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EVALUATING THE LATERALITY OF MARTIAL ARTS PRACTITIONERS THROUGH THE KINEMATIC ANALYSIS OF STRIKING TECHNIQUES

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Abstract. The purpose of this study was to objectively measure and highlight laterality differences of high-performance martial arts athletes with hitting techniques and comparing the results registered by each subject. The hypothesis of this research is that through kinematic analysis on both fighting stances (dominant and non-dominant) we can highlight the differences in laterality for each subject. We used a system of inertial measurement units based on 17 motion tracking sensors composed of 3D gyroscopes, 3D accelerometers and 3D magnetometers namely the MVN Xsens Awinda system. We acquisitioned data from 8 high-performance athletes practicing martial arts with hitting techniques. We calculated and analyzed kinematic parameters for some of the most frequently used techniques in this category of martial arts, more specific direct and circular kicks. In order to obtain information related to the level of laterality of the monitored athletes, we compared the values of these parameters for the technical executions on the dominant and non-dominant side and highlighted the significant differences through the Wilcoxon Signed Rank nonparametric significance test. To facilitate comparisons between subjects in terms of laterality, we drew up an original evaluation scale and created diagrams based on the scores obtained by them. Based on these evaluations, directing and individualizing training and choosing combat tactics can be made much more informed.

Keywords: martial arts, kinematic, laterality, MVN Xsens.

Introduction

Technology has undergone a major evolution in all fields of activity in the past century. Such improvements were felt not only in everyday life, but also in the field of sports. We considered that these innovative solutions are necessary and auspicious in Romanian martial arts as well.

There are two types of martial arts (as sports disciplines) competitions: the one that involves direct confrontation between practitioners, the fight being subdued to the specific rules of each style, and the one in which the ranking of the athletes is based on a score given by the referees for their individual or team performances without an active opponent. More specific, the last one refers to Kata. Kata comes from Japan and it means a fight with imaginary opponents. Some katas remained in the same form since the founder of the style created them and some katas are created by coaches and practitioners based on their skills and preferences.

Both attack and defense techniques in martial arts must be performed based on a set of motor qualities, the most important of which are speed, precision (in all styles) and strength (in full contact styles). As a consequence, performance-oriented techniques are trained to achieve the highest level of speed and the highest level of strength in the shortest possible time.

Fighting with an imaginary partner/targets, widely referred as “shadow fighting” is a very popular part of a martial artist's entire training. In this type of training, athletes try to perform their techniques as quickly and correctly as possible from the point of view of form.

Due to the very high execution speeds of the techniques specific to martial arts, it is impossible for the trainers to make a totally objective and complete analysis, considering the fact that many of the details of the execution evade 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 both by increasing the number of known techniques and combinations, as well as by the fact that they can be performed bilaterally, involving both hands and feet.

Therefore, a very useful quality of fighters is ambilaterality and it is targeted in their training from the beginning of their sports career.

Laterality can be considered an asset that is used in the choice of fighting tactics.

An athlete who executes the same techniques as well as possible also on the non-dominant side can easily surprise the opponents, can adapt to various opponents, can find solutions more easily even after the appearance of injuries in the fight or fatigue.

For this reason, we consider the possibility of objectively knowing the degree of technical correctness and the performance level of the executions on both sides for each athlete to be essential both for the individualization of the training and for choosing the optimal tactics.

Although laterality has been of major interest to neuroscientists over time, studies on the laterality of martial arts fighters are much more recent. Considering that we planned to carry out an analysis of the laterality of martial arts athletes starting from a kinematic analysis of the techniques performed by them, we started from the study of specialized research from the national and international literature that focused on both kinematics and laterality in this field and also the ones that referred to different means of acquiring data in this field.

Mikheev, M., Mohr, C., Afanasiev, S., Landis, T., & Thut, G. (2002) investigated the differences in the specialization of the cerebral hemispheres in high-performance judoka and a control group with no experience in the sports field. Their conclusions were that the analyzed athletes also perform tasks with the non-dominant arm more often, as opposed to the control group. The higher the level of technicality, the use of the non-dominant part is even higher. They attribute this behavior to neuroplasticity of the brain.

