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# KINEMATIC ANALYSIS OF A KARATE PUNCH IN EXPERIENCED AND NON-EXPERIENCED PRACTITIONERS

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**Abstract.** *Karate-Do designates the martial art that uses one's own body for the purpose of personal defense, aiming at the perfection of character while developing the mastery of all movements through the attainment of physical and mental balance. The Choku-Zuki is the first skill to be performed by the learner in the training process, but his best performance is generated from a developed neuromuscular coordination, whose analysis can be inferred through electromyographic patterns. The present study aims at analyzing kinesiologicaly distinct groups regarding the experience in training the Karate-Do martial art when executing their punches, correlating the kinematic patterns obtained by the use of Arduino in conjunction with the MPU6050 motion tracker, presenting the best performance of the punch and diagnosing the main divergences that may cause injuries in the process of developing the martial art.*

**Keywords:** *Biomechanics, Karate-Do, Arduino, Kinematics, Choku-Zuki.*

## 1. INTRODUCTION

In its etymology, Karate-Do has the "Path of Empty Hands" as meaning, designating the martial art practiced with empty hands, which uses its own body with the aim of defending itself. It does not define who is the winner or loser, not even the best or the worst; aims to improve the character of his practitioner, making him dominate all the movements of the body, for this the full potential for the attainment of physical and mental balance is used. Mind and body unite, fostering a complete technique and a calm and serene character (Guimarães, Guimarães, 2002).

In the initial training process of the martial art, the simplest punch to be instructed by the master is the Choku-Zuki, which consists of a direct punch focused in the middle of the opponent's chest, starting from a static position. The Choku-Zuki serve as a foundation for the development of other more complex strokes, such as Gyaku-Zuki and Oi-Zuki, but their performance is not trivial since it requires a sequence of joint actions involving various components such as pelvis, trunk and upper limbs for energy transmission (Vences Brito et al., 2011).

Schmidt and Wrisberg (2000) refer to the motor learning process as a modification of the internal processes that determine the ability to produce action, in which individual progression levels increase with practice. Thus, it is understood that the systematic training of karate consists of a method of learning specific motor tasks from the conscious repetition of the motor patterns of each blow (Vences Brito, 2012), and these behaviors can be identified through kinematics and electromyographic patterns generated during the execution.

According to Vences Brito et al. (2011), what is sought in the execution of the Choku-Zuki is the greatest amount of energy when shoot the fist as fast as possible in the target attack, characterizing a ballistic action. The short duration of the movement causes several limitations of proprioceptive and visual corrections and their effects are executed according to the patterns generated by the neuromuscular coordination, making difficult the learning process realized by the master to his apprentices, since all this depends of strategies of motor learning which results in changes in internal muscle activation processes (Schmidt and Wrisberg, 2000 apud Vences Brito et al., 2011). It is known that transient forces, transmitted through the skeleton, are harmful (Whittle, 1999 apud Souza, 2002) and poor positioning of the components during movement can aggravate the consequences that arise in the upper segment.

The highest frequency of injuries in Shotokan karate practitioners is recorded in the lower limbs, with 39.86% of the total recorded injuries, followed by upper limbs with 33.11%, head with 22.30%, trunk with 2.70% and neck with

2.03% (Souza *et al.*, 2011). Factors such as age, graduation and hours of training per week had significant differences among participants, with practitioners less than 18 years old, graduations between the white and black belts and training up to 3 hours per week presented fewer occurrences of than those who were 18 years of age or older, with high grades and trained more than 3 hours per week (Zetaruk *et al.*, 2000). Starting from this hypothesis, it is not enough to know only the magnitude of the blow, but to correlate the trauma with the kinematics performed in the execution.

Several studies have investigated punch strength among various combat sports, however, there is a paucity of research examining kinematic, kinetic and electromyographic patterns during athlete performance (Rinaldi *et al.*, 2018). These objectives are important factors for the development of teaching strategies, given the constancy of injuries in athletes during the learning process and in combat.

To achieve the proposed objective, Vences Brito (2012) used a three-dimensional kinematic analysis, which used four electromagnetic sensors arranged on the first thoracic vertebra, in the external and medial position of the arm, on the posterior face of the forearm (on the wrist) and at the fixed target. In this study, the kinematic behavior of the dominant arm of each participant was analyzed, coupling the electromagnetic sensor to the distal anatomical point of the forearm and allowing free performance without a fixed target.

## 2. METHODS

The present study aims at analyzing kinesiological groups of individuals who differ in their experience in Karate-Do martial art training when performing their strokes, thus correlating the kinematic concepts of each group.

