BIOMECHANICAL ANALYSIS OF FIST PUNCH GYAKU-ZUKI IN KARATE

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The purpose of this study was to characterise the most used fist punch in karate, the so called Gyaku-Zuki. Having a look at current publications, most of them describe the Gyaku-Zuki in a verbal form or they concentrate on analyses about physical parameters. In order to understand and even improve the movement, it is necessary to describe the punch by using biomechanical parameters. Recording the performance of three different karatekas with a VICON system, this study only focuses on the basis-version of Gyaku-Zuki. After giving the movement a structure, first results can be presented e. g. the total time of movement and maximum velocity of fist. For performing a punch all three athletes require less than 400ms and reach a maximum of fist velocity of about 8m/s. So this study will help to understand the Gyaku-Zuki and will pave the way for further analyses.

KEY WORDS: karate, Gyaku-Zuki, kinematical analysis.

INTRODUCTION:

Karate Kumite is characterised by two active athletes fighting against each other in a certain area (DKV, 2008). The purpose of this study is to analyse the most used fist punch in karate kumite, the so called Gyaku-Zuki. Although performing an attack with the leg is judged with three points, lots of attacks are made by using fist punches in kumite. The main reasons for using the fist punch Gyaku-Zuki are that the execution does not require much time and the movement is less complicated compared to a kick e.g. Mawashi-Geri. In order to be better than the opponent and receiving the judgement, the aim of the karateka is to reduce the total time of movement of the used technique.

Regarding the situation of publications in karate, there are analyses concentrating on physical education (e. g. Lehmann & Jedliczka, 1998). Furthermore there are analyses which explore karate movements by using technical equipment and biomechanical methods e. g. Sforza et al. (2000). But a lot of the existing publications describe the Gyaku-Zuki in a verbal form, e. g. Wichmann (1985), Lind (1999) and Okazaki & Stricevic (1987) who do not consider biomechanical information. The first essential biomechanical investigations of karate techniques were carried out by Emmermacher et al. (2005, 2007) and Witte et al. (2005, 2007). But a complex three-dimensional kinematical analysis of the Gyaku-Zuki was not reported yet. So the aim of the study is:

- to get knowledge and understanding about the movement structure and the specifics of the fist punch.
- to analyse the total time of movement and velocities of punching fist in order to optimise both during execution of movement.

Before starting the research it is important to know that there are many different types of performing the Gyaku-Zuki. This study will only focus on one version which is presented on the first position in the following Table 1. This version is characterised by the athlete standing still in an upright position before performing the fist punch with active hip movement. Table 1 presents also a short description of different possible versions of the Gyaku-Zuki in kumite.

METHOD:

Three male karatekas with different graduates participated in this study: subject I (4^{th} Kyu), subject II (3^{rd} Dan) and subject III (2^{nd} Dan).

Each karateka executed different versions of the fist punch Gyaku-Zuki (see Table 1), whereas each version was performed for six times. As already mentioned, the focus of this study will be the execution of variant 1 only, because this version represents the basic one. The other versions have been performed and recorded for further analyses and comparisons between the techniques. The break between the six punches was about one or two seconds, among the different series of the Gyaku-Zuki the break was about three minutes.

For recording the fist punches, a VICON system consisting of eight VICON MX 40 cameras was used. The sample rate was 200 Hz. Recent investigations proved, that this sample rate is adequate (e. g. Hofmann 2006). For placing the markers, the positions of the plug-in-gait marker system with 42 markers were selected. In order to cut, smooth and analyse the data, embedded functions of Polygon and Bodybuilder were used. In addition Microcal Origin was used to analyse the data as well.
To characterise the Gyaku-Zuki generally as well as individually, it is important to divide the movement in specific phases for instance on the basis of path-time-courses and velocity-time-courses. With the help of the different phases of the movement being described in the following chapter, the similarities and differences of techniques for each athlete can be explored. Furthermore important kinematical parameters can be determined and calculated such as: total time of movement, times of phases and velocities of hip, shoulder and fist.

