# BIOMECHANICS OF JUDO BREAKFALL FOR OSOTO-GARI IN ADOLSECENT JUDOKAS

**Sentaro Koshida[1], Takanori Ishii[2], Tadamitsu Matsuda[3], and Toshihiko Hashimoto[1]**

**Faculty of Health Sciences, Ryotokuji University, Urayasu, Japan[1]**
**Doctoral Program in Physical Education, Health and Sport Sciences, University of Tsukuba, Tsukuba, Japan[2]**
**Faculty of Health Science, Uekusa-Gakuen University, Chiba, Japan[3]**

Regardless of relatively higher head injury occurrence, few studies have investigated the biomechanics of a judo breakfall technique in adolescent judokas. The aim of the present study was to demonstrate biomechanical characteristics of the breakfall technique performed by experienced adolescent judokas during the “osoto-gari” throw by comparing it with those performed by experienced adult and novice adult judokas. Motion data from the breakfall technique were collected with a three-dimensional motion analysis method. No significant differences were observed in the hip and neck movement patterns between the novice and the adolescent judokas ($p > 0.05$), but not between the experienced adult and adolescent judokas.  This suggests that regardless of experience, the breakfall skill level of the adolescent judokas is not similar to that of adult experienced judokas.

**KEY WORDS:** martial arts, head injury, motion analysis

**INTRODUCTION:** Head injuries sustained during judo have gained significant public attention in Japan because of the incidence of severe head injuries suffered by adolescent judokas. Even minor traumatic head injuries may lead to serious consequences in the young; therefore, effective injury prevention plans are required. It has been reported that 30%–50% of traumatic head injuries in judo occurred when a judoka was thrown backward, in techniques such as the osoto-gari (Kamitani et al, 2013). When thrown by an opponent, a judoka applies a judo breakfall to prevent injury. Therefore, judokas must master an appropriate backward breakfall technique, and an effective method for teaching breakfall technique may play an important role in preventing head injuries.
Koshida et al. (2014a) demonstrated that the pattern of hip movement during the backward breakfall for osoto-gari significantly differed between experienced and novice adult judokas. In addition, a greater trunk flexion angle was seen in novice judokas as compared with the experienced judokas. These results suggest that skilled judokas tend to maintain an upright posture during the early phase of the breakfall movement, but novice judokas do not. In addition to skill level, younger judokas may demonstrate a specific biomechanics in backward breakfall because of different physical characteristics; however, such biomechanical parameters have not been well documented. Identifying the biomechanical differences in the backward breakfall movement adopted by adolescent and adult judokas could lead to the development of a better backward breakfall teaching strategy. The objective of the present study was to investigate the biomechanics of the backward breakfall for osoto-gari performed by experienced adolescent judokas versus that performed by adult judokas of different skill levels.

**METHODS:** We recruited five adolescent male judokas from local judo teams for this study. At the time of the study, each young judoka had at least four years of competitive judo experience. The median (range) for the relevant parameters were as follows: age, 19.9 (14.0–16.0) years; height, 166.9 (159.2–168.5) cm; weight, 57.3 (48.3–63.1) kg; judo experience, 7 (4.0–9.0) years. For comparison, we used the data sets of the mean angle data of the backward breakfall movement from eight experienced and four novice judokas reported by Koshida et al. (2014a). We obtained written informed consent forms for the young judokas’ participation from their parents or legal guardians. The study protocol was approved by the Ethics Committee of the Faculty of Health Sciences, Ryotokuji University.

The test protocol included three sets of backward breakfall performed in response to osoto-gari throws by one tester (the thrower), a 3rd-degree-black belt judoka with over 20 years' experience. The thrower had a left-handed style; therefore, the left lower extremity of the participants was always swept first from the osoto-gari move.
We attached 41 reflective markers (diameter, 1.9 cm) on the landmarks of the participants as shown in Figure 1. The participants were instructed to wear judo clothes designed to improve the visibility of the attached markers[2] and protective headgear to ensure safety during the measurement.
Three-dimensional 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 cut-off frequency. Neck, trunk, right/left hip, and right/left knee joint angles in the sagittal ($z$–$x$) plane were calculated, as defined in Figure 2. We analyzed the backward breakfall movement from the time when the thrower's leg first touched the participant to the time when the head of the participant was at the lowest position in the vertical axis. The kinematic data were then normalized to 100% to facilitate intergroup comparison. The peak head moment data were also calculated to evaluate the stress applied to the neck-head segments.

