KINEMATICS OF JUDO BREAKFALL FOR OSOTO-GARI

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The purpose of this study was to identify kinematic parameters of breakfall for osoto-gari that can be distinguished between the experienced and the novice judokas. Eight experienced and four novice judukas volunteered to participate in the study. The motion data of the breakfall for osoto-gari were collected with a three-dimensional motion analysis technique. Our result demonstrated that there are significant differences in the hip movement pattern between the experienced and the novice judokas ($p<0.05$). In addition, the angle-time pattern of neck was also statistically different between the two groups; however, the difference of the angle pattern of the neck was not as meaningful as that of the hip. Our result suggests that judo coaches need to focus more on having novice judokas maintain the posture so that they will improve the breakfall skill effectively.

KEY WORDS: Martial arts, head injury, motion analysis

INTRODUCTION: Head injuries sustained during the sport of judo have gained significant public attention because of the incidence of severe cases among novice judokas in Japan[1]. It has been reported that 30 to 50% of the traumatic head injuries occurred when they were thrown backward with such technique as Osoto-gari (Figure1). In addition, the number of the head injury occurrence is relatively higher in novice judokas or judokas who had recently started practicing judo with opponents at a higher level. When judokas are thrown by an opponent, they apply a breakfall technique to avoid being injured. Therefore, it is reasonable to hypothesise that the skill level of the judo breakfall may be useful in identifying judokas at a high risk of head injury and that improvement of the skills for a breakfall will decrease the number of head injuries sustained during judo.

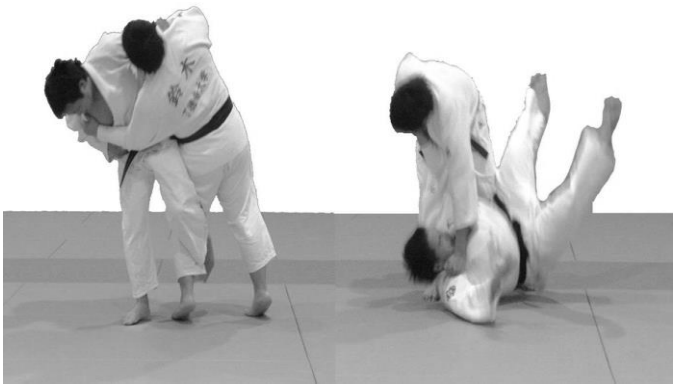

Figure 1: Breakfall technique for Osoto-gari

The importance of the breakfall skill to ensure the safety for judokas has been stated in many texts, and it is crucial especially for novice judokas to acquire an appropriate breakfall skill. On the other hand, its kinematics has not been well documented. By identifying the kinematic characteristics that can be distinguished between experienced and novice judokas, coaches could advance an effective injury prevention plan. Therefore, we aimed to investigate kinematics of the neck, trunk, hip and knee during the judo breakfall movement in response to osoto-gari and compare the biomechanical variables between experienced and novice judokas.

METHODS: We recruited eight experienced and four novice male judokas from the university for this study. The group of the novice judokas had no experience of either competitive or recreational judo except in physical education class, and all had had at least ten 90- minute

sessions of the judo class offered by the university. The group of the experienced judokas had enrolled in the university's judo team and had at least five years of competitive judo experience by the time of the experiment. The mean (range) age 19.9 (18.0 – 22.0) years, height 167.9 (158.6 – 183.8) cm, weight 70.1 (56.6 – 84.7) kg, years of judo experience 11.1 (7.0 – 18.0) years. in the experienced group, and 21.3 (21.0 – 22.0) years, 173.6 (169.0 – 180.0) cm, 71.3 (62.0 – 81.9) kg in the novice group. After notifying all the participants of the purpose and the risk of the experiment, we received written consent forms of the attendance from them. The study protocol was approved by the Ethics committee of the Faculty of Health Sciences, Ryotokuji University.

The experimental protocol included three sets of breakfall in response to being thrown with osoto-gari onto the matt by one tester (the thrower) who had over 20 years' experience in Judo (with a 3rd degree blackbelt). The thrower had a left-handed style; therefore, the left lower extremity of the partiipants was always swept when they were thrown with osoto-gari.

