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Kinematic Analysis in Combative Sports

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Key words: kinesiology, biomechanics, martial arts, three dimensional analysis

Abstract

The article is focused on the description of possibilities of kinematic analysis in area of combatives. Many coaches have analysed the movement of athletes based on observation. Observation is not accurate enough for exact analysis because a single observer is not able to see greater details and physical parameters of movement.

Objectives. In the article, we have described the possibilities of kinematic analysis and the possibilities of their transfer to sport and training practices based on long term experiences with the SIMI system and in connection with the running projects at Faculty of Sports Studies.

Material and methods. Kinematic analysis represented by the SIMI system offers a wide scale of possibilities such as comparison in three dimensional space, simulation and modification of input parameters to improve the technique. As an example we have chosen front kick named *mae geri*, executed by both a man and a woman.

Conclusions. Our analysis was based on exact physical parameters. We have evaluated and compared the technique of each proband, in a high number of physical parameters such as velocity, acceleration, chain of movement during kick and stroke and we have tried to optimize the movement. This possibility has been helping us for a couple of years to determine trends in many sports disciplines and we would like to use it further in combative area.

Introduction

The article is focused on a description of possibilities of kinematic analysis in the area of combatives. Many trainers have analysed movement of athletes based on observation. For exact analysis, observation is not accurate enough because a single observer is not able to see any details and physical parameters of movement.

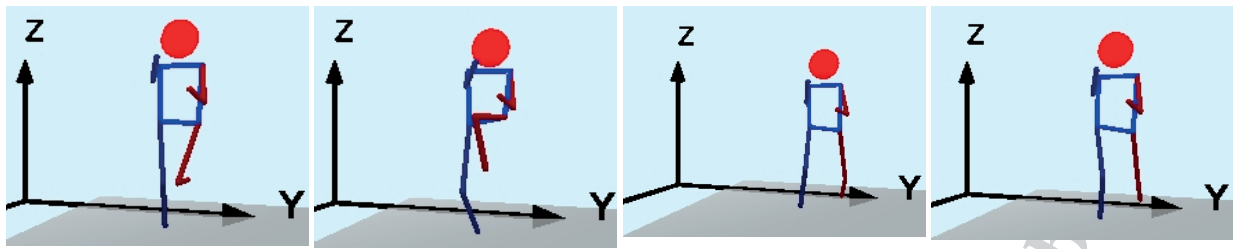
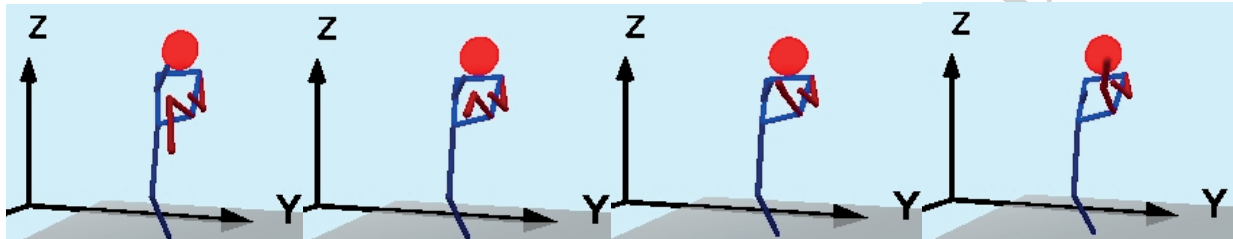
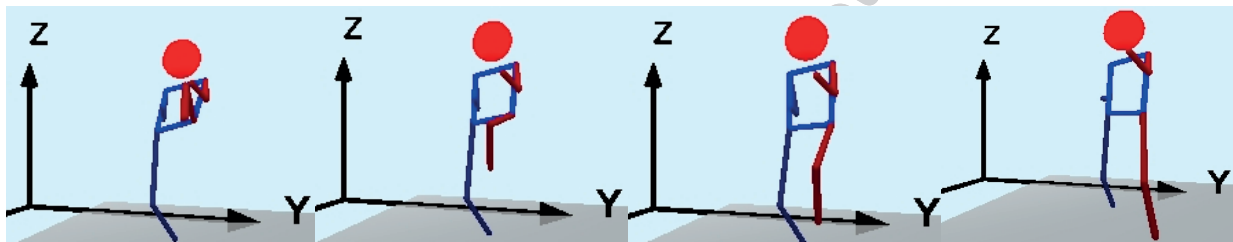
Keri waza (kicking) are characterized by attacks of karate. If the kicking technique is managed adequately, kicks with legs may have a stronger effect than blows with arms. The limiting factor is the equilibrium efficiency kicking ability, since body weight rests on only one leg. The hardest moment is to maintain balance at the moment of the impact of the kicking leg on the target. For all the kicking techniques, it is a principle that the art goes through the entire body, not the leg itself. Involvement of other body parts is limited mainly by moving hips forward. This makes it possible to maximize the effect of the technique. The kicking leg should always be quickly