Gursoy R. (2009) analyzed the number of defeats in relation to the total number of fights of boxers with experience of 4-15 years, divided by the criteria of the dominant arm (left-handed and right-handed). The result of this research was that the left-handers had a defeat percentage of 19.32 out of an average of 120.6 matches and the right-handers a defeat percentage of 42.25 out of an average of 127.8 matches. Statistically, left-handed boxers are more successful.

Sterkowicz, S., Lech, G., Blecharz, J. (2010) proved that at a high level of technicality, left-handed judokas have significantly higher chances of winning battles. They showed the effect of the laterality of the upper and lower train on the preferred directions of attack.

Baker J, Schorer J (2013) tried to correlate the orientation of the fighting stance with the success in MMA (mixed martial arts). They studied 1468 cases from a reliable database. They took into consideration not only the position of the fight and the percentage of victories, but also the number of fights, comparing the athletes with a similar number of fights. A first conclusion was that those who adopt the southpaw stance (17%) are more than the average left-handed in the general population (10-12%). Statistically they did not prove a significant difference in terms of percentage of victories between the two guards. They also couldn't conclude whether the victories were due to attacks or defenses, therefore reactions, not actions on that stance. The authors stated that MMA are very complex, that it is difficult to correlate success with a single factor and that there are few databases in this regard.

Băiţel, I., Pătru, L. M. (2019) in this study, the influence of practicing sports on children is highlighted. For the 2 groups of children, the ruler test and touch the plates test were applied and also they measured the reaction speed to visual and auditory stimuli. The results recorded by the athletes were better (both the reactive times and the laterality differences were lower) than in non-athletes.

Witte, K., Emmermacher, P., Bystrzycki, S., Potenberg, J. (2007) studied the mawashi geri and ura-mawashi geri kicks executed with both the front foot and the rear foot using the VICON data capture system based on 8 MX 40 cameras with a purchase rate of 250 Hz. The aim of the study was to find kinematic similarities and differences between the 4 variants of techniques. They found that

the relationships between them depended on the subject, instead, for all the subjects analyzed, the shortest duration of execution was of the mawashi geri kick with the front foot.

Kim, Jae-Woong, Kim, Jemin, Lee, Sang-Woo, Han, Ki-Hoon, Kwon, Young-Hoo. (2010) set out to study the effect of the distance at which the target is located on the twist angle of the hip, torso, pelvis and on the attack movement in the circular taekwondo kicking technique. Twelve holders of black belts performed this shot over 3 distances, small, medium and large. They obtained data using a three-dimensional video analysis. It was found that the adjustment for different distances was accompanied by hip rotation, hip flexion and twisting to the left of the hip. The distance of the target especially influences the achievement of the control function of the pelvis and the balance function of the trunk.

Kimm, D., Thiel, D. (2015) using an accelerometer based on a micro-electro-mechanical system, built by the SABEL laboratories of The University of Griffith, the authors measured the jab and cross strikes executed by 16 athletes. From the recorded accelerations, they calculated the speeds of the punch techniques. Their conclusions were that the speed of the fist depends more on experience than on age or gender, it is significantly influenced by the scale. A shortcoming of the study mentioned by the authors is that based on the accelerometer and video images one cannot fully highlight the withdrawal movement.

Gavagan, C. J., Sayers, M. (2017) compared athletes from 3 different styles and tried to show the correlation between the attack foot speed at mawashi geri and the force of impact, using 7 Qualisyss Motion Capture System cameras with a purchase rate of 500 Hz and an 8SP PowerLab pressure plate synchronized with an AD converter system. Differences were found in the duration of execution between the muay thai group and the taekwondo group. It also determined the angular velocity in the knee extension which was significantly higher in the taekwondo and karate group than in muay thai. Despite these differences, they also highlighted common movement patterns and concluded that the effectiveness of the kick is conditioned by the axial rotational speed of the pelvis, the flexion speed of the hip and the speed of extension of the knee along with rapid movements of the center of mass towards the target.)