### 2.1 Participants

Approximately 11 practitioners with age mean value 47,90 (SD = 14,56) years, of both genders, with minimal graduation in white belt, participated in this project, which are part of the Server Life Quality Program - Living in Harmony of the Federal University of Rio Grande do Sul. North - UFRN. The exclusion criteria are:

- History of recurrent shoulder subluxation;
- History of fractures and surgery in the shoulder complex in the last 12 months;
- Neurological findings that are abnormal and systemic pathologies;
- Treatment with corticoid injection in the 3 months prior to the evaluation.

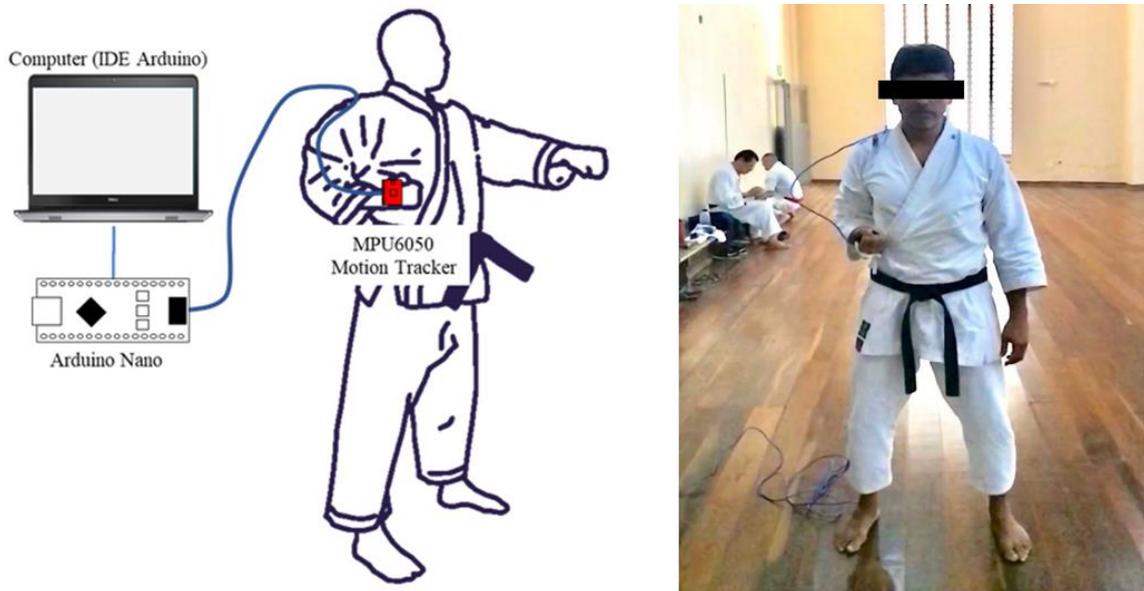


Figure 1. Schematic diagram of devices assembly and illustrative image of experimental design.  
Source: Own author.

### 2.2 Instrumentation

The kinematic data is obtained through the use of microcontrollers in operation with specific circuit boards for each objective. For the study, the availability of Arduino Nano, for data control and interpretation, and motion-tracking type shields will be required.

The motion tracker used was the MPU6050, measuring 20.9x15.8mm, and in terms of its performance, it collects a set of data, with 1000 Hz of sampling rate of signal acquisition, which includes three-axis gyro data, three-axis

accelerometer data, and data of temperature; and synchronizes this sampling with the user-defined rate, as well as being operational in four different ranges and sensitivities with a digitally programmable low pass filter.

The device was created from the connection of the movement tracker to the Arduino Nano, grouped in a way as to allow the coupling at the appropriate points of analysis of the movement, such as the wrist, elbow and center of gravity of the athlete. In this case, the motion tracker was attached to a glove to ensure the same wrist analysis point in all participant executions, as shown in Fig. 1.

### 2.3 Experimental Design

Once developed the system, with the Arduino IDE software version 1.8.7, a code was developed to control and treat the signals received by the Arduino Nano connected to the signal receiver, adapting the best working condition of the circuit.

A sensor was connected to each volunteer in the static position, to digitize anatomical points and to construct the coordinate system for each articulation studied, allowing the transformation of sensor data into local coordinate systems, defined by each studied anatomy. Participants were then instructed to punch unilaterally in two styles of Choku-Zuki, as shown in Fig. 2, according to the instructor's voice command to start. Five successive strokes of complete Choku-Zuki (with the wrist positioned on the iliac crest) was performed in sequence of five successive repetitions from midway (started by the elbow positioned on the iliac crest), with a spacing of 5 seconds between each repetition. The punches were performed by the dominant upper limb of each participant. It is remarkable that the electromagnetic sensors were not removed between the repetitions.

