) studied the Mawashi-Geri and Ura-Mawashi-Geri kicks performed with both the front and back legs using the VICON motion capture system (8 MX 40 cameras, 250 Hz). Their study aimed to find kinematic similarities and differences between individually performed techniques. The authors found that the relationship between them depended on the fighter; however, the shortest movement times recorded by athletes were for the Mawashi-Geri kick with the front foot.

Kim et al. (2010) studied the effect of target height on the trunk, pelvis and thigh kinematics in the taekwondo roundhouse kick. Nine male black-belt holders performed roundhouse kicks for two target heights (Body and Face), and the data were obtained using a 3D video motion analysis. The authors found that "in order to kick to Face, the athletes need to utilize the greater anterior-posterior hip displacement, pelvis left tilt, and hip abduction and internal rotation motion" (Kim et al., 2010, p. 2).

Kimm and Thiel (2015) used an accelerometer based on a micro-electro-mechanical system (developed in the SABEL Labs at Griffith University) to measure two types of punches, namely the jab (with the lead hand) and the cross (with the rear hand), performed by 16 athletes. The recorded acceleration profile helped them calculate the maximum speed for each punch. The authors concluded that "the overall hand speed improves with experience regardless of gender or age" (Kimm & Thiel, 2015, p. 506). However, it should be noted that using an inertial accelerometer does not allow to determine the full retraction movement.

Gavagan and Sayers (2017) compared three martial arts disciplines to see whether there were differences in roundhouse kicking leg kinematics between highly skilled athletes. A nine camera infra-red motion capture system (500 Hz) was used to record the 3D lower limb kinematics. The data were captured with a PowerLab 8SP system and synchronised via an AD converter. Differences were found for mean execution times between Muay Thai and taekwondo athletes. It was also determined that knee extension velocities were significantly higher in taekwondo and karate athletes compared to the Muay Thai group. Despite these differences, the authors highlighted common movement patterns and concluded that the effectiveness of the roundhouse kick performance depended on the combination of rapid

pelvic rotation, hip flexion and knee extension velocities, associated with rapid movements of the centre of mass towards the target.

Hölbling et al. (2017) used a VICON 3D motion capture system to collect kinematic data and tracked several parameters of the double-side kick, namely: height of the kick leg, distance to the frontal shoulder at the end of both chambering phases, horizontal velocity during both chambering phases, length of the six functional phases, and total duration.

With the help of a 3D video motion analysis system, Diniz et al. (2021) monitored several kinematic parameters of the roundhouse kick performed by athletes from three martial arts disciplines. According to these authors, Muay Thai athletes should increase the distance from the opponent during combat, while taekwondo and karate athletes should decrease it to improve their technique.

Polak et al. (2016) state that few studies have been published in recent years about the use of motion analysis systems in sport and no article discusses this issue in the context of combat sports and martial arts. Therefore, they addressed this topic in order to determine what motion analysis systems were used at that time or could be used by coaches and athletes involved in the above-mentioned sports fields. The study gives a brief description of each system with their main advantages and disadvantages, concluding that "not all of types of motion analysis systems used in sport are suitable for combat sports and martial arts" (Polak et al., 2016, p. 105).

Kim et al. (2017) compared the accuracy of a human motion capture system applicable to dance and taekwondo programmes. For this, they used the Xsens equipment consisting of a set of inertial sensors and eight Kinect sensors (with a capturing speed of 30 frames per second). The conclusion of the study was that the proposed system provided "a more than 20% improvement over the single Kinect system" (Kim et al., 2017, p. 187). However, some dynamic movements (e.g., jump kicks, high kicks) are not well tracked, which results in incorrect joint positions during the posture reconstruction.

The *purpose* of the present study was to objectively measure and highlight laterality differences in striking techniques between elite martial artists and to compare the results obtained by each athlete.

The *tasks* of the study were to select the athletes based on the criteria of experience and competitive records, to select the techniques to be analysed from among the most used in competitions and to select the kinematic parameters relevant for our purpose.

The research *hypothesis* is that kinematic analysis of both fighting stances (dominant and non-dominant sides) can reveal laterality differences for each athlete.