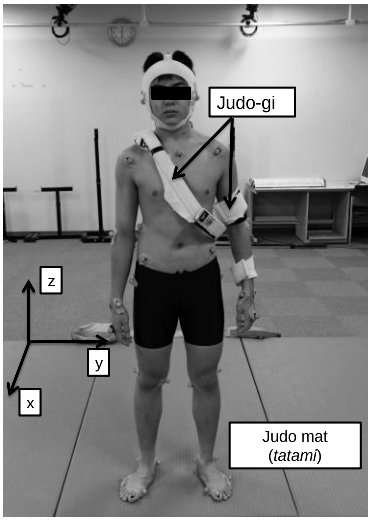


**Figure 1: Experimental set up.**

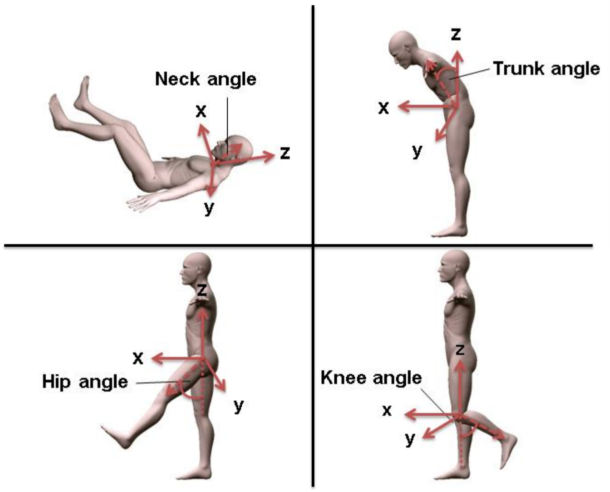


**Figure 2: Definition of the angle calculation.**

All statistical analyses were performed with R, a free statistical software package (http://www.gnu.org/). 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 indicated that the trends of two regression lines were not statistically equivalent. When homogeneity was confirmed, we performed analysis of covariance 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 ($\eta^2$). In addition, a Kruskal–Wallis test was performed to compare peak head moments in three planes during the backward breakfall among the three groups. Statistical significance was set at $p < 0.05$ in this study.

**RESULTS:** The mean (standard deviation) angle curves of the neck, hip, and knee flexion during the backward breakfall in both groups are shown in Figure 3. Significant linear relationships were observed in all but the right knee angle-time lines in the group of the experienced judokas. Regression formulae for the neck, right hip, left hip, and left knee angle–time plots in the adolescent group were $y = 0.2195x + 7.331$, $y = 0.6257x - 10.515$, $y = 0.7747x - 2.0590$, $y = 0.600x + 21.959$, and $y = -0.2704\mathrm{x} + 39.498$. The homogeneities of the regression line in the neck and both hips were confirmed between the adolescent and novice judokas (neck: $F = 0.517$, $df_1 = 1$, $df_2 = 905$, 1 $p = 0.472$; right hip: $F = 3.428$, $df_1 = 1$,

$df_2$ = 905, $p$ = 0.064; left hip, $F$ = 0.019, $df_1$ = 1, $df_2$ = 905, $p$ = 0.889). In contrast, the homogeneities of the regression lines were not confirmed in any angles between the adolescent and experienced judokas. Because we encountered difficulty in tracking the rib markers in one participant, we were not able to calculate the mean trunk angle for this study.
Table 1 shows the median peak (range) head moment in the sagittal, frontal, and horizontal plane. No significant differences were seen in peak head moments in any motion plane among the adolescent, experienced, and novice judokas ($\chi^2$ = 2.167, $df$ = 2, $p$ = 0.339)