We attached 41 reflective markers (diameter: 1.9 cm) on the landmarks of the participants as shown in Figure 2. The participants were also asked to wear judo clothes designed to improve the visibility of the attached markers[3] as well as a headgear to ensure safety during the measurement (Figure 2).

Three-dimensional (3D) marker trajectory data (200 Hz) were obtained with a 20-camera Mac3D motion analysis system (Motion Analysis Corp., Santa Rosa, CA, USA). The marker trajectory data were then low-pass filtered through a Butterworth digital filter at a 6-Hz cutoff frequency. Neck, trunk, right/left hip, and right/left knee joint angles in the sagittal (z-x) plane were calculated as defined in Figure3. We analyzed the breakfall motion from the time when the thrower's leg first touched the participant to the time when the head of the paritipant was at the lowest position in the vertical axis. The kinematic data were then normalized into 100 % to facilitate the group comparison.

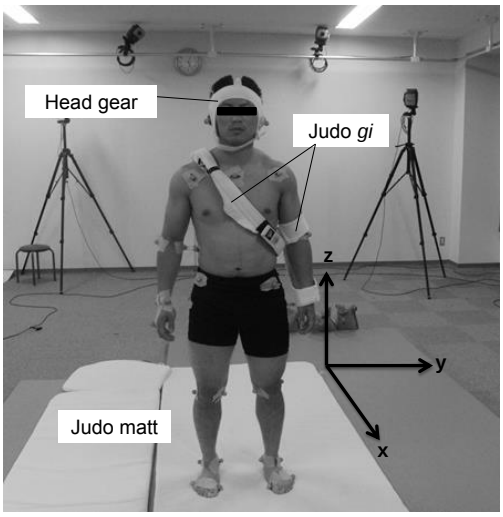

Figure2: Experimental set up

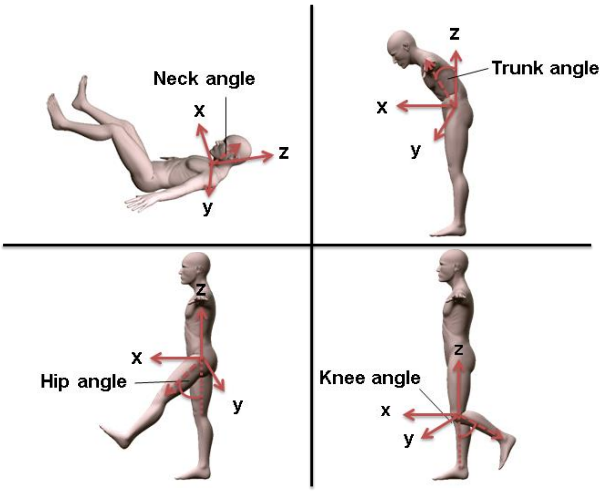

Figure3: Definition of the angle calculation

All statistical analyses were performed with the Microsoft Office Excel 2010 (Microsoft Japan Co., Ltd, Tokyo, Japan) and a free statistical software R. For kinematic comparisons, we performed linear regression analysis for joint-angle curves of the neck, trunk, hip and knee in each group. We then tested the homogeneity of the regression lines between the two groups. If homogeneity was rejected, it meant that the trends of two regression lines were not statistically the same. When homogeneity was confirmed, we performed analysis of covariance (ANCOVA) to compare differences in the angle–time plots between the experienced and the novice judokas. The effect size was also calculated by using a correlation ratio (η^2).