Hölbling, D., Preuschl, E., Hassmann, M., Baca, A. (2017) used a 3D-motion Vicon capture system as a method of data acquisition and tracked several parameters of the doubled side kick, such as: the height of the kicking leg, the distance from the advanced shoulder of the foot at the end of the reinforcement phases, the speed of the foot during the reinforcement phases and the total duration of the kick.

With the help of 3D video analysis, Diniz, R., Del Vecchio, F. B., Schaun, G. Z., Oliveira, H. B., Portella, E. G., da Silva, E. S., Formalioni, A., Campelo, P., Peyré-Tartaruga, L. A., Pinto, S. S. (2021) followed several kinematic parameters of the circular kick performed by subjects from 3 different styles. Their conclusions were that in order to improve their technique, athletes in muaythai must increase the strike distance, while athletes in taekwondo and karate must reduce it.

Polak, E., Kulasa, J., VencesBrito, A., Castro, M. A., Fernandes, O. (2016) state that there are few studies published in recent years about the possibility of using motion analysis systems in sport and that not a single one in combat sports, so they have carried out an approach with the aim of determining which of the devices or methods may be applicable in this field. Next, the authors presented several systems of motion analysis, with the advantages and disadvantages of each one, and concluded that not all of them are suitable for the peculiarities of movements in martial arts and combat sports.

Kim, Y., Baek, S. and Bae, B.-C. (2017) compared the accuracy of data acquisitions related to human movement using dance and taekwondo techniques. For this they used the MVN Xsens equipment as a reference system and one, then a system consisting of 8 Microsoft Kinect cameras with a purchase rate of 30 fps. The conclusion of the study was that when using a single Microsoft Kinect camera, the accuracy is around 60%, when using the system, around 80%. However, the system could not faithfully record the rapid movements either.

The purpose of this study was to objectively measure and highlight laterality differences of high-performance martial arts athletes with hitting techniques and comparing the results registered by each subject.

The objectives of the study were the following: the selection of the subjects based on the criteria of experience and competitive records, the selection of techniques to be analyzed among the most used in competitions, the calculation of the values of the kinematic parameters relevant to our purpose, the calculation of the differences recorded between the dominant and the non-dominant sides, designing a scale for evaluating the laterality and creating diagrams to facilitate the comparison between the subjects.

The hypothesis of this research is that through kinematic analysis on both fighting stances (dominant and non-dominant) we can highlight the differences in laterality for each subject.

Methodology

The subjects of the research were 8 senior athletes, national and international champions (European and World Championships) practitioners of three of the most popular martial arts styles: karate, kempo and kickboxing. They were informed about the purpose of the study and they expressed their informed consent regarding participation. All necessary measures have been taken to protect private data.

The study was carried out within the National Research Institute for Sport from Bucharest. The equipment used for data acquisition was the Awinda version of MVN Xsens that uses 17 wireless sensors with an acquisition frequency of 60 Hz.

The striking techniques for which the data acquisition was made were among the most used at the competition level, namely direct and circular kicks.

The kinematic parameters chosen for calculation and comparison were: the maximum speed of the hitting segment, the flexion-extension angle of the knee at the moment of impact and the duration of the execution of the technique.

After a standard warming up program, the subjects were equipped with the MVN Xsens gear and it was calibrated for their anthropometric parameters. Each one executed according to his own style as quickly and technically correct as possible 10 executions of each mentioned technique, both with the right leg and with the left one. The techniques were executed towards an imaginary target, as in shadow fighting training. All subjects have as their dominant side the right one.

The recorded data were converted to .xslx format and the mentioned parameters were calculated starting from the positions of the sensors in the 3D space. The results were statistically processed using the Wilcoxon Signed Rank nonparametric significance test.

Results

In order to validate the differences in the recorded values of the monitored parameters, a conventional significance threshold, called alpha threshold, was established with a value of 0.05 ($p \leq 0.05$), representing a confidence level of 95%.

