MOTION ANALYSIS OF *IAIDO* SKILL BY USING MOTION DATA

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The purpose of this research was to make a quantitative analysis of *Iaido* (the Japanese art of using the Japanese sword). We carried out experiments of motion capture on *Kirioroshi* (a straight overhead slash) movement of *Roppon-me* (a sword thrust using two hands) in *Iaido*. The proficiency of *Iaido* performance was evaluated by calculating PCA (Principal Components Analysis) and cluster analysis of parameters of body movement. In addition, it is expected that our research will help *Iaido* practitioners and masters with *Iaido* training through provision of new information on I*aido* movements.

KEY WORDS: *Iaido*, martial art, motion capture, motion analysis.

INTRODUCTION:

Recently, martial art has been frequently studied and analyzed using motion capture system, however, research into *Iaido* has been rarely analyzed. *Iaido* is the Japanese art of drawing the Japanese sword, the associated with controlling movements of striking or slashing, and then replacing the Japanese sword in its scabbard. There are several studies in the literature relating to martial art analysis through the measurement of body motion, for instance, the characteristic of *Wing Chun* movement [1], training systems [2], and foot movement analysis for *Tai Chi* [3], etc. However, quantitative analysis of an *Iaido* practitioner has not been published. In the following study, the movement of *Kirioroshi* (a straight overhead slash) of *Roppon-me* (a sword thrust using two hands) of *Iaido* was evaluated (see Figure 1). The *Iaido* practitioner needs adequate training to control the speed of body and arms to undertake the *Kirioroshi* movement. In particular, the *Kirioroshi* movement of *Roppon-me* requires the *Iaido* practitioner to carefully manage the slash movement and the transfer and retainment of body movement. In this research, we aim at quantitatively comparing the proficiency of an *Iaido* practitioner using motion data.

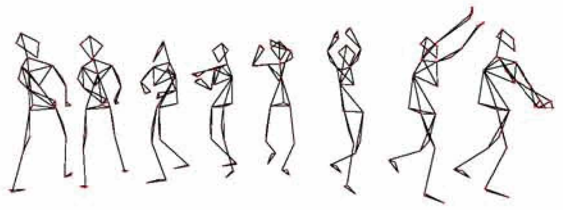


Figure1: *Kirioroshi* movement of *Roppon-me*.

Table 1. *Iaido* career of subjects.

Subject	Sex	*Iaido* career	Grade (*dan*)
Beginner C	Male	0 years	0
Beginner S	Male	0 years	0
Skilled A	Male	3 years	2
Skilled M	Male	3 years	2
Skilled T	Male	4 years	2
Skilled K	Male	5 years	3

METHOD:

Subject: Six students (age = 24.2±4.9 years, body height = 167.7±5.3 cm, body mass = 57.8±5.7 kg, career = 2.5±2.1 years) of *Iaido* were recruited as subjects in this experiment (see Table 1). Four subjects (A, M, T, K) have a skilled level and the other subjects are beginners (C, S). Skilled A was not trained in *Iaido* for the 3 months prior to testing motion data.

Procedure: Thirty-two (32) markers were attached on the body of each subject in order to capture motion data using an Eagle-Hawk system (Motion Analysis Corp.). We captured data with a sampling rate of 60Hz and recorded each performance three times for each subject.

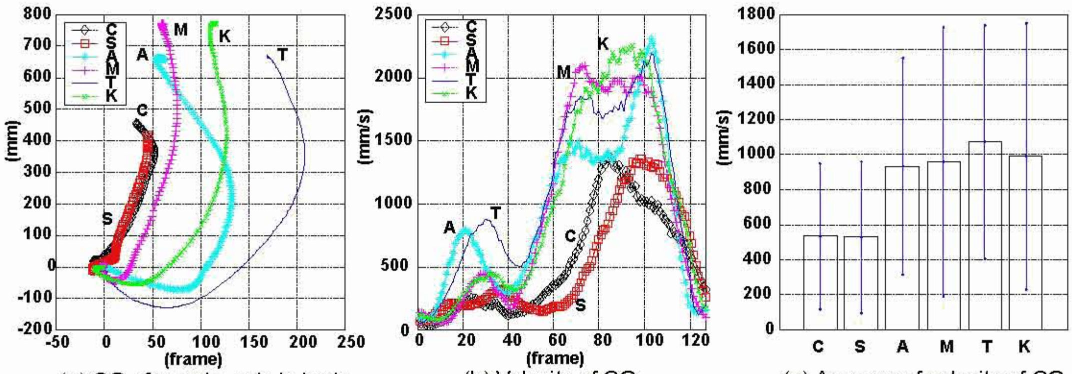
Table 2. Definition of parameters

No.	Parameter	Definition
1	Center of gravity	Using 19 virtual markers calculated by 32 markers
2	Velocity of right hand	Using right hand marker
3	Angle of root	Angle between chest and neck from root
4	Angle of neck	Angle between head and chest form neck
5	Angle of right pelvis	Angle between right shoulder and left hip from right hip
6	Angle of left pelvis	Angle between left shoulder and right hip from left hip

Data Analysis: A detailed definition of parameters is summarized in Table 2. Captured data are normalized before the analysis of the *Kirioroshi* movement. PCA was used to reduce the multidimensionality of the parameter set prior to extracting feature parameters linked to the proficiency of the subjects. We then used cluster analysis to classify the proficiency of subjects using the feature values calculated by PCA.

