BIOMECHANICAL ANALYSIS OF DIRECT PUNCH BASED ON MOVEN'S EQUIPMENT DATA AQUISITION

Introduction

Using newest conquests of science and technology is a measure of progress in all areas of modern life. Therefore no exception can do sports, being widely recognized that in the fight with itself, with an opponent, with time, distance or nature, science and technology can become formidable allies. The role of specialists multidisciplinary trained or the collaboration between specialists of several areas of activity crisscrossing the sport performance has become essential for both in deepening knowledge of human possibilities and the accession to the highest sporting performance .

Deepening knowledge of human movement, using science and technology in training should result in the optimization of cooperation and especially communication between the athlete and coach, by conveying clear, objective data that allow a better orientation to the sensations and living of acts and actions of the athletes.

The natural consequence would be to increase performance without neglecting the broadening of knowledge. That is why I propose a theme pioneered in martial arts and striking combat sports, ie biomechanical analysis of a striking technique using inertial navigation technology built into MOVEN equipment.

Unlike most of the studies about the use of this technology in various domains, which had as goal only to demonstrate that it is possible to use it, without having a practical finalization, I am here to demonstrate the way in which our biomechanic analysis methodology can be applied, and, more than that, we propose an evaluation method of the physical preparation (as elements of the sportive form) through the kinematic parameters' prism of the techniques monitorised with the MOVEN equipment.

For this I covered all the stages of a structured analysis of the movement: preparation, observation, data acquisition, evaluation and the establishment of the intervention methods. The acquisition of the informations was continuous and dynamic. I followed the movement's features and I have established a strategy of methodic observation which I implemented in the watching of the video recordings. I concentrated my attention towards the movement sequences and the way to delimitate them.

After essential parameters calculation (position and velocity for certain body segments, fist's acceleration, intersegmentar angles) and after their variation in time representation, I highlighted the invariants and the variability of the movement. On one hand I have identified similarities and differences

between the striking systems (full, semi and non-contact) and on the other hand I identified strengths and weaknesses of the subjects's executions and I presented effective intervention methods to improve performance.

Further, I have created a scale for the evaluation of full-contact strikes based on criteria independent to the weight category of the subjects. After properly grading the kinematic parameters and comparing different values I drew conclusions regarding the physical potential of the degree of automation in execution, the constancy of execution and the importance of this aspect in sports.

I finished this enterprise thinking about making the application sphere of this study bigger, by periodically testing sportsmen in national teams in more martial arts and for more techinques, so that we will have a more consistent data base. For this, the creation of an evalutation scale for each certain technique is a necessity.

Last but not least, we think about the necessity and utility of studies in which more equipments are used simultaneously with synchronized acquisitions, so that the knowledge level will considerable increase.

Part one

Through the objectification of the characteristic parameters of motor acts and actions we can obtain valuable information that can be utilised as feedback (be it direct or indirect, via coach or the specialist who analyzes and arguments the human perception), thus creating much finer and more efficient adjustments of the studied actions.

Thus, the present paper aims on one hand to study and describe as thoroughly as possible the execution of certain striking techniques from martial arts and other striking combat sports, seeking not only the augumented knowledge to which we have acces through new technologies, but also methods of optimising technique and methods of improving athletic performance. For this, MOVEN equipment was used, the only one existent in our country at the moment, which, through the richness of kinematic data it provides, can be regarded as an extremely useful tool in the study of human movement, with use in many sporting activities.

To accomplish this feat I have started studying specialised literature on the areas that intertwine in this research: martial arts and other combat sports, kinesiology and functional anatomy, the method of execution of the cross and jab strikes, biomechanics, the improvement of human movement, analysis methods and the description of the most modern instruments for measuring human movement. Of these, I have paid particular attention to the inertial

navigation technology and the MOVEN equipment encorporating this technology.

Second part

In the second part of the work I have established a methodology for direct punch biomechanical analysis. I started from the premise that there are differences between kinematic parameters of direct punches applied by the same subject in different strike systems (full-contact, semi-contact and full-contact) and these differences can be highlighted using data acquired using the MOVEN equipment.