Table 1. The maximum velocity of the hitting leg

Spor	Subject	Fist	Cases	Am	Me	Stdv.	CV	p
Karate	S1	Right	10	10.99	10.80	0.49	4.4%	**0.047**
		Left	10	12.04	12.21	1.28	10.6%	
	S2	Right	10	13.43	13.40	0.69	5.1%	0.799
		Left	10	13.34	13.88	1.15	8.6%	
	S3	Right	10	10.68	10.82	1.46	13.7%	**0.017**
		Left	10	10.18	9.91	1.50	14.7%	
	S4	Right	10	11.46	11.55	0.32	2.8%	**0.009**

Kempo	**S5**	**Left**	10	12.39	12.43	0.59	4.8%	0.445
		Right	10	11.90	12.00	0.57	4.8%	
	S6	**Left**	10	11.58	11.83	0.74	6.4%	**0.037**
		Right	10	8.88	8.58	0.76	8.5%	
		Left	10	9.34	9.25	0.45	4.9%	
Kickbox	**S7**	**Right**	10	11.43	11.35	0.67	5.9%	0.285
		Left	10	11.62	11.62	0.57	4.9%	
	S8	**Right**	10	10.98	11.06	0.52	4.8%	0.575
		Left	10	10.83	10.91	0.55	5.1%	

Cases – Recorded values (10 values per subject); Am – Arithmetic mean; Me – Median; Stdv. – Standard deviation; CV – Coefficient of variation; p- Asymp. Sig. (2-tailed) of the Wilcoxon Signed Ranks Test;

Analyzing the executions of the 8 athletes included in the analysis (Table 1), on both guards, both those made with the right foot and those made with the left foot, it is found that the maximum speed recorded per kick with the right foot does not statistically significantly differ from that made with the left foot in half of the athletes. Exceptions were registered in the case of an athlete practicing karate (S1), an athlete practicing kempo (S4) and an athlete practicing kickboxing (S6), situations in which the speeds recorded with the left leg are significantly higher than those made with the right foot. Likewise, in the case of the karate athlete (S3), the difference between the two kickers is statistically significant, but the higher value is recorded for kicks with the right foot.

Table 2. The maximum knee extension of the hitting leg

Sport	Subject	Fist	Cases	Am	Me	Stdv.	CV	p
Karate	**S1**	**Right**	10	163.54	162.89	8.79	5.4%	0.721
		Left	10	165.29	165.34	6.50	3.9%	
	S2	**Right**	10	169.38	170.88	5.08	3.0%	0.445
		Left	10	167.07	166.82	8.90	5.3%	
	S3	**Right**	10	158.09	158.24	5.64	3.6%	**0.005**
		Left	10	149.27	148.10	4.86	3.3%	
Kempo	**S4**	**Right**	10	176.53	176.97	1.69	1.0%	0.878
		Left	10	176.91	176.69	1.40	0.8%	
	S5	**Right**	10	174.96	175.14	1.81	1.0%	**0.028**
		Left	10	177.20	177.78	1.74	1.0%	
Kickbox	**S6**	**Right**	10	176.64	177.86	2.91	1.6%	0.285
		Left	10	177.81	178.17	1.15	0.6%	
	S7	**Right**	10	176.60	176.97	1.89	1.1%	0.959
		Left	10	176.36	176.83	1.51	0.9%	
	S8	**Right**	10	176.84	176.94	1.14	0.6%	0.093
		Left	10	175.63	176.00	1.83	1.0%	

Cases – Recorded values (10 values per subject); Am – Arithmetic mean; Me – Median; Stdv. – Standard deviation; CV – Coefficient of variation; p – Asymp. Sig. (2-tailed) of the Wilcoxon Signed Ranks Test;

Analyzing the executions of the 8 athletes included in the analysis (Table 2), both those made with the right foot and those made with the left foot, it is found that the knee angle recorded per kick

with the right foot does not statistically significantly differ from that made with the left foot at most athletes. Exceptions were recorded in the case of an athlete practicing karate (S3) – in which the angle value is statistically significantly higher when kicking with the right leg and in a kempo athlete (S5) – a situation in which the angle value is significantly higher big on the left foot shot.