Research questions:

1) What are the differences between martial artists in terms of speed of the right fist and speed of the left fist during straight punches?
2) What are the differences between martial artists in terms of elbow extension angle at the end of straight punches performed with the right fist and the left fist?
3) Are there significant differences between martial artists in terms of duration recorded per punch performed with the right fist and the left fist?
4) Are there significant differences between martial artists in terms of maximum speed recorded per roundhouse punch performed with the right fist and the left fist?

5) What are the differences between martial artists in terms of elbow extension angle recorded per roundhouse punch with the right fist and the left fist?

Methodology

Participants

The research participants were 8 senior athletes, national and international champions (at the European and World Championships) practising three of the most popular martial arts styles: karate, Kempo and kickboxing. They were informed about the study purpose and gave their consent to participate. All necessary measures were taken to protect their private data.

Procedure

The study was conducted at the National Institute for Sport Research in Bucharest. The equipment used for data collection was Xsens MVN Awinda (60 Hz) consisting of 17 wireless sensors. Data were collected for some of the most commonly used striking techniques, more specifically, straight and roundhouse punches.

The kinematic parameters chosen to be calculated and compared were: maximum speed of the striking limb; flexion-extension angle of the elbow at the moment of impact; duration of technical execution.

After a standard warm-up programme, athletes were fitted with Xsens MVN equipment that was calibrated to their anthropometric parameters. Each athlete performed 10 times each mentioned technique in a personal style using their right fist and left fist as quickly and technically correct as possible. The techniques were performed towards an imaginary target, as in “shadow combat” training. For all athletes, the right side was dominant.

The recorded data were converted to .xslx format, and the above parameters were calculated based on sensor positions in the 3D space. The results were statistically processed using the non-parametric Wilcoxon Signed-Ranks Test of significance.

Results

To validate the value differences between the monitored parameters, a conventional significance threshold (Alpha threshold) was set a *p* value of 0.05 ($p \leq 0.05$), representing a 95% confidence interval.

Table 1. *Maximum speed of the fist in straight punches – Descriptive statistics*

Sport	Athlete	Fist	Cases	Am	Me	SD	CV
Karate							
	A1						
		Right	10	7.52	7.60	0.86	11.5%
		Left	10	7.60	7.65	0.61	8.0%
	A2						
		Right	10	7.19	7.03	1.51	21.0%
		Left	10	7.05	7.34	1.21	17.1%
	A3						
		Right	10	5.64	5.99	1.17	20.7%
		Left	10	5.25	4.69	1.21	23.1%
Kempo							
	A4						
		Right	10	6.94	6.78	0.69	9.9%
		Left	10	6.26	6.37	0.73	11.7%
	A5						
		Right	10	5.70	5.54	0.60	10.5%
		Left	10	5.41	5.37	0.57	10.6%
Kickboxing							
	A6						
		Right	10	5.15	5.20	0.38	7.4%
		Left	10	5.15	5.00	0.60	11.7%
	A7						
		Right	10	5.78	5.81	0.69	12.0%
		Left	10	5.87	5.67	0.87	14.8%
	A8						
		Right	10	5.32	5.36	0.55	10.3%
		Left	10	5.05	5.08	0.26	5.1%

Note: Cases - Recorded values (10 values per athlete); Am - Arithmetic mean; Me - Median; SD - Standard deviation; CV - Coefficient of variation.

Table 2. *Maximum speed of the fist in straight punches – Wilcoxon Signed-Ranks Test*

Sport	Athlete	Z	p	W	R
Karate					
	A1	-.153[b]	.878	26	-
	A2	-.764[c]	.445	20	-
	A3	-.663[c]	.508	21	-
Kempo					
	A4	-2.395[c]	.017[*]	4	.535
	A5	-1.886[c]	.059	9.5	-
Kickboxing					
	A6	-.051[b]	.959	27	-
	A7	-.153[c]	.878	26	-
	A8	-1.580[c]	.114	12	-

Note: Z - calculated value of the Wilcoxon Signed-Ranks Test: b. Based on negative ranks; c. Based on positive ranks; p - significance level; * Difference is significant at $p < 0.05$; W - Wilcoxon value; R - effect size.