This research falls into the category of oriented fundamental research, with the potentiality of results promotion in the applied research area and in training practice. Therewith is a multidisciplinary research, intersecting here fields of sports training, physiology, biomechanics, inertial navigation technology. I aimed to bring more information so that coaches can intervene on the execution of strokes training depending on the style practiced by their athletes. The purpose of this research is to establish a methodology for direct punch biomechanical analysis using aquired data from MOVEN system.

Premise: given that the literature review I did not find data on the differences between kinematic parameters of punches in sports combat when applying these kicks in different impact systems (full-contact, semi-contact and non-contact) we carried out this research. In this context, I issued the following **assumptions** :

- MOVEN equipment, originally designed for tracking human motion in order to achieve 3D animations, can provide data allowing to highlight the differences between kinematic parameters of punches applied in different impact systems;
- The original biomechanical analysis methodology proposed by us will highlight these differences from aquisitions made using equipment MOVEN data .

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Objectives: capturing the essential aspects for studied techniques and confirmation that MOVEN equipment can be used for a precise biomechanical analysis.

A constant stage was the literature review in an attempt to acquaint as many of the research carried out both in the field of biomechanics techniques in combat sports and those who use new technologies for data acquisition.

Another stage was topic selection and proper data acquisition. After establishing aimed kinematic parameters for analysis data processing followed (conversion, import, processing) and calculation of kinematic parameters set for all the strikes. Next steps in the research were to explain the results and preliminary conclusions detachment. Finally settled intervention measures for effective implementation in striking techniques .

The assignments of the research were:

1. Establishing biomechanical analysis methodology for chosen striking techniques ;
2. Cinematic data acquisition using MOVEN equipment;
3. Data processing, calculation of the parameters (position, length of the trajectory, velocity, acceleration, intersegmentar angles) and plotting their variation over time;
4. Establishing and calculation of kinematic parameters for corresponding movement sequences;
5. Identify the differences between full- contact, semi contact and non - contact strikes;
6. Analysis of obtained information and conclusions detachment

Research organization, subjects, location

Data acquisition for the preliminary study were carried out in June 2012, in the Laboratory of Biomotry in National Research Institute for Sport - Bucharest. I made aquisitions on a subject practicing kickboxing, senior on national value. Subject fights at 86 kg weight category, 1.83 m height and 1.97 m span. He has a strong track record and is a multiple national champion , both junior and senior in all combat systems .

After installing MOVEN equipment on the topic we realized the calibration uploading some anthropometric parameters of the subject, on which MVN Studio software generated a corresponding avatar. After the calibration the subject was instructed on the series of strikes that would manage, followed by the data acquisition. There were direct punches jab and cross without completion (in the air) semi-contact and full-contact.

Data processing and analysis

After .mvn export and data import into Excel, a data processing was done on several levels. First I calculated starting from position coordinates for each plan, segments’s position in space, movement and velocity for each frame and I have represented their variation over time. Then I calculated fist’s acceleration

in each frame and I represented its variation over time. I did the same thing for intarsegmentar angles. I gain information about all the sstrikes in each series.

Next I analyzed every strike partly considering the identified sequences :

1. Walking and momentum in the leg on the same side with the striking arm;
2. Hips and shoulders rotation in the strike direction;
3. 3.The movement beginning of the arm from the guard position - defined by the angle β when it continuously increasing;
4. The beginning of the attack itself, pointed by the moment when the elbow's extension angle α becames continuously increasing;
5. The impact with the target, coincident with the moment when is recorded minimum acceleration fist (in our calculations);
6. The fist's contact with the target, which lasts from the moment of impact until it reaches the maximum angle α;
7. The fist's retirement in guard position, which begins with the continuous decrease of angle α .

It should be noted that some of the sequences overlap, but their assignation can be accurately performed and in the graphic representations of parameter variation over time is easy to see the influence on the fist's speed of the movement of certain body segments.