RESULTS: The mean [standard deviation] angle curves of the neck, trunk, hip and knee flexion during the breakfall in both groups are shown in Figure 4. There were significant linear relationships in all but right knee angle-time lines. Regression formulae for the neck, trunk, right hip, left hip and left knee angle–time plots in the experienced group were $y = 0.1489x + 3.9207$, $y = 0.3678x - 14.850$, $y = 0.6007x - 6.7$, $y = -0.3809x + 4.0014$, and $y = -0.3770x + 47.39$, respectively, while those for the novice group were $y = 0.2011x - 2.7837$, $y = 0.3799x - 9.4397$, $y = 0.7008x - 2.8164$, $y = 0.7660x - 3.1498$, and $y = 0.2778x - 50.005$, respectively. The homogeneities of the regression line in the neck, both hips, and both knees were not confirmed between the experienced and the novice judokas (neck, $F = 7.690$, $df_1 = 1$, $df_2 = 1208$, $p = 0.01$, $\eta^2 = 0.006$; right hip: $F = 9.68$, $df_1 = 1$, $df_2 = 1208$, $p < 0.01$, $\eta^2 = 0.008$; left hip, $F = 135.81$, $df_1 = 1$, $df_2 = 1208$, $p < 0.001$, $\eta^2 = 0.101$; left knee, $F = 7.099$, $df_1 = 1$, $df_2 = 1208$, $p < 0.01$, $\eta^2 = 0.006$). In contrast, the homogeneities of the regression lines were confirmed in the trunk slopes between the novice and experienced judokas (trunk: $F = 0.5840$, $df_1 = 1$, $df_2 = 1208$, $p = 0.445$). The result of ANCOVA for trunk data revealed significant differences in the adjusted mean values of the trunk ($F = 170.99$, $df_1 = 1$, $df_2 = 1209$, $p < 0.001$, $\eta^2 = 0.12$) between the two groups.