withdrawn after the completion of the active phase of the kick. This is to prevent the opponent's kicking leg from being caught or from making the adversary to prop the leg. Therefore, foot should be withdrawn on the ground and made ready for another attack [Nakayama 1994].

Front kick (*mae geri*)

The front kick is the most frequently used of all karate kicks because it can be performed very fast with little wind-up, and it is difficult to block. There are slight variations in how to perform a front kick, from a quick snap kick to a very powerful thrusting front kick.

Mae geri (front kick) is a technique usually performed in the low zone (*gedan*) on the knee or mid-range (*chudan*) on the genitals, abdomen or solar plexus. It is one of the most common techniques that allows direct elimination of an adversary or to keep a safe distance. *Mae geri* is

Fig 1. Preparatory phase of *mae geri*Fig 2. Main phase of *mae geri*Fig 3. Final phase of *mae geri*

carried out in three stages: preparatory, main and final.

Objectives

Based on long term experience with Simi system and in connection with running projects at the Faculty of Sports Studies, the article describes the possibilities of kinematic analysis and possibilities of transferring it to sport and training practice.

Phases of *mae geri*

Figure 1: **Preparatory Phase** (from the basic stance to a lifted leg)

Preparatory Phase:

1st raise one knee, hold the foot parallel to the ground, but keep the ball rather than the heel,

2nd hold the tibia near perpendicular to the ground,

3rd slide the heel backwards as far as possible, perpendicular line from the knees should fall to a point at the tips of toes,

4th knee and toes facing the same direction,

5th raise your toes up and ankle brace,

6th relax the knee joint and keep it pliable, ready for further movement.

Figure 2: **Main Phase** (from the lifted leg to the knee extension) Main stage:

1st lean your upper body as much as possible in the direction of the kick, if it deviates from the kick, you lose balance,

2nd use your side, push it in the direction of the kick,

3rd the kick is executed by thrusting leg forwards in a straight path,

4th the kick is performed easily and quickly, but at the time of impact, the objective is to strengthen the legs

5th foot must hit the target when the leg is fully strained

Figure 3: **Final Phase** (from leg protraction to return to standing)

Final phase:

1st when the leg has struck, pull the hips parallel with your leg back to the initial position,

2nd after returning to the initial position put the kicking leg into the basic position.

Methods

We measured the movement of the front kick *mae-geri* in female (specialist in *karate/shotokan*) and male (specialist in *aikibudo*) performance. Figures 1-3 illustrate the three dimensional system of 15 different moments of the movement divided into three phases - preparatory, active and final. These frames are taken from a film which captured movement reflex points located on key parts of the body and their subsequent merger. The advantage of such a display compared to common observation is the ability to re-scan movements from all angles and the possibility of an unconventional point of view from below through the floor. Clicking on the system coordinate axes gives an indication of the direction of the observer's point of view; it is also important to focus on other graphic program outputs.

Subjects

Two probands (1 female, age = 25, height = 160cm, mass = 51kg; 1 male, age = 30, height = 182cm, mass = 80kg) were scanned by Simi motion system during the front kick *mae geri*.