With the data collection of the performance, the information was transposed in Excel, to isolate the kinematic patterns established by the movement and from these results, it is possible to present the best performance of the stroke and to diagnose the main divergences that could cause injuries in the athlete in the process of developing the martial art. Through the Excel scatter plot with smooth lines, the point acceleration module means were correlated with the percentage of the total execution time. The associated error bars were developed by the STDEV function, which calculates the standard deviation from a sampling, in this case, the point accelerations during the punch execution.

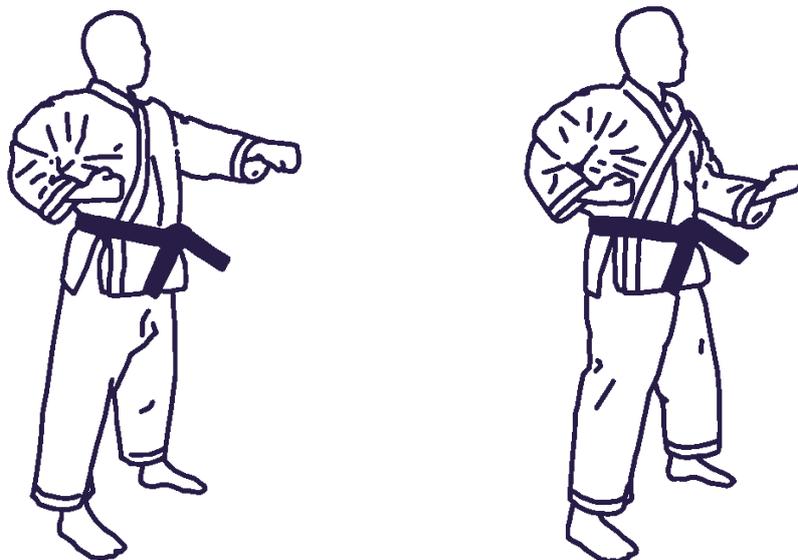


Figure 2. Two styles of Choku-Zuki punch, complete (left) and midway (right).

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### 3. RESULTS AND DISCUSSION

The execution of the blow taught by the great masters demonstrates a pattern that induces the transfer of energy from the proximal to the distal region, characterizing a ballistic action due to the fact that it is performed as fast as possible. To accomplish this, the acceleration peak in the direction of the longitudinal axis of the motion must be reached in a shorter period of time within the execution. Based on the hypothesis that the motor control and movement strategies are improved with the longer training time and graduation of the practitioner, a comparative graph of the behavior of the acceleration resulting from the hand was plotted from the execution of 5 complete punches by white (lower graduation) and black (higher graduation) belts, as shown in Fig. 3.

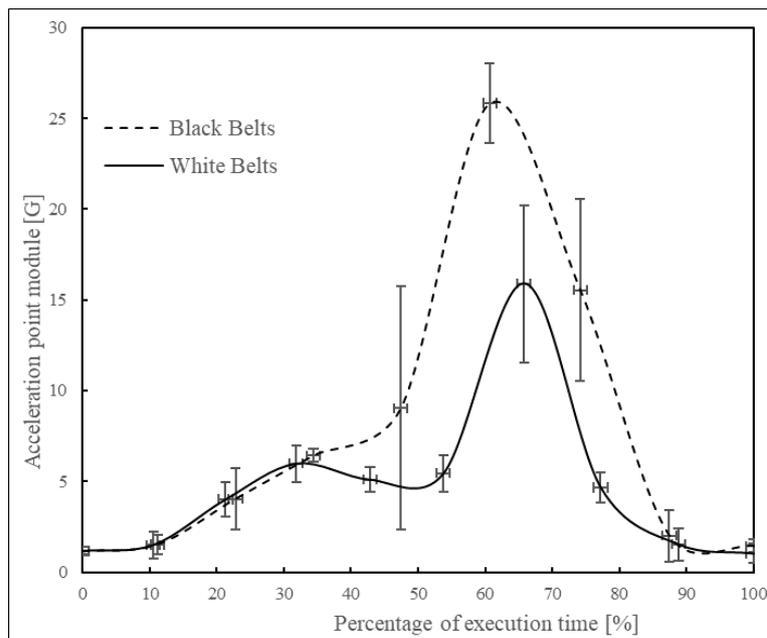


Figure 3. Behavior of the resulting acceleration during the execution of complete Choku-Zuki.  
Source: Own author.

