KINEMATICS OF *MEN* STRIKING MOTION IN *EIGHTH DAN* KENDO PLAYERS

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The purpose of this study was to explore the time series kinematic variations during the *men* striking motion in *eighth dan* kendo players. Moreover, the magnitude of the individual difference and timing at which it appeared were investigated. Ten *eighth dan* kendo players performed *men* striking towards one of two targets (*men* or *kote*) with maximum effort immediately after an LED lamp was lighted. The motions were recorded using a motion capture system. This study examined the time series kinematic variations during the *men* striking motion, and revealed that the movements of the *shinai* (sword), right and left shoulders, and right hip differed substantially among individuals from each standard deviation.

KEYWORDS: kendo, *eighth dan,* kinematics

INTRODUCTION: The objectives of practicing kendo are not only improving competitive ability, but also achieving superior kendo, such as promotion to a higher *dan* (qualification of rank). Kendo *dan* examinations are conducted from first *dan* to *eighth dan*. It is said that the kendo *dan* indicates the technical skill of the kendo (All Japan Kendo Federation, 2012). There is an age restriction for taking the *dan* examination; for example, kendo players who are 45 years of age or younger are not eligible to take the eighth *dan* examination. Thus, all kendo players with the eighth *dan* should be 46 years of age or older. All kendo players aim to achieve the *eighth dan*, which is the highest *dan*, while continuing kendo practice for a lifetime. However, passing the *eighth dan* examination is extremely difficult: only 19 players out of 3695 examinees passed the exam in 2019, meaning that the passing rate was 0.5%. Therefore, it is considered that players who have the *eighth dan*, are super experts with exceedingly high skills, even though their ages may be relatively high (often older than 46 years).
In previous biomechanical research, numerous discussions have been presented regarding the striking motion in kendo (Hamaguchi et al., 1977, Horiyama et al., 1977, Murase et al., 2017). However, these previous studies focused on college players or relatively young players. Few researches have investigated the striking motions of *eighth dan* kendo players.
The purpose of this study was to explore the time series changes in the body joints and *shinai* angles during the *men* (face) striking motion in *eighth dan* kendo players. Moreover, the magnitude and timing of the individual differences in the motion of the *shinai* and body joints were investigated. The results may provide very useful information for kendo coaches when instructing the *men* striking motion.

METHODS: Ten kendo players who had the *eighth dan* participated in this study (Age: 60.8 ± 4.9 years, body height: 1.73 ± 0.04 m, body weight: 77.8 ± 7.1 kg, experience: 50.5 ± 4.9 years). All the participants were male players because female players currently have no eighth *dan.* Prior to the experimental trials, participants were asked to engage in warm-up and practice striking the *men* and *kote* (forearm) with the *shinai* that they would use in the trials. The trials in this study were conducted using a similar procedure to that in Murase et al. (2017). Reflective markers were attached to 41 anatomical points of each participant's body and *shinai*. The targets (*men* and *kote*) were set 2.3 m in front of the participants, and LED lamps were attached to both targets and randomly lighted. The participants were instructed to strike the *men* or *kote* whose lamp lighted up as quickly as possible and with maximum effort. The motions of the participants striking the *men* or *kote* were recorded using a motion capture system with 12 cameras. The sampling frequency was set to 250 Hz. The analysis range of the striking motion was from the moment the body's center of gravity moved with a velocity of more than 0.1 m/s (motion start) to the moment at which the target was struck (target hit) (Fig. 1, left). A right-handed global coordinate system was established, in which the direction of

forward movement in relation to the strike target was defined as the Y-axis, the lateral direction was defined as the X-axis, and the vertical direction was defined as the Z-axis.
A rigid link segment model of the entire body was constructed using 14 body parts (head, trunk, left and right upper arms, forearms, hands, thighs, lower legs, and feet) (Fig. 1, left). The location of the body's center of gravity in the YZ plane was obtained using the body segment parameters of Ae et al. (1996).
The upper body, shoulder, elbow, wrist, hip, knee, ankle, and *shinai* angles were calculated according to the same methods as those of Murase et al. (2017), as illustrated Fig. 1 (right, θ1 to θ14).
In this study, we only focused on the *men* striking motions. These kinematic data were normalized using the time from the motion start (0%) to target hit (100%). The average and standard deviation (SD) values were obtained for each 1% of time for the angles of the *shinai* and body joints. The changes in the average value of each angle were considered to represent the standard motion of the *men* striking of *eighth dan* kendo experts, while the SD values represented the variations among them.