Both subjects were examined for not having any pathology of the lower limb or cardiovascular system or balance problems; otherwise in good health condition.

The measuring was executed in Biomechanics laboratory at the Faculty of Sports Studies, in Brno, the Czech Republic.

Data acquisition and study record

Kinematic analysis was in our research represented by Simi system. This system offers a wide scale of possibilities such as comparison in three dimensional space, simulation and modification of input parameters to improve the technique. As an example, we chose front kick *mae geri*, executed by a man and a woman alike.

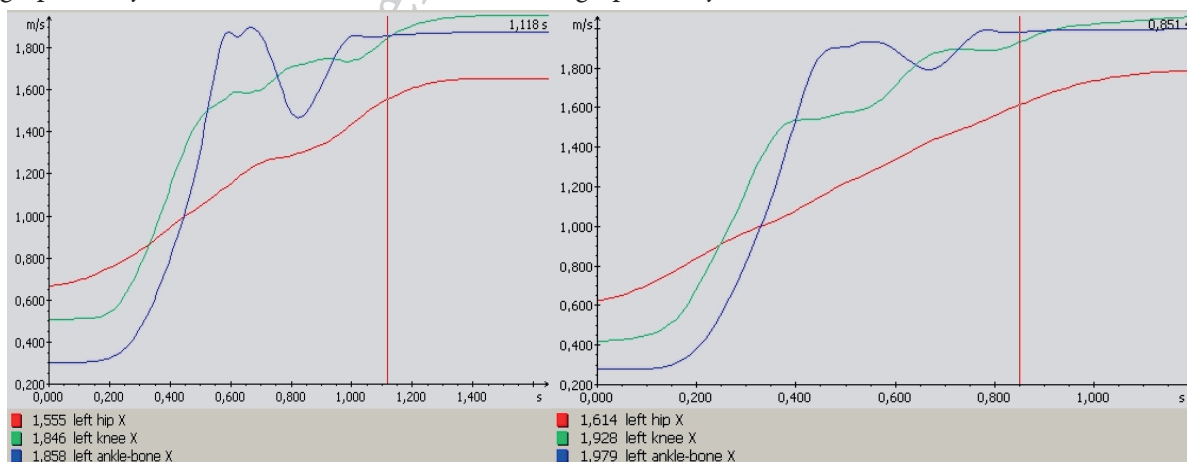
Simi Motion is a motion analysis software which has been developed in close cooperation with leading scientists and institutes from all over the world.

Its modular design means that a customized system tailored to each user's requirements can be quickly and easily produced. Typical modules which are available are 2D or 3D kinematics (image based motion analysis), inverse dynamics and support for several DV or high-speed video cameras and for EMG, force plates, pressure distribution measuring equipment and other devices.

1) Sequencing of body segments ankle, knee, hip (X axis – front-rear scan)

graph 1: object 1 (woman)

graph 2: object 2 (man)



— Object 1 finished kick (all three phases) at 1.118 sec and object 2 at 0.851sec.

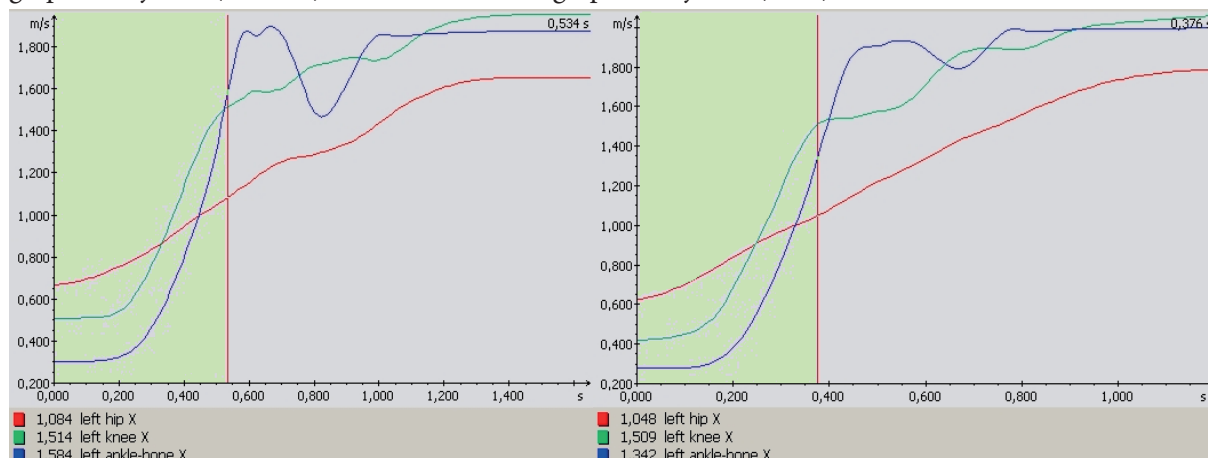
— Time difference is 0.267 sec.