RESULTS AND DISCUSSION :

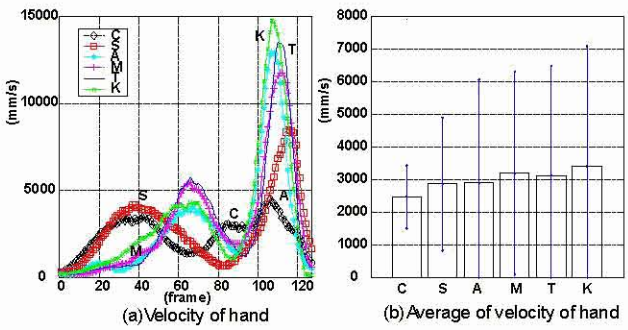
In this research, we quantitatively compared the proficiency of subjects by calculating feature parameters from motion data. In the following section, we will describe the result of our analysis of the *Kirioroshi* movement of *Roppon-me*.



(a) CG of x and z axis in body (b) Velocity of CG (c) Average of velocity of CG

Figure 2: Center of gravity during *Kirioroshi*.

Center of Gravity (CG): Firstly, we quantitatively analyzed the CG of the subjects doing Kirioroshi. The CG can be used to indicate the transfer and retainment of body movement. The position of the CG in each body segment can be calculated by using anthropometric data (segment weight and segment length) as proposed by Matsui [4]. Figure 2 (a), (b) and (c) indicate the transfer of CG of each subject, the velocity of CG and the average of velocity of CG, respectively. Skilled level subjects have more transfer of CG than that of the beginners C and S (see Figure 2 (a)). At the moment of the slash movement, skilled subjects have a velocity variation of CG of approximately 600 mm/s greater than that of beginners C and S (see Figure 2 (b) and (c)). Skilled level *Iaido* practitioners use the *Iaido* technique called *Jo-ha-kyu* while executing *Kirioroshi*. *Jo-ha-kyu* is characterized by a sense of rising motion; for instance, from a small slash to the larger slash. Beginners C and S have less transfer distance and CG velocity compared to the skilled subjects, because they did not use the *Iaido* technique of *Jo-ha-kyu* and their lack of *Kirioroshi* training with the



(a)Velocity of hand (b)Average of velocity of hand

Figure 3: Velocity of right hand during *Kirioroshi*.

Japanese sword. Therefore, we noticed that the parameter of velocity of CG can be used to classify the proficiency of an *Iaido* practitioner.

Velocity of hand: Secondly, we compared the velocity of the right hand of subjects when executing *Kirioroshi*. The right hand leads the slash while the left provides support of the Japanese sword. This method allows the tip of the sword to achieve maximum speed during the slash. In this experiment, we used a wooden sword of 500g to ensure the safety of the subjects. Figure 3 (a) and (b) indicate the velocity of right hand of each subject, and the average of velocity of the right hand, respectively. Skilled subjects have more velocity of the right hand than that of beginners C and S (see Figure 3 (a)). During the slash movement, the velocity variation of the CG of skilled subjects was approximately 5000~10000 mm/s greater than that of beginners C and S. Therefore, skilled subjects act quickly, i.e. about 3000mm/s, but beginners C and S act slower at about 2500 mm/s velocity (see Figure 3 (b)). The difference in velocity of the right hand of subjects is related to their career length and training time in *Iaido*. We noticed that the parameter for right hand velocity can also be used to classify the proficiency of an *Iaido* practitioner.

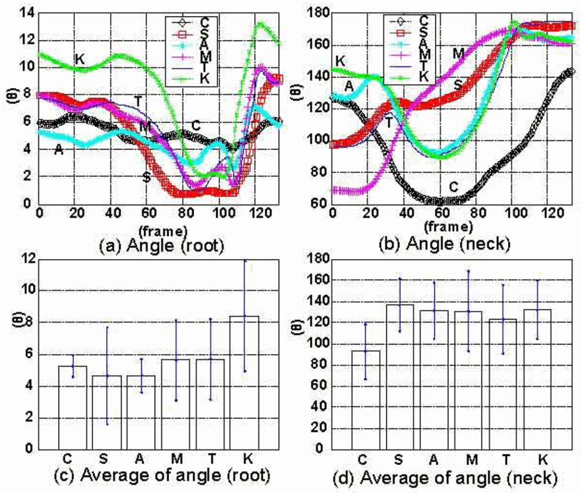


Figure 4: Angles of root and neck during *Kirioroshi*.