Primary for this level of analysis is to establish temporal benchmarks and defining movement's sequences. Follow then the length's of the segments trajectory calculation in the determined motion sequences, the fist's average speed calculation in these sequences, the distance traveled by the fist calculation in these sequences.

The next level of analysis consists of synchronization of all strikes of a series at the start of elbow extension and average speed, acceleration, intersegmentar angles calculation. To verify that the media is significant I calculated parameters's variation coefficients and I reported to the homogeneity limit proposed by Dragomirescu and Drane. These average values characterize each impact system and were represented on the same graph to highlight the differences and similarities .

I list below the main similarities and differences identified between impact systems.

Similarities :

- During the time T_0 , the fist's, elbow's and shoulder's behavior is similar (speed variation curves overlap almost perfectly - except in the shoulder full contact strikes)
- During the time T_1 velocity increasing up to maximum speed have the same slope (shoulder full contact up to a point) ;

- Shoulder behavior is identical in semi contact and non-contact kicks.

Differences :

- The maximum fist's and elbow's velocity decrease in order full-contact/ semi-contact/ non- contact;
- The shoulder's velocity is much lower in full-contact strikes (shoulder became force factor in these strikes).

In the first part of the steppind sequence and elbow extension, segments's behavioris the same to a point (the moment of impact). This can be seen very well in the variation in time of the intersegmntar angles α and β curves. Elbow's extension continues after impact, but differently for each style of hitting.

In full-contact strikes elbow's extension increase with the lowest speed (slope is the lowest in the impact zone) due to resistance of the bag. On the other hand, the maximum angle of elbow extension is the lowest, due to the need to protect the joints in full-contact impact.

In semi-contact strikes, the elbow's angle of extension variation is continuous, registered values being slightly higher than maximum extension angle in full-contact.

In non-contact strikes, the behavior is different at the end of the fist advance. After reaching a peak of elbow extension, it comes a slight flexion, followed by a new extension (second maximum or peak on the elbow's extension curve) and then begin a continuous fist's retrait in guard position (continuous α angle decrease). As I mentioned earlier, this behavior occurs because antagonists intervention in motion control and to the neutralizer, which suppresses secondary movement agonists) .

General conclusions of the preliminary research

The assumptions were confirmed , the proposed methodology is so precise that detects fine differences of kinematic parameters in different impact systems.

Third part

In the third part of this thesis, named „Contributions to assessing the level of technical and specific training through the kinematic parameters of the direct punch", I assumed that the execution of a technique, technical preparation and physical preparation are interrelated to each other, physical training ensuring energy substrate necessary for a performance techniques, while technical training ensures energy efficiency of implementation through

increased efficiency induced by a coordination inter and intra- muscular. For information on how these issues intertwine to achieve the top performance, I can evaluate the punching techniques executed by the subjects. This evaluation should take into account the determinants of an effective execution.

The aim of this research is to demonstrate how the methodology of biomechanical analysis we developed can be used to describe the level of performance (reflected in technical trening and in some aspects of specific phisycal training) through the cinematic parameters of the strikes.

The objectives of the research are biomechanical analysis of the strikes executed by the subjects on different weight categories, the ranking of the strikes upon their efficiency and the correlation of the efficiency with the level of performance.

The assignements of the research were as follows:

1. Identifying kinematic parameters that influence the effectiveness of a strike and establishing their importance in an efficient execution
   - literature study
   - create specific rating scale for every striking system
2. The ranking of the strikes using the cinematic parameters rating scale
   - data aquisition for each subject
   - data processing and cinematic parameters computing
   - the ranking for all strikes
3. Modeling an ideal strike for each topic
   - detecting the first three ranked strikes
   - the sinchronization of the strikes and computing average cinematic parameters
   - modeling of the strike for each topic
4. Strike analysis and inference regarding the level of performance for each subject at the moment of testing
   - comparison of modeled strike score and score average of 3 with the maximum score of the strike for each topic and with the overall average of all strike of each topic

Although it was an observant study, from the beginning I expected to meet the following correlations between variables (which we have not yet found in the literature studies):

Hypothesis 1 - the specific physical preparation and technical training can be correlated with kinematic parameters of the strikes executed by the subjects.