— Trajectories of all three body segments are almost the same.

2a) Sequencing of body segments ankle, knee, hip – preparatory phase (X axis – front-rear scan)

graph 3: object 1 (woman)

graph 4: object 2 (man)

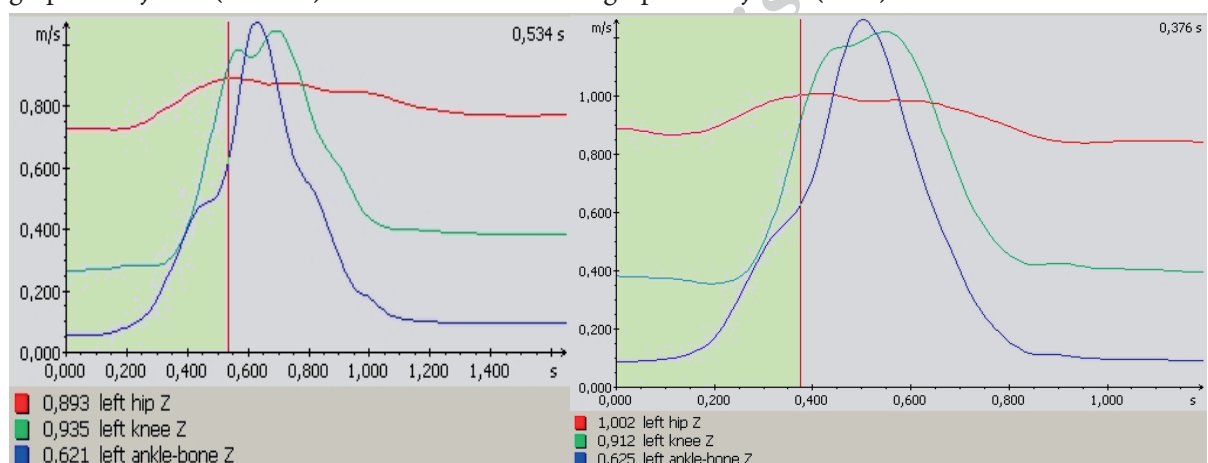


- Object 1 finished preparatory phase at 0.534 sec, object 2 at 0.376 sec.
- Time difference is 0.158 sec .
- Object 2 is faster in this phase.

2b) Sequencing of body segments ankle, knee, hip – preparatory phase (Z axis – vertical scan)

graph 5: object 1 (woman)

graph 6: object 2 (man)