Table 1 Different variants of execution regarding Gyaku-Zuki in Kumite

1. Gyaku-Zuki starts standing still with active movement of hip.
2. Gyaku-Zuki starts standing still with no active movement of hip.
3. Gyaku-Zuki starts with step movement, whereas the punch starts after landing.
4. Gyaku-Zuki starts with step movement, whereas the punch starts during the step.
5. Gyaku-Zuki version 1 with intentional rotating fist.
6. Gyaku-Zuki version 1 with intentional non-rotating fist.
7. Gyaku-Zuki during running forward.

RESULTS:
A movement phase structuring on the basis of the velocity-time-courses will be attempted within the scope of the present study in order to carry out an objective movement analysis and particularly a temporal structuring. Figure 1 shows the three-dimensional path-time-courses as well as the 3d-velocity-time courses of hip, shoulder and fist of the punching side of the body of subject I. Using special points of time of these parameters e. g. maximum velocities, it is possible to realise a biomechanical phase structure.

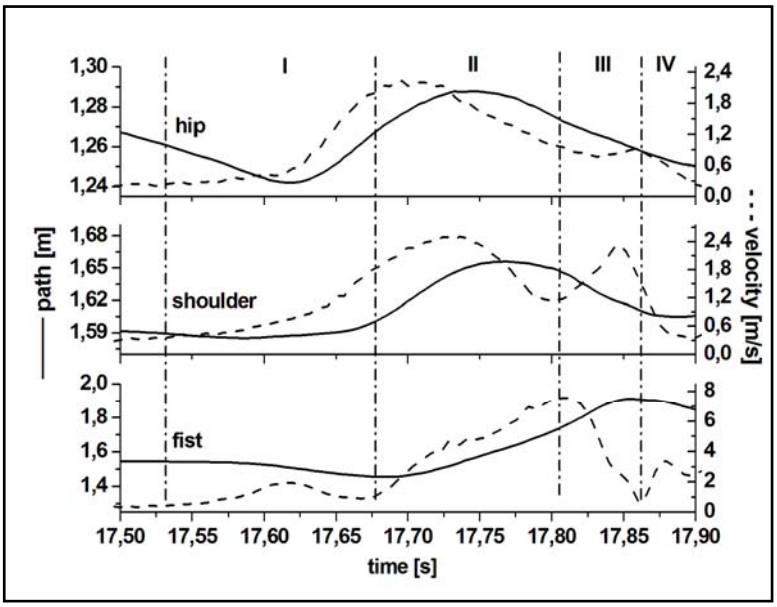

Figure 1: Phases of movement with three-dimensional path-time-courses and velocity-time-courses of hip, shoulder represented by subject I

Having a look at the Figure 1, one can see, that the fist punch is divided into four different phases, symbolised by I, II, III and IV. Phase I describes the early part when the hip is starting the punch. To give the movement an exact point of beginning, the start is at 10 % of the maximum hip velocity. The end of phase I is equal to the beginning of phase II. The exact

point of time was chosen, when the rising of the punching velocity of the fist is higher than the highest rising of the velocity of the shoulder. This second phase represents the extension of the arm and lasts till the fist has reached its maximum velocity. Then phase III starts directly representing the deceleration of fist until the minimum of velocity is reached. This point of time is equivalent to the full extension of the arm. Finally phase IV is finishing the movement by simply going back to the starting position. So the end of phase IV needs not to be determined and the total time of movement consists of the summation of phase I, II and III.