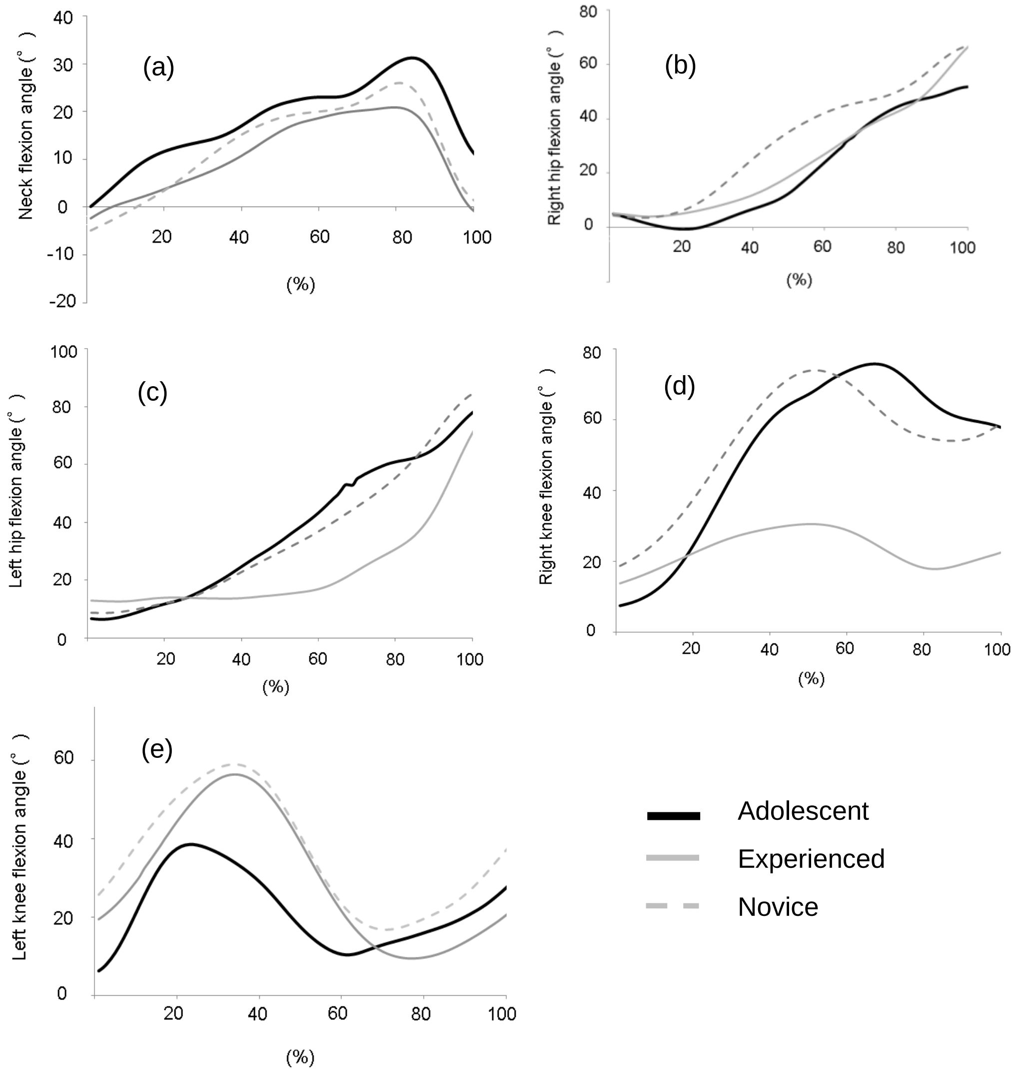


**Figure 3: Angle–time curves in the neck(a), the right (b), and left (c) hip and the right (d) and left (e) knee in the adolescent (N = 5), experienced (N = 8), and novice judokas (N = 4).**