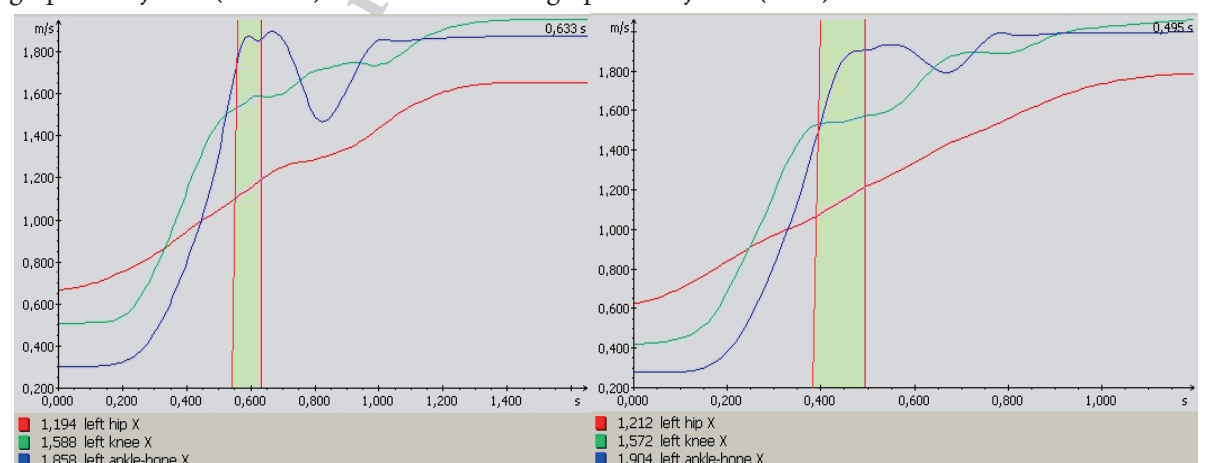


In the video it can be seen that object 2 did not do the preparatory phase *hiki ashi* absolutely perfectly (knee was not sufficiently at the top and the heel is not lifted properly adducted to the backside), this was the reason that the preparatory phase is shorter than in object 1 who performed the preparatory phase accurately (according to the methodology karate).

3a) Sequencing of body segments ankle, knee, hip – active phase (X axis – front-rear scan)

graph 7: object 1 (woman)

graph 8: object 2 (man)



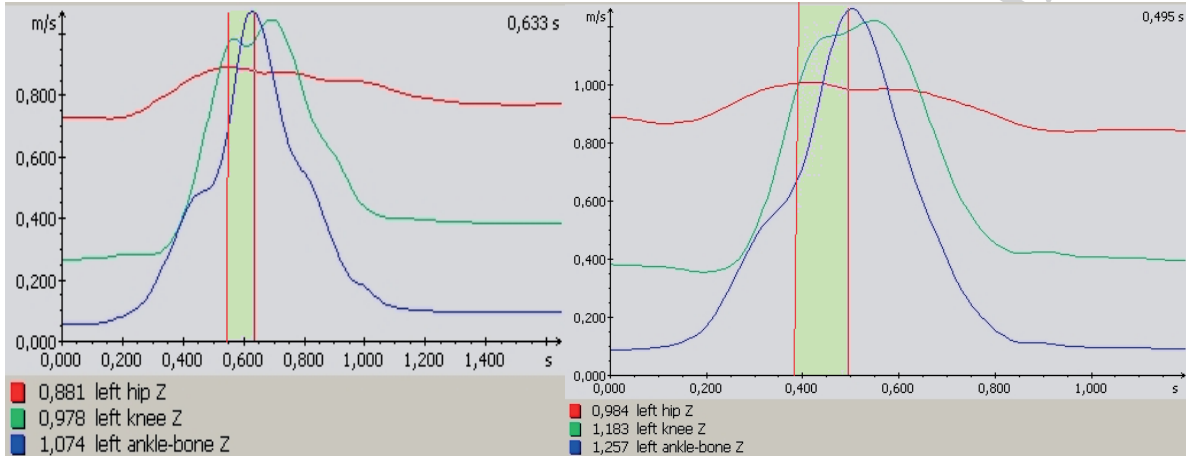
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- Object 1 started active phase at 0.544 sec and finished at 0.633 sec.
- Therefore the whole process of this phase is 0.089 sec.
- Object 2 started active phase at 0.376 sec and finished at 0.495 sec.
- Therefore the whole process of this phase is 0.109 sec.
- Time difference between two objects is 0.020 sec in this phase.
- Object 1 is faster in this phase.