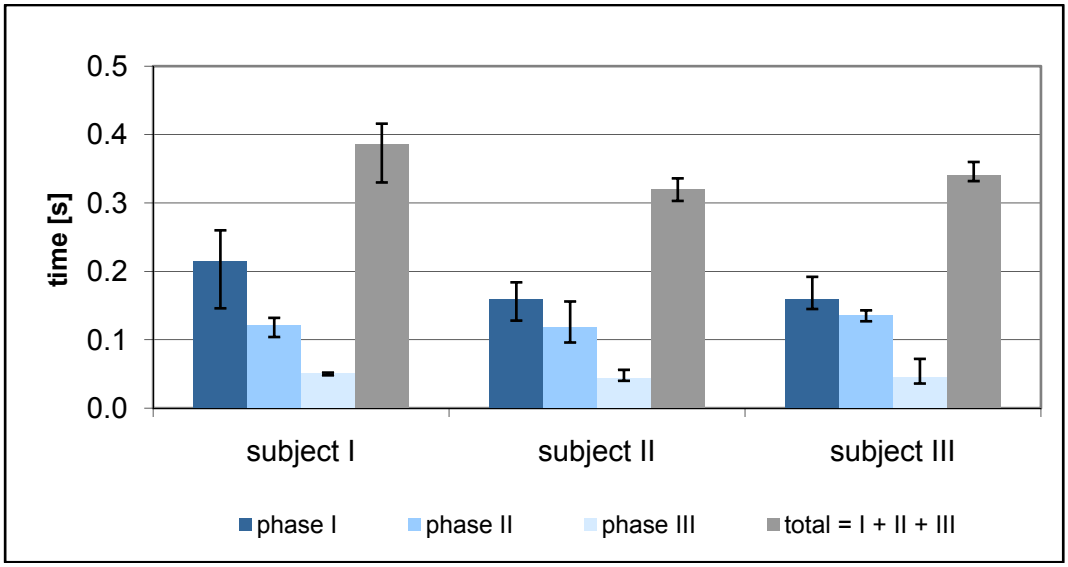

Figure 2: Mean total times and phase times of six executions for each subject

The total time of movement for all three subjects is shown in Figure 2. It can be seen, that subject I needs the longest time for performing the Gyaku-Zuki with an average of about 386ms. Subject II requires the shortest time for performing the Gyaku-Zuki with 320ms only. Subject III needs 341ms. Having a look at the different phases it is obvious that subject I requires the most time during phase I, which seems to be optimised most. In contrast to that, especially phase III is very constant for all athletes. In order to get an impression about the existing velocities of the joints of interest and the fist while performing a Gyaku-Zuki, the following Table 2 shows the average maximum velocities over six executions of every subject. The data exhibit, that all three athletes almost reach the same velocity with their punching fist, although they have different total time of movements (see Figure 2) and subject III has the smallest average maximum velocity of the hip.

Table 2 Average maximum velocities (six executions of Gyaku-Zuki each)

subject	v_{max} hip [m/s] (Min; Max)	v_{max} shoulder [m/s] (Min; Max)	v_{max} fist [m/s] (Min; Max)
I	2,5 (2,2; 2,8)	2,9 (2,5; 3,2)	8,4 (7,6; 8,8)
II	2,5 (2,3; 2,8)	3,4 (3,1; 3,6)	8,1 (7,4; 8,4)
III	1,5 (1,3; 1,8)	3,1 (2,8; 3,3)	8,3 (7,4; 8,8)

DISCUSSION:

By movement structuring on the foundation of biomechanical parameters it is possible to find differences and similarities of the temporal movement structure between the athletes (see Figure 1 and 2 as well as Table 2). Especially the analysis of the total time of movement is very important. This characteristic time must be very short to be successful during the fight. By means of this analysis it is possible to get information about the duration of executing the punch. The different values for each phase and the total time of movement indicate where

the determining differences and potentials of each athlete are located. With the help of the Vicon MX 40 it is possible to record and analyse all points of interests of the body with the same high quality, which is a big difference compared to the early beginnings in 1972, when Nakayama tried to analyse velocity-time-courses first. So this study ties in with analysing karate techniques using biomechanical methods and modern technical equipement as recently done by e. g. Emmermacher (2005) and Hofmann (2006). Although this study represents only six punches per subject of variant 1, it describes a basis which admits a biomechanical analysis of other versions in future.

CONCLUSION:

Regarding the situation in karate, this study of the important fist punch Gyaku-Zuki will help to understand the movement, especially the phase structure, and to determine the total time of movement. Further analyses with the present data will prove if there are correlations between maximum velocities and total time of movement, between the phases itself and the trajectories of the fist. Especially these characteristics have not been analysed in recent literature (e. g. Sforza 2000 and Witte 2005). Finally, future analyses will show how a process of punching may be optimised which has not been tried yet as well.

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