Analysis of the two fighting stances (dominant and non-dominant sides) for the 8 athletes (Table 1 and Table 2) shows that the maximum speed recorded per punch is not significantly different for the right hand compared to the left hand in most athletes. The exception is a Kempo athlete (A4), in whose case the speed is significantly higher for the right fist than the left fist.

Table 3. *Elbow extension angle at the end of straight punches – Descriptive statistics*

Sport	Athlete	Fist	Cases	Am	Me	SD	CV
Karate							
	A1						
		Right	10	168.32	166.82	5.67	3.4%
		Left	10	165.55	167.18	9.44	5.7%
	A2						
		Right	10	154.78	160.27	12.06	7.8%
		Left	10	154.51	156.02	7.67	5.0%
	A3						
		Right	10	160.84	160.95	2.07	1.3%
		Left	10	159.98	159.79	7.66	4.8%
Kempo							
	A4						
		Right	10	164.99	166.39	7.50	4.5%
		Left	10	163.18	162.34	5.09	3.1%
	A5						
		Right	10	161.41	162.42	11.41	7.1%
		Left	10	154.78	156.81	11.45	7.4%
Kickboxing							
	A6						
		Right	10	162.70	161.78	3.12	1.9%
		Left	10	160.67	159.97	5.13	3.2%
	A7						
		Right	10	165.45	165.95	10.03	6.1%
		Left	10	164.85	164.95	9.38	5.7%
	A8						
		Right	10	156.82	158.19	8.38	5.3%
		Left	10	165.03	164.70	6.09	3.7%

Note: Cases - Recorded values (10 values per athlete); Am - Arithmetic mean; Me - Median; SD - Standard deviation; CV - Coefficient of variation.

Table 4. *Elbow extension angle at the end of straight punches – Wilcoxon Signed-Ranks Test*

Sport	Athlete	Z	p	W	R
Karate					
	A1	-.459[c]	.646	23	-
	A2	-.255[c]	.799	25	-
	A3	-1.070[c]	.285	17	-
Kempo					
	A4	-.459[c]	.646	23	-
	A5	-.866[c]	.386	19	-
Kickboxing					
	A6	-1.070[c]	.285	17	-
	A7	-.357[c]	.721	24	-
	A8	-2.395[b]	.017[*]	4	.535

Note: Z - calculated value of the Wilcoxon Signed-Ranks Test: b. Based on negative ranks; c. Based on positive ranks; p - significance level; * Difference is significant at $p < 0.05$; W - Wilcoxon value; R - effect size.

Analysis of the two fighting stances (dominant and non-dominant sides) for the 8 athletes (Table 3 and Table 4) shows that the elbow extension angle recorded per punch is not significantly different for the right hand compared to the left hand in most athletes. The only exception is a kickboxing athlete (A8), in whose case the angle has a significantly higher value for the left fist than the right fist.

Table 5. *Duration of straight punches – Descriptive statistics*

Sport	Athlete	Fist	Cases	Am	Me	SD	CV
Karate							
	A1						
		Right	10	0.14	0.14	0.02	14.2%
		Left	10	0.15	0.15	0.02	10.4%
	A2						
		Right	10	0.11	0.11	0.01	8.1%
		Left	10	0.12	0.12	0.01	9.5%
	A3						
		Right	10	0.13	0.13	0.01	10.7%
		Left	10	0.12	0.12	0.02	14.5%
Kempo							
	A4						
		Right	10	0.16	0.16	0.01	7.4%
		Left	10	0.16	0.15	0.02	12.0%
	A5						
		Right	10	0.16	0.18	0.03	20.9%
		Left	10	0.16	0.17	0.03	17.8%
Kickboxing							
	A6						
		Right	10	0.15	0.15	0.01	6.2%
		Left	10	0.15	0.14	0.01	9.5%
	A7						
		Right	10	0.16	0.17	0.02	11.4%
		Left	10	0.15	0.15	0.01	6.9%
	A8						
		Right	10	0.15	0.15	0.01	9.8%
		Left	10	0.14	0.13	0.02	12.6%

Note: Cases - Recorded values (10 values per athlete); Am - Arithmetic mean; Me - Median; SD - Standard deviation; CV - Coefficient of variation.