3b) Sequencing of body segments ankle, knee, hip – active phase (Z axis – vertical scan)

graph 9: object 1 (woman)

graph 10: object 2 (man)

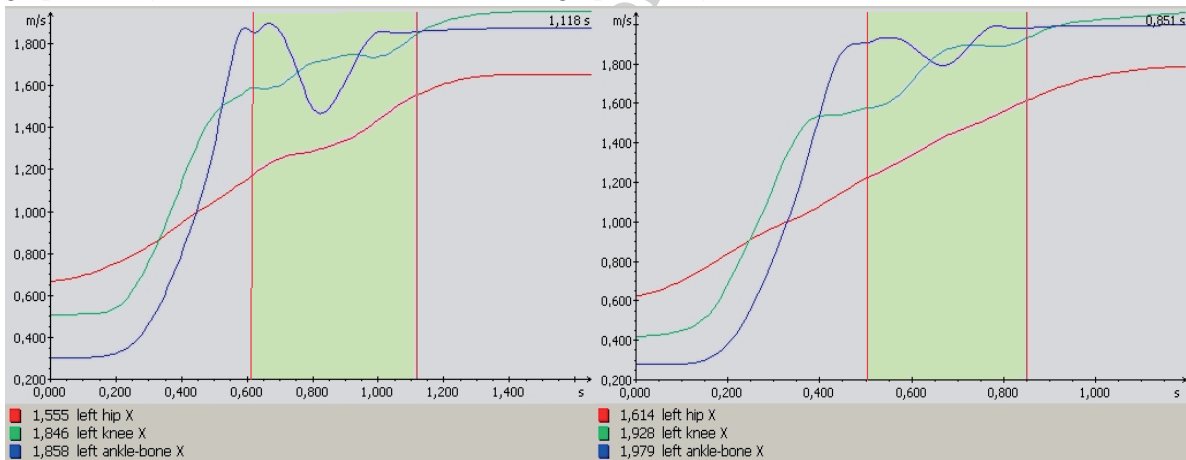


The active phase was faster by object 1 who implies higher efficiency of this kick; it can be assumed that object 2 is part of the kick forces prepared under the preparatory phase and object 1 stretched the knee significantly to complete the kick, which is not correct and may cause injury of the knee joint.

4a) Sequencing of body segments ankle, knee, hip – final phase (X axis – front-rear scan)

graph 11: object 1 (woman)

graph 12: object 2 (man)

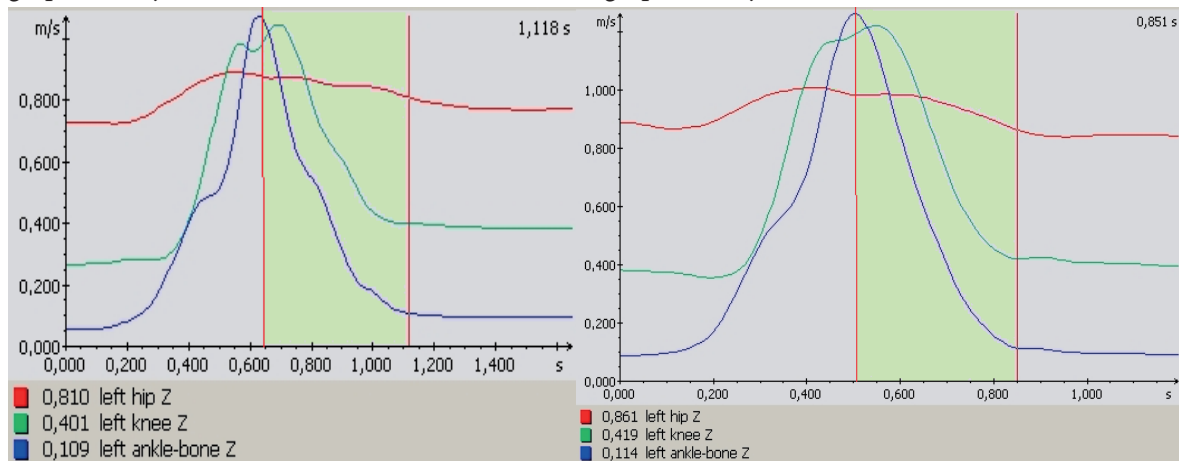


- Object 1 started final phase at 0.643 sec and finished at 1.118 sec.
- Therefore the whole process of this phase is 0.475 sec.
- Object 2 started final phase at 0.505 sec a finished at 0.851 sec.
- Therefore the whole process of this phase is 0.346 sec.
- Time difference between two objects is 0.237 sec in this phase.
- Object 2 is faster in this phase.