**DISCUSSION:** The present study demonstrates that the hip movement on the side where the judoka is swept by a thrower is very similar between novice and adolescent judokas with several years of judo experience during the backward breakfall for osoto-gari. Analysis of covariance revealed no significant differences in the left hip joint angle between the adolescent and novice judokas. In contrast, a significant difference was seen between the adolescent and experienced judokas. According to the qualitative observation of the angle–time curves, the mean left hip angles started flexing at approximately the time when 20% of the phase and kept increasing the flexion angles from about 60°to 80°in the both adolescent and novice groups, whereas the hip angles remained slightly flexed until approximately 60 % of the phase in the experienced judokas. These results suggest that even if some adolescent judokas have years of judo experience, the kinematics of breakfall for osoto-gari in the adolescents may be more similar to that of novice judokas than to that of experienced judokas

**Table 1**
**The peak moments of the head segment in sagittal, frontal, and horizontal planes in the adolescent (N = 5), experienced (N = 8), and novice judokas (N = 4)**
**The absolute values are shown in the table.**

Median (range)

| | | Adolescent | Experienced | Novice |
|---|---|---|---|---|
| Sagittal plane | (Nm) | 17.0 ( 7.0 – 19.3) | 20.3 (12.0 – 29.1) | 25.9 (16.3 – 33.0) |
| Frontal plane | (Nm) | 9.5 ( 6.2 – 15.1) | 12.3 ( 9.0 – 32.7) | 12.3 ( 5.5 – 21.0) |
| Horizontal plane | (Nm) | 6.7 ( 2.2 – 9.2) | 6.2 ( 2.6 – 11.6) | 13.6 ( 1.6 – 16.3) |

We also demonstrated no significant differences in the neck flexion pattern between the adolescent and novice groups. Moreover, although there was a marked difference in the trend of the neck angle–time curves between the experienced and novice judokas, it seems that the difference may not be significant because of the small effect size. In all three groups, the mean angle of the neck flexion increased from the beginning until approximately 15°–20° and decreased abruptly in the last phase of the motion. Because judo coaches usually instruct students to pay great attention to the neck flexion during the backward breakfall, the neck flexion pattern in the sagittal plane may not affect its kinematics, indicating that sagittal plane neck kinematics during the breakfall motion may not be a good biomechanical parameter for evaluating the skill level of the backward breakfall for osoto-gari. The neck kinematics in novice adolescent judokas needs to be investigated to verify this speculation.
The results of the peak head moment demonstrated that no significant differences exist in any motion plane among the three groups. There may be a tendency toward greater peak head moment in the sagittal plane in the novice judokas as compared with the other groups. However, the interpretation of this result warrants careful consideration, because individual variation may have affected the results. Further research is needed to elucidate the relationships between the peak head moment and the breakfall biomechanics.
Koshida et al. (2014b) demonstrated a significant difference in the biomechanics for osoto-gari between experienced and novice judokas, but not for ouchi-gari, another technique for throwing an opponent backward. The previous and current results suggest that it is important for coaches to recognize that the backward breakfall technique for osoto-gari may be remarkably difficult for adolescent judokas to learn.

**CONCLUSION:** We found a more similar pattern in the hip movements during the osoto-gari breakfall between the adolescent and novice judokas than between the adolescent and experienced judokas. In addition, the peak head moments imposed during the backward breakfall did not differ between the groups.

**REFERENCES:**
Kamitani, T., Nimura, Y., Nagahiro, Y., Miyazaki, S., & Tomatsu, T. (2013). Catastrophic head and neck injuries in judo players in Japan from 2003 to 2010. *American Journal of Sports Medicine*, *41* 1915-21. doi: 10.1177/0363546513490662.
Koshida, S., Ishii, T., Matsuda, T., & Hashimoto, T. (2014a). Kinematics of judo breakfall for osoto-gari. *Proceedings of XXXII international conference on biomechanics in sports*, 397-400. Retrieved from https://ojs.ub.uni-konstanz.de/cpa/article/view/6045/5525.
Koshida, S., Ishii, T., Matsuda, T., and Hashimoto. T. (2014b, September). *Kinematics of judo backward breakfall in different throwing techniques*. 5th conference of the Asian Society of Sports Biomechanics, Taipei, Taiwan.