

## THREE-DIMENSIONAL MOTION ANALYSIS OF THE “TENKAN”-TECHNIQUE IN AIKIDO

Kazutoshi KIKKAWA<sup>1</sup>, Hidetaka OKADA<sup>1</sup>, and Hikaru  
KURATOMI<sup>1</sup> The University of Electro-Communications,  
Tokyo, JAPAN<sup>1</sup>

Aikido is a Japanese martial art established by Morihei Ueshiba (1883-1969). A major characteristic is that there are neither competitions nor is there practice in form of competition. Generally, practice involves an instructor demonstrating a technique, after which it is practiced in pairs. The present study therefore sought to perform a three-dimensional analysis of the "Tenkan" a typical aikido technique, and to clarify the differences and factors related to the techniques for experts, intermediates, and beginners. We discussed the difference of deviation of the center of mass and evaluation of the ground reaction forces.

### INTRODUCTION:

Ueshiba (2005) described as follows: "Tenkan" is the using the front foot as a pivot point and turns 180 degrees to one's rare. In Tenkan, one keeps the knees flexible, and the body stable. Furthermore, it is emphasized that after turn, the performer who is called as "Tori" finishes in a well-balanced stance. In this research, we present the motion analysis for Aikido's "Tenkan", a technique which is used to deflect the attack of an opponent, and discuss its difference according to level of development of aikido skill.

### METHODS:

The participants consisted of 14 healthy males with various degrees of experience, ranging from beginners (4 of them, with less than 120 training days), intermediates (5 of them, between 120 to 300 days) and experts (5 of them, more than 1500 days). The "Tenkan" technique was performed individually and three-dimensional motion analysis as well as measurement of the ground reaction forces were done.

#### 1. Experiment

Fig.-1 shows a serial pictures of "Tenkan" motion. "Tenkan" was performed twice for each left and right "Hanmi" (half-body stance), four times in total. The position of 53 reflective markers were captured with 11 infrared



Fig.1: Serial photo of Tenkan

cameras with a optical motion capture system (Optitrack S250e, Natural Point Inc.) at 200 Hz., and the ground reaction forces were measured with a force platform (9287B, Kistler Inc.) at 1000 Hz.

## 2. Data analysis procedure

(1) Experimental approach and classification: “Tenkan” starts in a half-body (Hanmi) stance with one foot forward and ends in a backward turn, where the forward foot is used as pivot point. While in Aikido-training, the left and right variant of “Tenkan” are performed together, in this research both of them were performed and analyzed separately. As x-axis, the mediolateral direction was used, as y-axis the anterior-posterior direction and as z-axis the vertical. The moment when the velocity of the heel of the turning foot in the xz-plane exceeded 0.2 m/s was defined as the start of the “Tenkan”. The moment when the opposite leg (Swing Leg, SWL) reached the minimal velocity after touch down was defined as the end of the “Tenkan”. Furthermore, the instant when the SWL took off the ground was defined as SWL\_off. The time from the start to the end of the motion was then normalized from 0 to 100 [%].

(2) Data analysis: The data were smoothed with the 4<sup>th</sup> order Butterworth digital filter in the range of 8-18 Hz of cut-off frequency. The smoothed data were processed with motion analysis software (Visual3D, C-motion Inc.) and the center of mass of the performer and the kinematics of the lower limbs were calculated. As the same time, the factors of ground reaction force acting on the turning leg (the three components of GRF, the center of pressure, and the free moment of z-axis) were calculated. To examine the differences among the three groups of experts, intermediates, and beginners, one-way analysis of variance (ANOVA) was performed. Subsequently, Bonferroni’s multiple comparison test as post hoc method was applied after observing the significant difference in ANOVA.