Table 6. *Duration of straight punches – Wilcoxon Signed-Ranks Test*

Sport	Athlete	Z	p	W	R
Karate					
	A1	-.877[b]	.380	10.5	-
	A2	-1.667[b]	.096	3.5	-
	A3	-.849[c]	.396	-	-
Kempo					
	A4	-.905[b]	.366	12	-
	A5	-.241[c]	.809	20.5	-
Kickboxing					
	A6	-1.027[c]	.305	11	-
	A7	-.952[c]	.341	11.5	-
	A8	-1.552[c]	.121	5	-

Note: Z - calculated value of the Wilcoxon Signed-Ranks Test: b. Based on negative ranks; c. Based on positive ranks; p - significance level; * Difference is significant at $p < 0.05$; W - Wilcoxon value; R - effect size.

Analysis of the two fighting stances (dominant and non-dominant sides) for the 8 athletes (Table 5 and Table 6) shows that the duration recorded per punch is not significantly different for the right hand compared to the left hand in most athletes.

Table 7. *Maximum speed of the fist in roundhouse punches – Descriptive statistics*

Sport	Athlete	Fist	Cases	Am	Me	SD	CV
Karate							
	A1						
		Right	10	8.84	8.75	1.69	19.1%
		Left	10	8.38	8.90	1.67	19.9%
	A2						
		Right	10	9.71	9.62	2.4	24.7%
		Left	10	8.32	8.45	2.58	31.0%
	A3						
		Right	10	6.48	6.48	1.58	24.5%
		Left	10	6.28	6.35	1.94	30.9%
Kempo							
	A4						
		Right	10	8.62	8.12	1.42	16.4%
		Left	10	10.23	9.81	1.58	15.4%
	A5						
		Right	10	6.99	6.87	1.18	16.9%
		Left	10	6.98	6.83	0.82	11.8%
Kickboxing							
	A6						
		Right	10	8.35	7.94	1.43	17.1%
		Left	10	7.61	6.68	2.3	30.1%
	A7						
		Right	10	8.16	8.22	1.74	21.4%
		Left	10	6.20	5.98	1.08	17.4%
	A8						
		Right	10	8.60	8.65	1.25	14.5%
		Left	10	8.80	8.77	1.03	11.7%

Note: Cases - Recorded values (10 values per athlete); Am - Arithmetic mean; Me - Median; SD - Standard deviation; CV - Coefficient of variation.

Table 8. *Maximum speed of the fist in roundhouse punches – Wilcoxon Signed-Ranks Test*

Sport	Athlete	Z	p	W	R
Karate					
	A1	-1.682[c]	.093	11	-
	A2	-2.803[c]	.005[*]	0	.626
	A3	-1.070[c]	.285	17	-
Kempo					
	A4	-2.803[b]	.005[*]	0	.626
	A5	-.459[b]	.646	23	-
Kickboxing					
	A6	-1.580[c]	.114	12	-
	A7	-2.803[c]	.005[*]	0	.626
	A8	-.561[b]	.575	22	-

Note: Z - calculated value of the Wilcoxon Signed-Ranks Test: b. Based on negative ranks; c. Based on positive ranks; p - significance level; * Difference is significant at $p < 0.05$; W - Wilcoxon value; R - effect size.

Analysis of the two fighting stances (dominant and non-dominant sides) for the 8 athletes (Table 7 and Table 8) shows that the maximum speed recorded per roundhouse punch is not significantly different for the right hand compared to the left hand in most athletes. However, there are three exceptions: a karate athlete (A2), in whose case the speed is significantly higher for the right fist than the left fist, a Kempo athlete (A4), in whose case the speed is

significantly higher for the left fist than the right fist, and a kickboxing athlete (A7), in whose case the speed is significantly higher for the right fist than the left fist.