Hypothesis 2 - selected kinematic parameters for efficiency evaluation of the strikes are independent on the weight category of subjects.

Research organization, subjects, location

Data aquisitions were done in Biomotry Laboratory of the National Research Institute for Sport from Bucharest and in the Ciprian Sora Sport Club's gym. The subjects of this research are kick boxing practitioners, seniors on national and international value, from Sport Club UNEFS and Sport Club Ciprian Sora. Each athlete fights at a different weight category.

The research was conducted in the following manner :

- mounting the MOVEN equipment on the topic, using the straps
- opening a session acquisition and registration of some anthropometric parameters of reports monitored
- the calibration to N - pose and hand-touch
- beginning the MOVEN acquisition session
- processing data and interpretation of the results
- inference

Processing data and results interpretation

Using the biomechanical analysis methodology and computing cinematic parameters for full-contact and semi-contact cross strikes, I estabilished the determinant cinematic parameters for the strike efficiency in every fight system and we realized an evaluation scale starting from the from their share in achieving effective techniques.

Kinematic parameters taken into account in assessing the full-contact strikes are: average speed of fist, wrist's acceleration at impact, the difference between the line of the hips and the line of the shoulders at impact, maximum speed of fist recorded in the motion sequence described and the distance crossed by the fist in the time elapsed between the beginning of the elbow extension until the frame in which the minimum fist acceleration is recorded, related to the trajectory length of the wrist in the same time . This ratio d / L characterizes the deviation from the straight path of the fist in direct kick . The higher the ratio , the deviation is less. In semi-contact strikes, the parameters taken into account are the duration of the strike, the average speed of the fist, the impact control and linearity of the strike.

For all the strikes I computed the described parameters, I ranked them using the evaluation scales and, I prioritised the strikes. After I select the best strikes, I realized the sinchronization at the moment of the beginning of the elbow extension and I computed the average for all the parameters for every aquisition. In this manner I realized the modeling of an ideal strike for every subject. Ongoing from the time variation of the modelled strike parameters we

computed the others parameters used in the evaluation and we ranked them proper.

The modelled strike's ranking were compared with the overall average in order to evaluate the technical preparation, the automatization degree of the technique and the ability to consistently execute the proposed motric task. Comparing modelled strike score with the best three strikes average and with the maximum score I obtained informations regarding the specific physical preparation reflected through the cinematic parameters wich reside in motric capacities like execution velocity, explosive power, impact control.

Conclusions

The conclusions from the experimental part were the following:

1. Using kinematic analysis for the techniques performed by the athletes we obtain information on specific physical preparation of the athletes and about the quality and the level of technical preparation, coordination, variability and the degree techniques automatization;
2. Using this information, the coaches can guide the individual preparation of each athlete as required (lack of speed, strength, coordination, etc.);
3. The proposed assessment scale may be used for all weight categories, selection criteria being chosen independent on anthropometric measures of subjects;
4. The analysis of the best strikes reflects the potential of the athletes, whether or not specialized in full-contact or semi-contact fighting system;
5. The score of the modelled strike and the average of the best three provides information on the subject's physical preparation;
6. Assessing the differences between the scores of the best and worst strikes we obtained information on the degree of automation and consistency of execution.

Hypothesis 1 was confirmed.

Hypothesis 2 was confirmed.

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Theoretical conclusions regarding the methodology of biomechanical analysis are the following:

1. Starting from the position aquisition unitary values are obtained for all examined kinematic parameters of motion (displacement, velocity, acceleration , intersegmentar angles) ;
2. Ability to define precise temporal frame of the studied technique helps a deeper understanding of the movement.