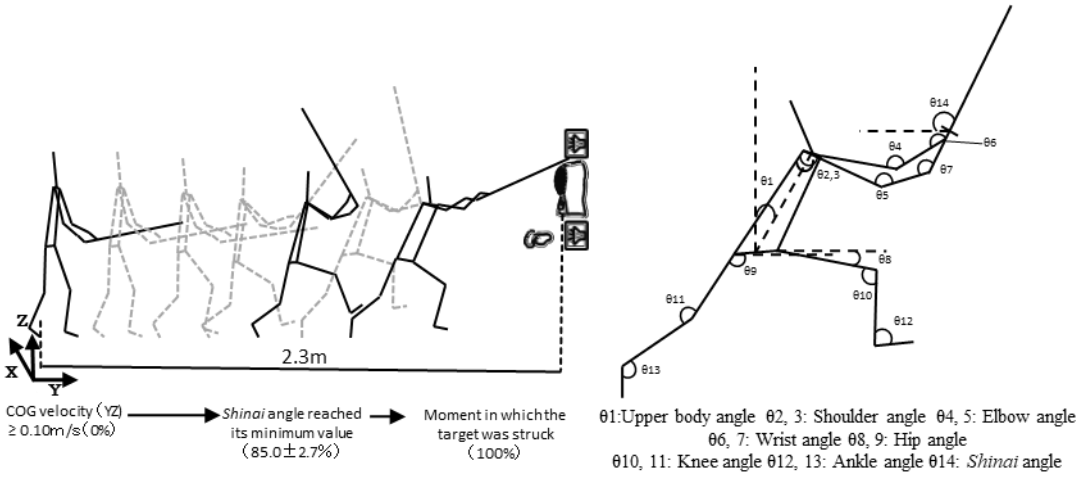

Fig. 1 Experiment setup, definitions of global coordinates system and range of analysis (left), and definition of the joint and *shinai* angles (right).

RESULTS: Figure 2 illustrates the time series changes in the average angles of the joints and *shinai* with ±1 SD variations of the 10 *eighth dan* kendo players during the *men* striking motion in normalized time. Regarding the extreme upper angles, the SD values of the left and right shoulder angles were substantially larger than those of the other joint angles from the normalized time of 50% to 95%. For the extreme lower angles, the SD of the right hip angle was substantially larger than those of the other joint angles from the motion start to *men* striking. The SD values of the other joints angles were relatively small compared to the left and right shoulder and right hip angles from the motion start to *men* striking. The SD of the *shinai* angle tended to be small from the normalized time of 0% to approximately 50%, drastically increased until approximately 80%, and then decreased until *men* striking.