The continuous curve, represented by the execution of the white band, reached a significantly lower maximum value of acceleration when compared to the dashed curve. It is observed that there is a previous growth of the module of the acceleration by the less experienced, close to the 10% of the complete time of execution, and that it occurs in a non-continuous manner, which can be a crucial factor for the reduction of energy transfer to the distal point. In the curve generated by practitioners with longer training time, the increase in acceleration occurs close to 15% of the total execution time and keeps increasing until the maximum value reached in the last 40% duration of the stroke. The rate of growth of the resulting acceleration of the wrist is considerably higher for the experienced, since it reaches higher values in smaller fractions of time. In competitions, this characteristic is well developed by the athletes, since they seek greater accuracy of the blow, reducing the time available for reaction and greater impact to the adversary, for example.

According to Vences Brito et al. (2011), the group with shorter training time tends to initiate and reach the angular velocity peak of forearm movements substantially earlier, obeying a different logic from that described empirically by the masters and verified in the more developed athletes of Karate. Based on the indirect influence of the rotational movements on the linear acceleration modules, these movements can be verified with the previous growth in the continuous curve. Moreover, the fact that the rotation about the longitudinal axis is generated in the early stages, may cause a larger torsion than desired by the practitioner, unprotecting the involved joints and causing instability to the punch, which potentiates the chances of the occurrence of injuries.

As with the complete punch, a comparative graph was developed between 5-punch executions starting halfway, as shown in Fig. 4. As expected, the accelerations achieved had lower results compared to those achieved during the full punch, because the differences in neuromuscular coordination patterns reduce the energy generated and transported during execution.

The acceleration increase continues from the initial 15% of performance, extending to 35% for the most experienced, and 50% for beginners, which causes the disparity between the maximum acceleration module achieved, as explained Vences Brito et al. (2011) when describing the movement pattern of less experienced athletes. The resulting acceleration growth rate is also higher for higher dan practitioners, achieving greater effectiveness in this type of punch.

As Shahbazi (2005) explains, it is possible that the performance from the elbow positioned on the iliac crest shortens the duration of the blow, since it has shorter ranges, but does not increase the energy delivered to the target, being functional when the goal is to obtain counterattacks during a fight. In the later stages of learning, this punch style is not as useful because the performances have already acquired a clear function of the act and a clear habit during the fighting. With a shorter duration of the attack, it is more difficult to control the position of the components and obtain proprioceptive corrections, increasing the incidence of injuries to the joints involved in the blow.

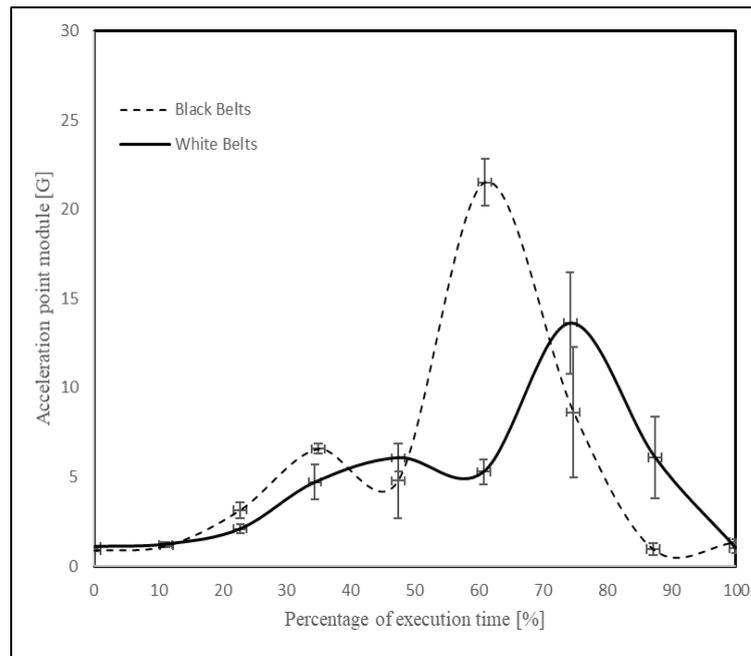


Figure 4. Behavior of the resulting acceleration during the execution of midway Choku-Zuki.  
Source: Own author.

#### 4. CONCLUSIONS

The patterns generated from the execution of the punches by the black belts presented better performance of the Choku-Zuki, both in vector acceleration module and in motion control. It can be inferred that the training time develops a better neuromuscular control, based on the favorable conditions of protection of the involved joints and the potentiality of the punch during its execution when compared to the patterns of movement of the less experienced ones. Although performance did not show a marked difference, small details in performance, such as anticipating angular acceleration towards the longitudinal axis, can generate an unfavorable movement pattern that will cause future injury to the athlete.

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