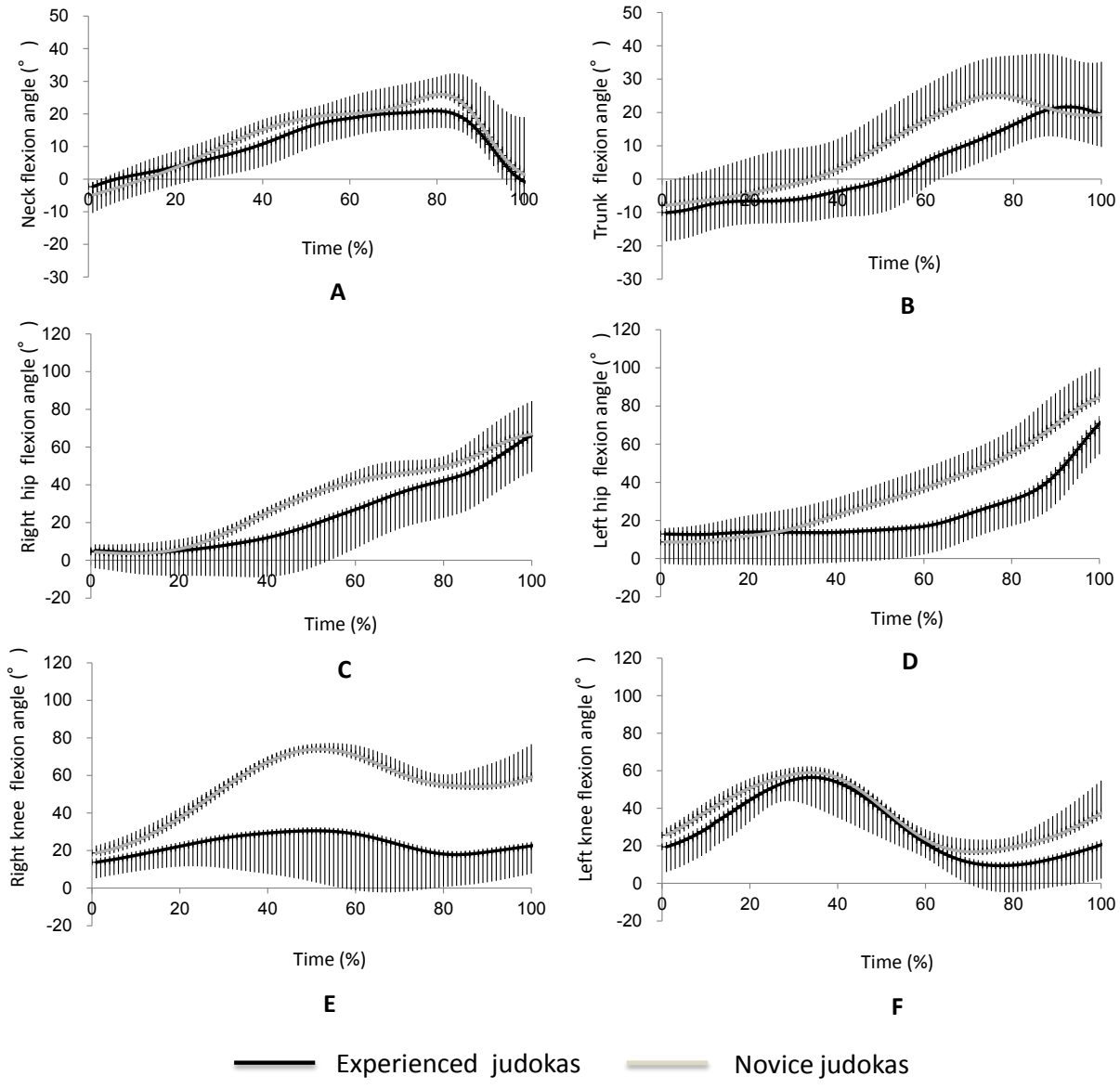

Figure 4: Mean (SD) angle-time curves of head (A), trunk(B), right hip (C), left hip (D), right knee (E), left knee (F) during the breakfall motion for osoto-gari

DISCUSSION: Our result demonstrated that we may be able to differentiate the skill level of judo breakfall for osoto-gari with hip and trunk movements. The result of homogeneity analysis of hip angle-time lines demonstrated that there were significant differences in the trend of hip joint angle-time slopes between the two groups. Especially, the large effect size indicates there seemed a meaningful difference in the left hip movement pattern. According to the qualitative observation of the angle–time curves, the left hip angles started flexing around 20 % of the phase and kept increasing the flexion angles from about 60°to 80°in the novice group, whereas the hip angles remained slightly flexed until approximately 60 % of the movement in the experienced judokas. In addition, greater trunk flexion angle was shown during the breakfall motion in the novice judokas than in the experienced judokas.

These results suggest that maintaining their body in more straight position especially during an early phase of the motion may result from high skilled breakfall. We speculate that the straight body position observed in the experienced judokas may have lengthened the distance of the moment arm and have contributed to better control of the angular velocity in back rotation around the center of mass. We will investigate the relationships between the angular velocity of body rotation and kinematics during the breakfall motion in our future study.

It is worth mentioning that regression analysis showed the significant linear relationships in the left knee angle-time line in the novice judokas, but not in the experienced judokas. Therefore, we did not perform the homogeneity analysis of the regression lines of left knee joint angle-time curve. However, the mean angle curves of the left knee showed an obvious difference between the two groups, and the experienced judokas showed a more extended knee position during the breakfall motion. Yabune et al (2011)[2] reported based on the qualitative analysis that the skilled breakfall for seoi-nage may be characterized by an extended knee position at the contact onto the matt. Although further analyses are required, we believe that the extended knee position during the breakfall might also be an important component of kinematic variables to differentiate the skill level of judo breakfall for osoto-gari.

Finally, we showed that the neck movement pattern was significantly different between the experienced and the novice groups. However, the interpretation of the result warrants careful consideration because of the small effect size. In both groups, the neck flexion angle patterns are similar; and the neck flexion angle increased until approximately 15°to 20° and decreased abruptly the last phase of the motion probably due to the impact of the body contact to the matt. Although the pattern was statistically significant, it seems that the difference was less meaningful.

In the instruction of how to do judo breakfall, neck and trunk flexion movements have attracted attention. However, our result suggests that we may not be able to differentiate experienced and novice judokas with neck movement during breakfall for osoto-gari. In addition, the flexed trunk position may characterize the breakfall kinematics in novice judokas. Therefore, to effectively teach the breakfall, we probably need to more emphasize maintaining straight posture in the motion.

CONCLUSION: We found significant differences in hip movement patterns between novice and experienced judokas. In addition, neck movement patterns and trunk angle–time plots were also significantly different; however, there were only small effect sizes.

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