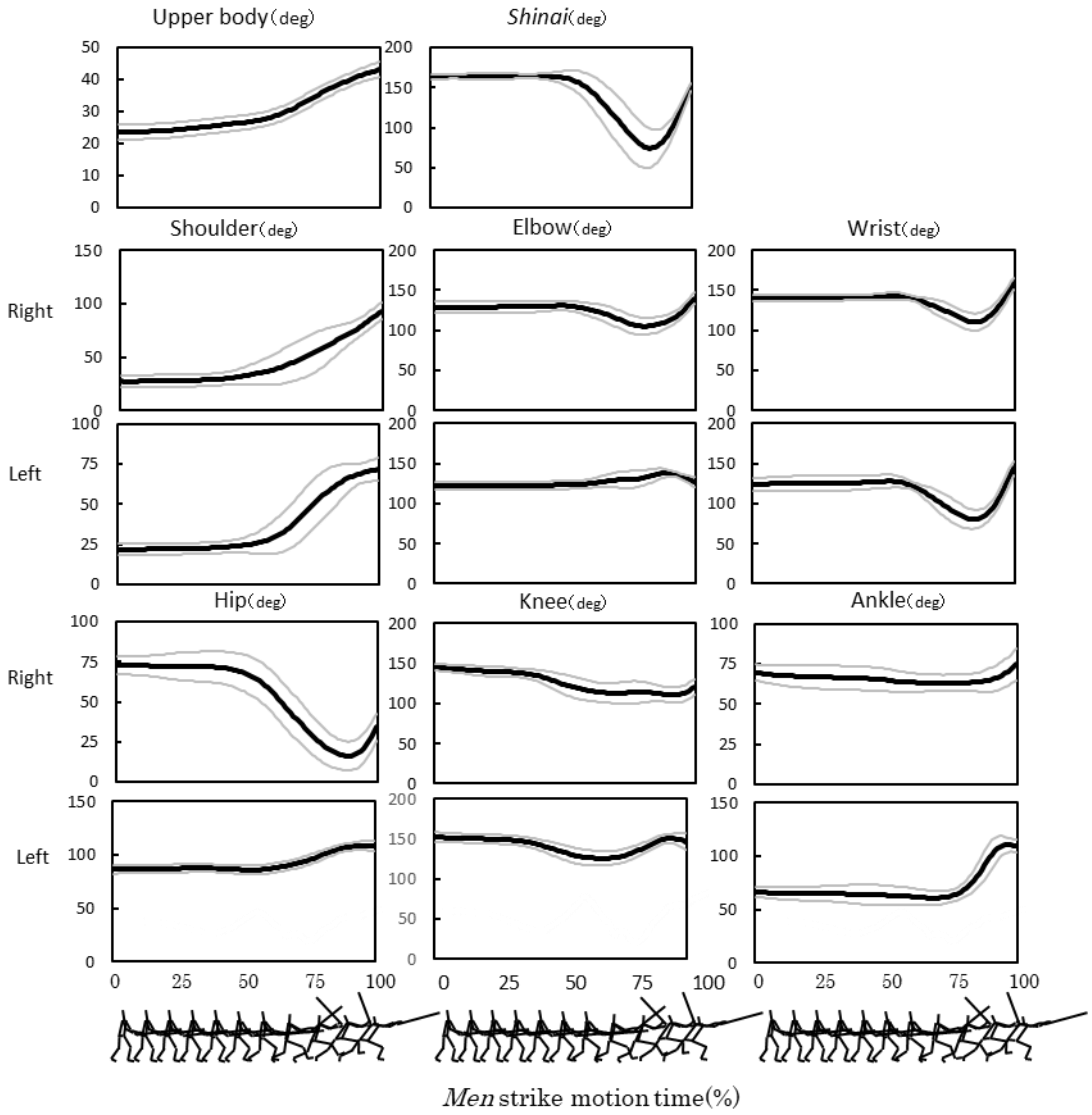

Fig. 2 Time normalized and averaged patterns of joint and *shinai* angles in 2-D plane in *men* strike motion.

DISCUSSION: The variation in the inter-individual movements could be expressed by the magnitude of the SDs. Ae and Kobayashi (2011) stated that the joints or phases for which the magnitude of the SDs is small are important, because this means that their motions are similar to one another among the groups. However, the joints and phases for which the magnitude of the SDs is large are not essentially important because this means that their motions are diverse with certain individual differences. This study explored the time series variations in the average joint and *shinai* angles during the *men* striking motion in 10 *eighth dan* kendo players.

The movements of the joints for which that the magnitude of the SD was small, namely the angles of the upper body, left and right elbows, left and right wrists, left hip, left and right knees, and left and right ankle, were common in the *eighth dan* kendo players, and are therefore considered as very important.

Few studies have reported on the time series variations of the average body joints and *shinai* angles during the *men* striking motion of *eighth dan* kendo players. Therefore, the results of this study may provide very useful information for kendo coaches to instruct *men* striking motions. It will be important to compare the striking motion between eighth dan players and other. We hope that all kendo players who want to be skillful will utilize the results of this study. In our future studies, we will reveal the characteristics of the motion in lower *dan* kendo players

and compare them with the results of this study. By doing so, it is possible to determine the key factors for improving motion-striking skills in kendo.

CONCLUSION: This study aimed to investigate the time series kinematics during the *men* striking motion in *eighth dan* kendo players, and their average and SD values. The *men* strike motions of ten *eighth dan* kendo players were recorded using a motion capture system. It was revealed that the parts in which the SD was large; that is, parts exhibiting large individual differences, were the angles of the left and right shoulders, right hip, and *shinai*. Moreover, the timing at which these individual differences appeared was from the moment at which the *shinai* was swing up to striking the *men*. For the angles of the upper body, left and right elbows, left and right wrists, left hip, left and right knees, and left and right ankles, the SDs were relatively small. Therefore, the motions of these parts were common among the *eighth dan* kendo players and are therefore considered as essentially important in the *men* striking motion in kendo.

REFERENCES

Ae, M.: Nihonjin yousyounen oyobi asurito no shintaibubunkeisu【Body Part Coefficient in Japanese Athletes】. Japanese Journal of Sports Science 15: 155-162, 1996 (in Japanese)

Ae, M., and Kobayashi I.: Dousabunseki kara dousa no kyoutusei to kosei wo kangaeru【Consideration of Individuality and Commonality from Motion Analysis】. Japanese journal of biomechanics in sports & exercise 15:88-95, 2011 (in Japanese)

Hamaguchi, M., Fukunaga, T., Hayashi, K., and Horiyama, K.: Kendo dagekidousaji no te, hiji, katakansetu kakudohenka no bunseki【Analysis of Hand, Elbow, and Shoulder angles in Striking Motion in Kendo】. Research Journal of Budo 10 (2) 43-45, 1977 (in Japanese)

Horiyama, K., Fukunaga, T., Hayashi, K., and Hamaguchi, M.: Kendo dagekidousaji no asi, hiza, kokansetu kakudohenka no bunseki【Analysis of Foot, Knee, and Hip angles in Striking Motion in Kendo 】. Research Journal of Budo 10 (2) 40-42, 1977 (in Japanese)

Murase N, Horiuchi G, Sumi K, Horiyama K, Sakurai S.: Biomechanical factors to shorten the movement time of men striking motion in kendo. International Journal of Sport and Health Science 15: 36-45, 2017

All Japan Kendo Federation.: Kendo, Iaido, Jyoudo Syougo, *dan*, kyu Sinsa kisoku【Guidebook about examination of *Dan*, Kyu (qualification of rank) and title in Kendo, Iaido and Jyoudo】. 11, 2012 (in Japanese)

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