4b) Sequencing of body segments ankle, knee, hip – final phase (Z axis – vertical scan)

graph 13: object 1 (woman)

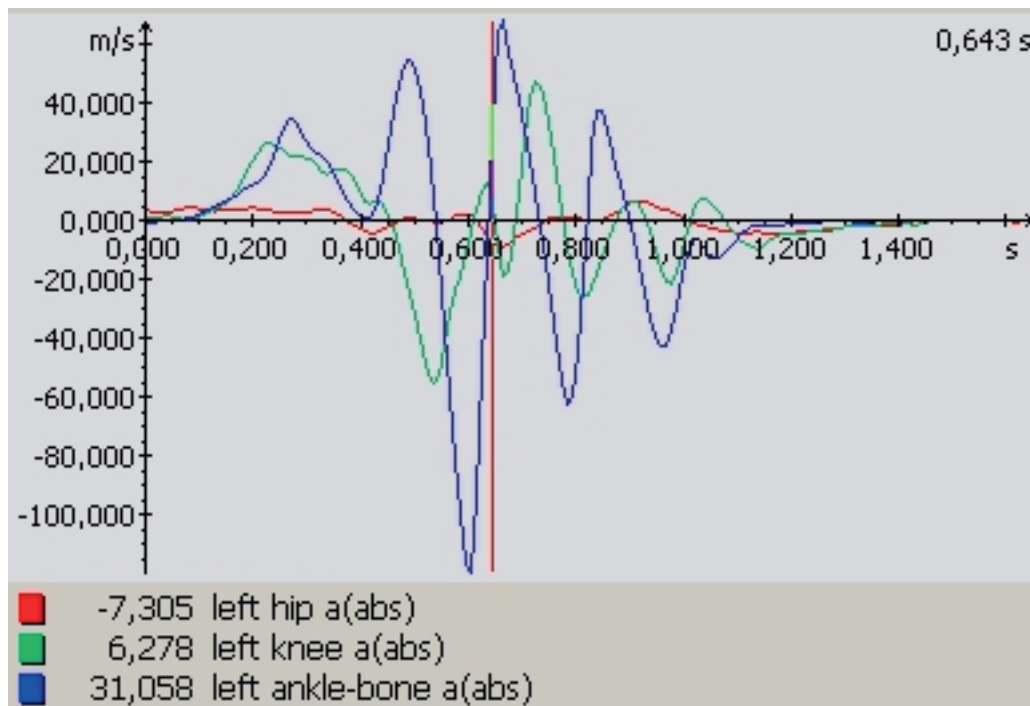
graph 14: object 2 (man)



The final phase was again faster by object 2 because it has been truncated to return to *hiki ashi* position and the proband previously set foot on the ground - although the efficiency of the kick at this stage has no effect, it is important for establishment of other techniques in the fight. Object 1 pulled the leg back correctly to the *hiki ashi* position and then put one foot on the ground, which results in prolonging this phase.