## RESULTS AND DISCUSSION:

**1. Center of Mass:** Figure 2 shows the average of the vertical displacement of the center of mass (solid line) and the standard deviation (dotted line) for each group. The amplitude is normalized with the standing height of the subject and the initial position is set as zero. The lines depicted at the upper part of Fig.-2 shows the significant differences between the

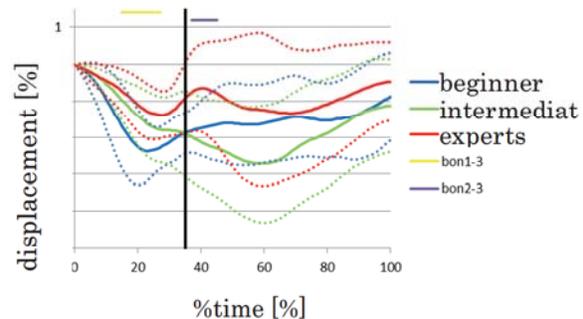


Figure 2 Vertical displacement of the center of mass

beginners and the intermediates (bon1-2), as well as for beginners and the experts (bon1-3), and the intermediates and the experts (bon2-3). The descent of the center of mass before the turning motion (marked with the vertical black line, SWL\_off) were an average of  $2.76 \pm 1.00$  [%] for beginners,  $2.07 \pm 1.07$  [%] for the intermediates and  $1.80 \pm 0.74$  [%] for experts. The motion amplitude of experts was significantly smaller than for beginners. In other words, experts avoided the larger descent of their center of mass during the initiation of the turning motion.

## 2. Evaluation of the center of pressure

The center of pressure of ground reaction force (COP) were converted to the sole coordinate system and the coordinates were normalized by the foot length of the subject. The maximal range of COP in the x-direction for beginners was  $33.27 \pm 11.22$  [%], for intermediates  $34.24 \pm 5.81$  [%], and for experts  $25.61 \pm 7.36$  [%], respectively. The maximal range of COP in y-direction for beginners was  $77.19 \pm 24.96$  [%], for intermediates  $65.16 \pm 21.32$  [%], and for experts  $62.46 \pm 13.25$  [%], respectively. For experts, the smaller variation of COP both in x- and y-direction indicates that they can turn with a smaller range of COP in the sole to perform the turning motion. Figure 3 and Figure 4 show the ankle joint angle of the turning foot of the x-axis (plantar flexion - dorsiflexion) and the z-axis (pronation - supination), which seem to link to the COP variation. The expert group showed the minimal angle variation. It means the joint remains fixed. In addition, the experts seem to turn with the smaller change of the COP with the ankle comparatively fixed.

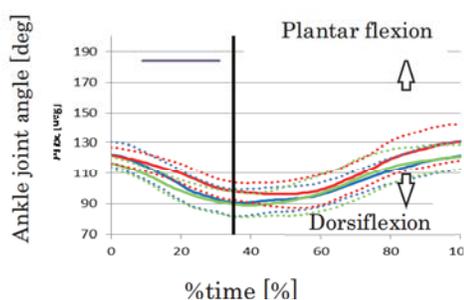


Figure 3 Ankle joint angle about x axis (Plantar flexion - Dorsiflexion)

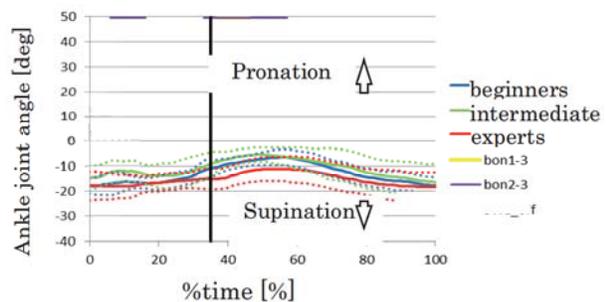


Figure 4 Ankle joint angle about z axis (Pronation - Supination)

## Conclusion:

For the “Tenkan”-technique, experts initiated the backward turn with a minimal lowering of their body’s center of mass and turned under a smaller range of the COP in their sole with fixed ankle joint.

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