Table 3. The duration of the foot techniques

Sport	Sportiv	Picior	Cazuri	Ma	Me	A.std.	CV	p
Karate	**S1**	**Right**	10	0.31	0.30	0.02	5.3%	0.157
		Left	10	0.32	0.32	0.02	5.8%	
	S2	**Right**	10	0.28	0.28	0.03	11.3%	**0.010**
		Left	10	0.30	0.32	0.04	12.1%	
	S3	**Right**	10	0.27	0.28	0.02	8.8%	**0.031**
		Left	10	0.29	0.29	0.04	14.6%	
Kempo	**S4**	**Right**	10	0.28	0.28	0.04	14.6%	**0.004**
		Left	10	0.26	0.26	0.04	16.3%	
	S5	**Right**	10	0.29	0.30	0.04	14.8%	**0.011**
		Left	10	0.32	0.31	0.05	15.1%	
Kickbox	**S6**	**Right**	10	0.30	0.30	0.01	4.4%	0.083
		Left	10	0.29	0.28	0.01	5.1%	
	S7	**Right**	10	0.30	0.30	0.01	3.8%	0.083
		Left	10	0.31	0.31	0.03	8.6%	
	S8	**Right**	10	0.28	0.28	0.02	8.8%	0.890
		Left	10	0.28	0.28	0.04	12.8%	

Cases – Recorded values (10 values per subject); Am – Arithmetic mean; Me – Median; Stdv. – Standard deviation; CV – Coefficient of variation; p – Asymp. Sig. (2-tailed) of the Wilcoxon Signed Ranks Test;

Analyzing the executions of the 8 athletes included in the analysis (Table 3), on both guards, both those made with the right foot and those made with the left foot, it is found that the duration recorded per kick with the right foot does not statistically significantly differ from that made with left leg in half of the athletes. Exceptions were registered in the case of two karate athletes (S2 and S3), situations where the duration is statistically significantly shorter for the right leg kick and two kempo athletes, one of them registering a statistically significantly lower duration with the left leg (S4) and one of them recording a statistically significantly shorter duration with the right leg (S5).

Discussions

Although there are differences between the level of execution of a motor action on the dominant side compared to the non-dominant one, for performance athletes the expectations are that performing the same tasks in the same conditions, they perform them identically or with the smallest possible differences. We consider that in sports with an opposing opponent this is very valuable, being a factor that can bring victory.

For an easier follow-up of the existence or lack of significant differences between the values of the kinematic parameters recorded by the dominant side and the non-dominant side, we present the results of the values of p for each statistical calculation (Table 7). The bolded values indicate significant differences.

Compared to other studies regarding laterality, we have included several kinematic parameters of the same techniques and we have shown that it is possible for some parameters to register significant differences, while for others they do not.

Table 4. Value of p for each kinematic parameter

Subject	The maximum velocity of the hitting leg	The maximum knee extension of the hitting leg	The duration of the foot techniques
S1	**0.047**	0.721	0.157
S2	0.799	0.445	**0.010**
S3	**0.017**	**0.005**	**0.031**
S4	**0.009**	0.878	**0.004**
S5	0.445	**0.028**	**0.011**
S6	**0.037**	0.285	0.083
S7	0.285	0.959	0.083
S8	0.575	0.093	0.890

We can observe, for instance, the ideal cases are represented by Subjects 7 and 8 where are no significant differences registered in any of the monitored kinematic parameters. In terms of laterality, their non-dominant side has executed the task with the same level of performance like the dominant one.

Conclusions

The hypothesis of this research is that through kinematic analysis on both fighting stances (dominant and non-dominant) we can highlight the differences in laterality for each subject.

We consider the purpose of the study achieved.

Also, the hypothesis that through kinematic analysis on both fighting stances (dominant and non-dominant) we can highlight the differences in laterality for each subject is confirmed.

With the help of MVN Xsens system, we were able to measure and highlight the differences in laterality very precisely and very thoroughly, referring to various kinematic parameters of some of the most representative martial arts techniques.

We drew up an original laterality evaluation scale with the help of which we managed to make a diagnosis of the subjects and facilitate comparisons between them.

In some of the athletes, in the case of the same technique, differences were recorded for certain parameters, while for others there were not.

Based on these evaluations, directing and individualizing training and choosing combat tactics can be made much more informed.

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