Table 9. *Elbow extension angle at the end of roundhouse punches – Descriptive statistics*

Sport	Athlete	Fist	Cases	Am	Me	SD	CV
Karate							
	A1						
		Right	10	152.38	153.29	10.18	6.7%
		Left	10	138.41	136.76	14.94	10.8%
	A2						
		Right	10	95.43	93.78	5.09	5.3%
		Left	10	99.16	99.94	2.82	2.8%
	A3						
		Right	10	96.30	97.76	4.66	4.8%
		Left	10	102.71	103.83	8.33	8.1%
Kempo							
	A4						
		Right	10	84.55	83.58	8.31	9.8%
		Left	10	83.09	83.85	5.33	6.4%
	A5						
		Right	10	99.03	94.37	9.51	9.6%
		Left	10	82.93	85.88	6.53	7.9%
Kickboxing							
	A6						
		Right	10	94.26	95.03	6.25	6.6%
		Left	10	79.68	79.59	4.20	5.3%
	A7						
		Right	10	75.74	76.43	2.41	3.2%
		Left	10	67.14	68.85	5.09	7.6%
	A8						
		Right	10	91.58	90.19	4.48	4.9%
		Left	10	88.42	87.53	6.73	7.6%

Note: Cases - Recorded values (10 values per athlete); Am - Arithmetic mean; Me - Median; SD - Standard deviation; CV - Coefficient of variation.

Table 10. *Elbow extension angle at the end of roundhouse punches – Wilcoxon Signed-Ranks Test*

Sport	Athlete	Z	p	W	R
Karate					
	A1	-2.599[c]	.009[*]	2	.581
	A2	-2.090[b]	.037[*]	7	.467
	A3	-1.580[b]	.114	12	-
Kempo					
	A4	-.663[c]	.508	21	-
	A5	-2.701[c]	.007[*]	1	.603
Kickboxing					
	A6	-2.803[c]	.005[*]	0	.626
	A7	-2.803[c]	.005[*]	0	.626
	A8	-1.682[c]	.093	11	-

Note: Z - calculated value of the Wilcoxon Signed-Ranks Test: b. Based on negative ranks; c. Based on positive ranks; p - significance level; * Difference is significant at $p < 0.05$; W - Wilcoxon value; R - effect size.

Analysis of the two fighting stances (dominant and non-dominant sides) for the 8 athletes (Table 9 and Table 10) shows that the elbow extension angle recorded per roundhouse punch is significantly different for the right hand compared to the left hand in most athletes. The values recorded for the roundhouse punch performed with the right fist are higher in the case of the following athletes: A1 (karate), A5 (Kempo), A6 and A7 (kickboxing).

Table 11. *Duration of roundhouse punches – Descriptive statistics*

Sport	Athlete	Fist	Cases	Am	Me	SD	CV
Karate							
	A1						
		Right	10	0.21	0.20	0.04	17.9%
		Left	10	0.20	0.20	0.03	17.6%
	A2						
		Right	10	0.18	0.19	0.01	6.3%
		Left	10	0.20	0.20	0.03	16.0%
	A3						
		Right	10	0.18	0.18	0.06	30.9%
		Left	10	0.19	0.22	0.07	34.9%
Kempo							
	A4						
		Right	10	0.22	0.21	0.03	14.0%
		Left	10	0.22	0.21	0.06	28.7%
	A5						
		Right	10	0.21	0.21	0.02	10.1%
		Left	10	0.24	0.25	0.05	19.6%
Kickboxing							
	A6						
		Right	10	0.21	0.21	0.03	13.8%
		Left	10	0.21	0.21	0.05	24.3%
	A7						
		Right	10	0.28	0.26	0.04	15.0%
		Left	10	0.24	0.21	0.07	27.6%
	A8						
		Right	10	0.21	0.22	0.03	13.1%
		Left	10	0.20	0.20	0.03	15.1%

Note: Cases - Recorded values (10 values per athlete); Am - Arithmetic mean; Me - Median; SD - Standard deviation; CV - Coefficient of variation.