Conclusions regarding data acquisition

1. Using inertial navigation technology provides high accuracy results, and is advantageous over other technologies already established the same accuracy (such as VICON for example), due to relative independence offered by wireless technology that offers the possibility to perform measurements open spaces, much higher and above this, the untying of a certain brightness;
3. Through MVN 3D avatar created by software and the graphical representations obtained, the athlete receives information which helps to adjust itself executions through a better awareness, until obtaining the desired performance;
4. By monitoring the evolution of the distances traveled by the various segments of the body involved in technical study, the duration of the elbow extension, elbow trajectory towards the wrist, many exercises can be designed to change these parameters as needed, thereby creating individual training methods which will result in a more rapid improvement of any techniques;
5. Using equipment MOVEN synchronized with other devices (EMG sensors and pressure plates pulstesters) would provide a multidimensional understanding of the studied movements;
6. In the martial arts and combat sports are many techniques that can be studied using MOVEN equipment. An advantage of using this equipment is that it can make simultaneous aquisitions, synchronized on two subjects.
7. Biomechanical analysis performed based on MOVEN aquisition is enough precise to enable fine highlighting differences occurring in the execution of the same technique in different fighting systems.

Highlighting the invariants and the variability and comparison executions of same subject and between different subjects helps a lot to discover features of execution and thus improve technique (with this statement we paraphrase Professor Mihai Epuran referring to the comparison kinograms; we have to view the variation in time kinematic parameters graphs comparing and records avatar each subject). Paraphrasing still subscribe "it is necessary that more coaches and athletes to love this side of the business, to form the habit of image analysis (graphs of variation of kinematic parameters in time - we say), to follow intentionally as many executions and not to forget , however, that one of the photo (monitored subjects - na) was caught in a particular context ".

Original features

Nationally, this is one of the first attempts direct kick biomechanical analysis of kick-boxing punch and certainly the first analysis using this

methodology. Although in 2012 I've tried in the dissertation thesis a study (more simplistic) on the direct punch, I discovered in the meantime shortcomings and errors of the method used then, this time I corrected missteps that I' ve identified.

Following the success of the Romanian athletes in international kick-boxing and thai boxing competitions, both junior and senior, leadership of the Romanian Federation of Martial Arts Contact has decided that there would be appropriate to bring a model champion for each weight category and characteristics of these models not just about somatosensory functional parameters or physical characteristics, but also include kinematic and kinetic characteristics of competitive techniques. In this regard, we are the first who started the realization of a database that includes these parameters. Naturally, we are at the beginning, but once open road, we will cover trying to analyze as many of the competitive techniques, using modern methods and means and, above all, accurate. These models will be presented to the athletes with potential to be used as standard and, as they will be exceeded, they will be replaced with another more efficient.

Using inertial navigation technology in biomechanical analysis for techniques of striking combat sports it is as new as it is challenging. Accuracy of information obtained after an acquisition quite easy makes MOVEN produced by Dutch company Xsens and the method presented to be worthy of consideration when desired biomechanical analysis of motric acts and actions in almost any sport not only from combat.

The feedback provided by using the method proposed by us (both data acquisition and analysis) is useful for the athlete either directly by viewing , for example, a 3D avatar created by the equipment's dedicated software as well as indirectly through coach or specialist who analyzes, understands and interprets the issues highlighted by increasing the perception of motion allowed by the equipment used. In this way it is possible to make fine and effective adjustments on the studied techniques.

Strikes rating scale is an original one, designed by us in order to achieve an objective grading of strikes according to their efficiency in order to establish a true model. In addition, by using this scale we obtained information on athletes's potential at the moment of testing and on the level of technical training and coordination. This information allows the individual training control such that training shortcomings of any kind being removed.

Another originality of the work is that our research subjects were champions in their weight categories, their performance measurement and evaluation being a benchmark for future testing and subjects .

Schemes of physical training presented in the second part are original, developed with specialists from the field (Prof . Dr. Dan Deliu) and specialists in the development of strength, speed and their combinations through complementary methods (researchers Liviu Angelescu and Andrei Dragomi).