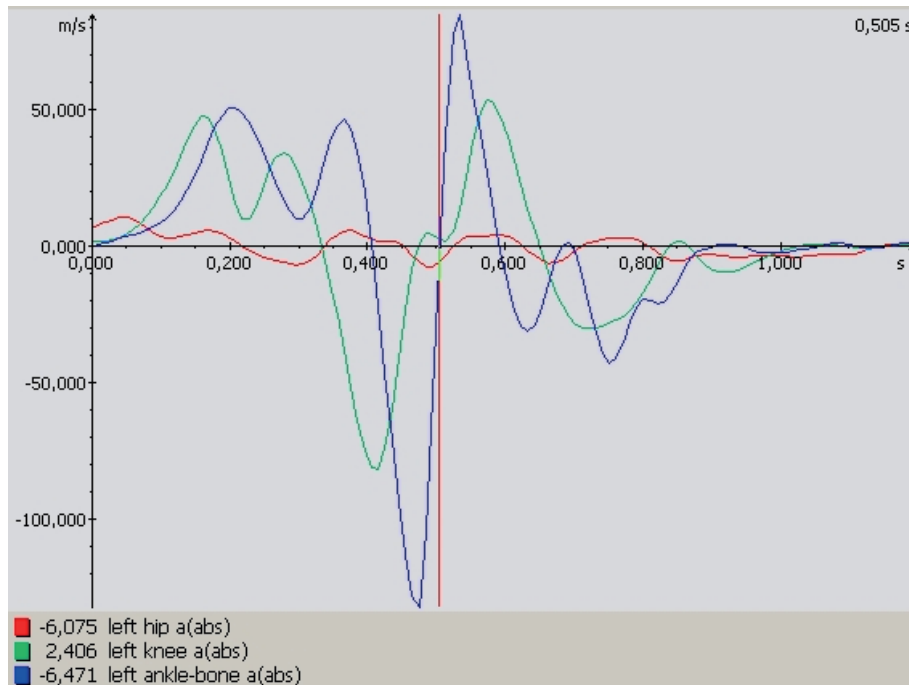
5) Acceleration of segments (absolute values)

graph 15: object 1 (woman)



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graph 16: object 2 (man)



The biomechanical analysis shows that:

Segments of the leg movement were performed faster in the preparatory and final phases by object 2.
Motion segments of the leg were faster in the active stage of object 1

Conclusions

Based on exact physical parameters, we evaluated and compared the techniques of each proband, in a high number of physical parameters such as velocity, acceleration, chain of movements during kick and stroke, and finally we attempted to optimize the movement. This possibility has been helpful for a couple of years to determine trends in many sports disciplines and we would like to use it in a combative area.

Based on the biomechanical and factual analysis, we can conclude that the efficiency of kick *mae geri* would likely be higher in object 1. The proband kicked out technically correctly (in accordance with the methodology of karate) and mainly achieved greater acceleration in the main phase of the kick. The technique would therefore result in hitting the target more effectively. Object 1 should avoid stretching the knee in completing the kick. Object 2 should improve the preparatory phase of the kick synchronization and transition into the active phase to increase the efficiency of the kick.

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Analiza kinematyczna w sportach walki

Słowa kluczowe: kinezylogia, biomechanika, sztuki walki, trójwymiarowa analiza

Abstrakt

Artykuł koncentruje się na opisie możliwości kinematycznej analizy w dziedzinie sztuk walki. Na podstawie obserwacji wielu trenerów poddawało analizie ruch sportowców. Obserwacja nie jest jednak wystarczająco dokładna w analizie ponieważ obserwator nie jest w stanie zobaczyć żadnych szczegółów fizycznych parametrów ruchu. Autorzy pracy opisują możliwości analizy kinematycznej i jej odniesienia do sportu i treningów opartych na długoletnim doświadczeniu z systemami SIMI oraz aktualnymi projektami prowadzonymi przez Wydział Sportu.

Kinematyczna analiza reprezentowana przez system SIMI oferuje szeroką skalę możliwości dla porównania w przestrzeni

trójwymiarowej, symulacji oraz modyfikacji parametrów wejściowych w celu poprawienia techniki. Jako przykład autorzy wybrali kopnięcie do przodu zwane *mae geri*, wykonywane zarówno przez kobiety i mężczyznę.

Analiza została oparta na dokładnych parametrach fizycznych. Autorzy ocenili i porównali każdą z technik z dużą liczbą fizycznych parametrów takich jak: prędkość, przyspieszenie, seria ruchów wykonywanych w czasie kopnięcia i uderzenia oraz podjęli próbę optymalizacji ruchu. Analiza pomaga od wielu lat w określeniu trendów w wielu dyscyplinach sportowych, stąd autorzy chcieliby prowadzić dalsze badania w dziedzinie sportów i sztuk walki.

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