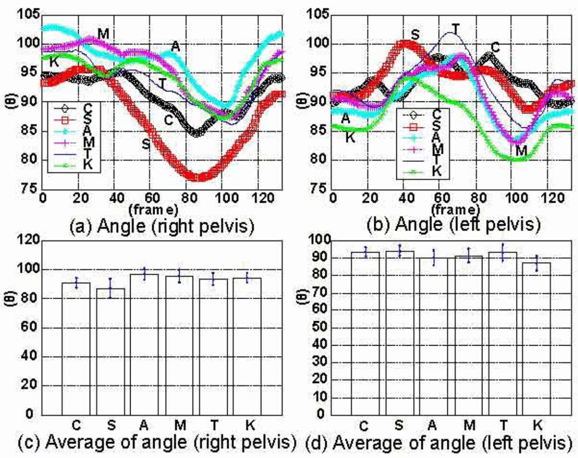


Figure 5: Angle of pelvis during Kirioroshi.

Angles of root and neck: Thirdly, we compared the angle variation of the root and neck of subjects while executing *Kirioroshi*. These angles are related to the stabilization of the upper half of the body. The difference in angle variation of the root in subjects was approximately 4~8° (see Figure 4(c)). Beginner C had less standard deviation than that of the other subjects due to the low velocity of the subject's CG and right hand (see Figure 4 (c)). As shown in Figure 4 (d), skilled subjects had a neck angle of approximately 130°, but the beginners C and S had 93° and 137° angle, respectively. We also noticed that beginners C and S had unstable angle variation compared to that of skilled subjects while executing *Kirioroshi*.

Angle of pelvis: Next, we compared the angle of the subject's pelvis during *Kirioroshi* execution. The angle of the pelvis is related to the stabilization of the lower half of the body on *Kirioroshi*. In particular, beginners C and S have instability of the right pelvis at the step of the right leg (see Figure 5 (a)). Beginners C and S have more angle variation of the pelvis than that of the skilled subjects (see Figure 5 (c) and (d)). Also, we noticed that the angle of pelvis parameter can be used to help classify the proficiency of *Iaido* practitioner.

PCA: Next, we used PCA to reduce the multidimensional parameter sets to a lower dimensionality for extracting the feature parameters for measuring proficiency. The parameters of Table 2 and the standard deviation of each parameter were used as sample data for PCA. The PCA scatter plot for each subject is illustrated in Figure 6. We have only plotted two PCA axes because the cumulative proportion of PC1 and PC2 is approximately 80% of the entire data set. PC1 has highly positively correlated to the standard deviation of velocity of CG and the standard deviation of velocity of the right hand. PC2 has highly positively correlated to the standard deviation of the angle of the right pelvis a nd the standard deviation of the angle of the root. PC1 is related to the velocity of the body during the slash movement, while PC2 is related to the stabilization of the body. Therefore, we can say that the proficiency of subjects can be classified by the velocity of transfer of the subject's CG and the stabilization of the angle of the subject's root and pelvis while performing *Kirioroshi*.

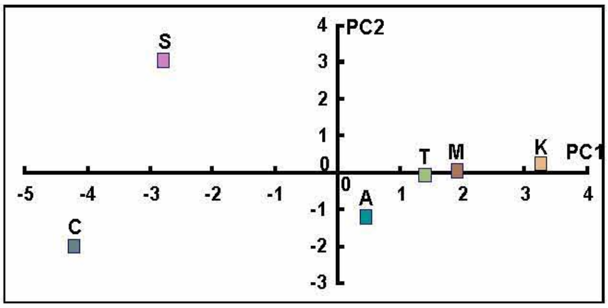


Figure 6: Results of PCA.

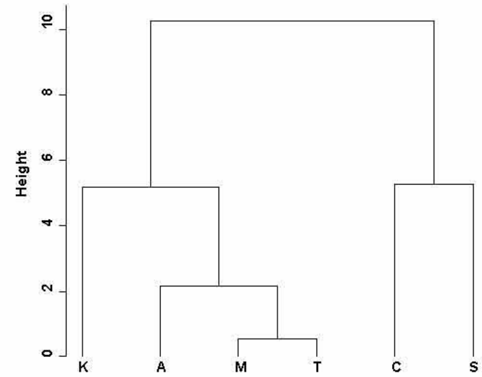


Figure 7: Results of cluster analysis

Cluster analysis: Finally, we used cluster analysis to classify subjects corresponding to the proficiency level by using the feature values of PC1 and PC2 calculated via PCA. The result of cluster analysis is illustrated in Figure 7. Subjects were classified into two groups. Beginners C and S belong to the second group and the skilled subjects to the first group. Also, the skilled subjects were further classified into career and grade groups. From the analysis results, we notice that the proficiency of an *Iaido* practitioner can be classified by using feature parameters of the velocity of body motion and the stabilization of the body while performing *Kirioroshi*.

CONCLUSION:

In this research, we carried out the quantitative analysis of *Iaido* proficiency by using motion data. As a result, we verified that a skilled subject has more velocity of CG and right hand movement and has a more stabilized body than th **Figure 7: Result of cluster analysis.** *Kirioroshi*. Therefore, we found that the feature values used in analysis of subjects can be used to classify the proficiency of an *Iaido* practitioner by using PCA and cluster analysis.

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