Table 12. *Duration of roundhouse punches – Wilcoxon Signed-Ranks Test*

Sport	Athlete	Z	p	W	R
Karate					
	A1	-2.111[c]	.035[*]	4	.472
	A2	-1.199[b]	.230	9.5	-
	A3	-.060[b]	.952	22	-
Kempo					
	A4	-.155[c]	.877	26	-
	A5	-2.153[b]	.031[*]	4.5	.481
Kickboxing					
	A6	-.240[b]	.810	20.5	-
	A7	-1.995[c]	.046[*]	8	.446
	A8	-1.732[c]	.083	6	-

Note: Z - calculated value of the Wilcoxon Signed-Ranks Test: b. Based on negative ranks; c. Based on positive ranks; p - significance level; * Difference is significant at $p < 0.05$; W - Wilcoxon value; R - effect size.

Analysis of the two fighting stances (dominant and non-dominant sides) for the 8 athletes (Table 11 and Table 12) shows that the duration recorded per roundhouse punch is not significantly different for the right hand compared to the left hand in most athletes. However, there are three exceptions: a karate athlete (A1), in whose case the duration is significantly longer for the right fist than the left fist, a Kempo athlete (A5), in whose case the duration is significantly longer for the left fist than the right fist, and a kickboxing athlete (A7), in whose case the duration is significantly longer for the right fist than the left fist.

It can be seen that Athlete 7, for instance, did not record significant differences in any of the monitored parameters for straight punches, but in the case of roundhouse punches, significant differences were revealed in all three kinematic parameters.

Another example, as the ideal case, is Athlete 3, who did not record significant differences in any of the monitored kinematic parameters; in terms of laterality, the athlete's non-dominant side carried out the task at the same level of performance as the dominant one.

Table 13. *Value differences between the monitored kinematic parameters*

Parameters	A1	A2	A3	A4	A5	A6	A7	A8
speed of straight punches	0.08	0.14	0.39	0.68	0.29	0	0.09	0.27
elbow extension angle in straight punches	2.77	0.27	0.86	1.81	6.63	2.03	0.6	8.21
duration of straight punches	0.01	0.01	0.01	0	0	0	0.01	0.01
speed of roundhouse punches	0.46	1.39	0.2	1.61	0.01	0.74	1.96	0.2
elbow extension angle in roundhouse punches	13.97	3.73	6.41	1.46	16.1	14.58	8.6	3.16
duration of roundhouse punches	0.01	0.02	0.01	0	0.03	0	0.04	0.01

To assess laterality differences for each athlete, we designed an original rating scale (Table 13). The statistics showed significant laterality differences for certain athletes, but we went further and quantified any laterality differences (Table 14). All scores were between 0 and 100 points, with the maximum value being awarded where the difference was 0. Regarding speed, we subtracted 1 point for every 0.05 m/s. In terms of elbow extension angle, we subtracted 1 point for each degree difference. As for the punching duration, we subtracted 5 points for every 0.01 s.

Table 14. *Scores awarded for each parameter*

Parameters	A1	A2	A3	A4	A5	A6	A7	A8
speed of straight punches	98	97	92	86	94	100	98	94
elbow extension angle in straight punches	97	100	99	98	93	98	99	92
duration of straight punches	95	95	95	100	100	100	95	95
speed of roundhouse punches	91	72	96	68	100	85	61	96
elbow extension angle in roundhouse punches	86	96	94	99	84	85	91	97
duration of roundhouse punches	95	90	95	100	85	100	80	95

To get a complete picture of laterality differences between athletes and highlight where something can be improved in terms of progress of the non-dominant side, a radar-like representation is used, where the differences recorded for each parameter are easy to observe (Figure 1).

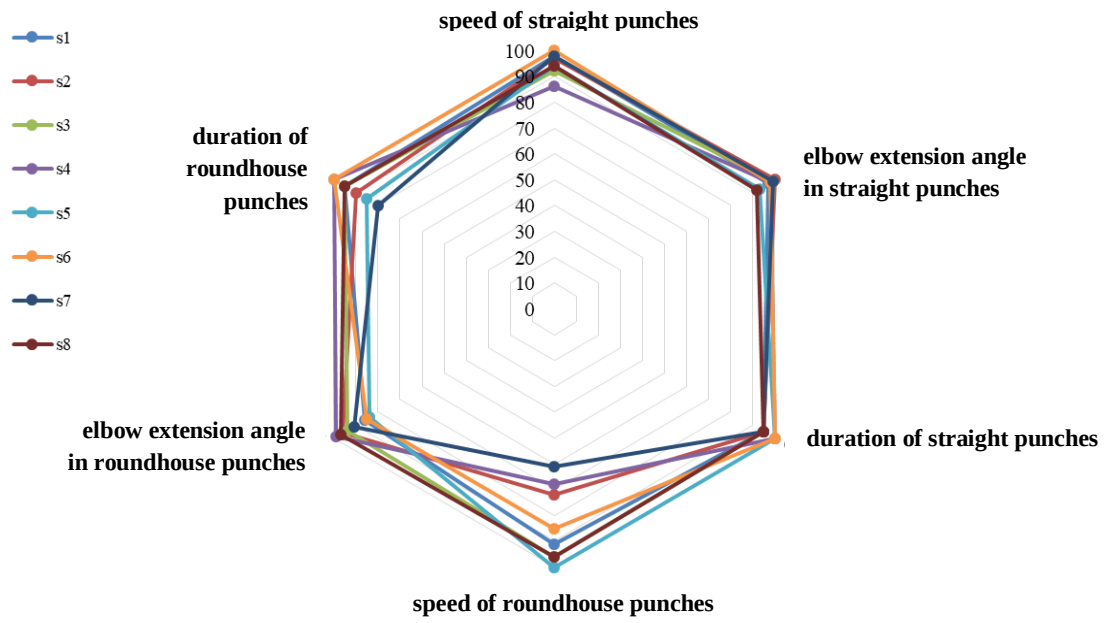

Figure 1. Laterality diagram for the analysed kinematic parameters

Discussion and Conclusion

Compared to other studies (Pătru et al., 2015; Băițel & Pătru, 2016), we have included several kinematic parameters of the same techniques and showed that certain parameters can record significant differences, while this is not possible for others. At the same time, we examined elite athletes and found significant differences even at this level.

Although there are differences between performing a motor action on the dominant side versus the non-dominant side, elite athletes are expected to perform the same tasks in the same conditions either identically or with the smallest possible differences. In sports with a creative opponent, this is a very important factor that can bring victory (Baker & Schorer, 2013).

As an element of originality, we designed a rating scale for laterality differences using the kinematic parameters of the analysed striking techniques. Moreover, based on the recorded scores, a diagnosis can be made for each athlete, which allows an objective comparison between them.

Regarding straight punches, significant differences were recorded in punching speed for one Kempo athlete. In terms of elbow extension angle, significant differences were recorded for one kickboxing athlete, and concerning the duration of straight punches, no significant differences were recorded for any athlete.

As regards roundhouse punches, significant differences were recorded in punching speed for one athlete from each style. In terms of elbow extension angle, significant differences were recorded for 5 of the research participants (2 karate athletes, 1 Kempo athlete and 2 kickboxing athletes). Concerning the duration of roundhouse punches, significant differences were recorded for one athlete from each style.

It can be seen that the scores obtained are very high and very close because all participants are elite athletes. It can also be noted that the largest differences are recorded for the speed of roundhouse punches, which involve a more complex technique than straight punches.

The research participants are all right-handed in everyday life, but they also recorded values without significant differences in certain actions performed with the left-right hands. As demonstrated by Dopico et al. (2014), we also believe that practising specific motor acts leads to a decrease in innate laterality differences.

The importance of laterality in the choice of fighting tactics and winning the victory has been highlighted in the literature (Sterkowicz et al., 2010), being very important to know the athletes' capabilities as precisely as possible.

With the help of the Xsens MVN system, we were able to measure and highlight laterality differences very accurately and thoroughly, referring to various kinematic parameters of some of the most representative martial arts techniques. In certain athletes, differences were recorded for some parameters in the case of the same technique, but this did not happen for other athletes. The assessments carried out will contribute to both the management and individualisation of training and the choice of combat tactics in a much more informed way.

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