THREE-DIMENTIONAL NECK KINEMATICS DURING BREAKFALL FOR OSOTO-GARI AND ITS ASSOCIATION WITH NECK FLEXION STRENGTH IN NOVICE JUDOKAS

Sentaro Koshida[1], Takanori Ishii[1], Tadamitsu Matsuda[2], Toshihiko Hasimoto[1]

Ryotokuji University, Chiba, Japan[1]
Uekusa-Gakuen University, Chiba, Japan[2]

The objective of this study was to demonstrate three-dimensional neck kinematics during breakfall motion for osoto-gari and to elucidate its association between neck strength in novice judokas. Twenty-one novice judokas volunteered to participate in this study. The Motion data was collected using a three-dimensional motion analysis technique. We found the neck motion occurs multidirectionally during the breakfall motion. In addition, the present result showed that the peak neck angular momentum the in frontal and horizontal plane accounted for approximately 30% of the peak neck extension momentum. Finally, there was no linear relationship between the peak resultant neck angular momentum and neck flexion strength, suggesting that neck strength in the single motion plane alone may not be associated with the risk of head injuries during judo.

INTRODUCTION: Head injuries, such as acute subdural hematoma, sustained during judo participation have gained widespread public attention because of the frequency and severity of these types of injuries. Previous findings have indicated that being thrown backward with osoto-gari (Figure 1) presents the greatest risk of head injury sustained during judo (Kamitani et al., 2013). Previous studies also demonstrated that severe head injuries mainly occur among young and inexperienced judokas, suggesting that the lack of the backward breakfall skills may increase the risk of head injury and that judo coaches and sports medicine professionals need to develop teaching / training strategies for backward breakfall skills acquisition among novice judokas to prevent judo-related head injuries effectively.

Backward breakfall motion is designed to ensure safety when a judoka is thrown backward and has several important biomechanical features. A judoka uses hands and legs to distribute the applied stress over the extremities and stabilize the neck in flexed position to avoid direct contact of the head to the floor in the motion. In particular, because direct and hard contact of the head with the judo mat is the most predominant mechanism, it may be crucial for novice judokas to improve neck stability for the judo related injury prevention.

Koshida et al (2016) reported that neck flexion angle started increasing gradually from the beginning until 80 to 90% mark in the breakfall motion, followed by abrupt neck extension. In addition, peak neck extension momentum in the breakfall was significantly greater in experienced judokas than novice judokas. These results suggest that it may be important for coaches to focus on strengthening of neck flexion to enhance its stability, allowing novice judokas to perform the backward breakfall motion safely.

However, the interpretation has still been open to discussion. Based on the visual observation of the backward breakfall for osoto-gari, it can be easily imagined that neck motion during the breakfall is multi-planner motion rather than single plane motion; therefore, coaches and sports medicine practitioners may need to take neck motion in other plane into consideration when developing the teaching / training paradigm for safer participation in judo. However, no study has quantified the three-dimensional neck biomechanics during the breakfall for osoto-gari. In addition, the potential association between the neck flexion strength and the risk of head injury risk has remained to be elucidated. This is particularly the case because little conclusion were drawn to support this relationship in the basic judo backward breakfall motion (Koshida et al., 2014). We therefore need to investigate this association as well.

The objective of this study was two folded. Our primary objective was to demonstrate the neck kinematics in three motion planes during breakfall motion for osoto-gari. In addition, we investigated whether there was linear relationship between neck strength and biomechanical parameter that reflect possible injury risk.

Figure 1: Sequence of movements in the osoto-gari technique

METHODS: Twenty-one novice male judokas volunteered to participate in the study. At the time of enrolment, each novice judoka had not previously participated in judo competitions, but had attended a minimum of 10 sessions of a judo course offered by the Ryotokuji University, Japan.

A set of 41 reflective sponge markers (diameter: 2.5cm) were placed on selected landmarks of the participants: the anterior superior illiac spines, the greater trochanters, the medial/lateral knees, the medial/lateral malleolus, the heads of the 1st and 5th metatarsal, the calcaneal tuberosities, the distal phalanx of the 1st digit of the feet, the medial/lateral epicondyles of the femur, the lateral costal borders (10th rib), the anterior/posterior shoulder, the manubrium of the sternum and its posterior side, the medial/lateral elbow joints, the medial/lateral wrists and the 3rd metacarpal heads of the hands.

The measurement protocol included three sets of successful breakfalls in response to being thrown with osoto-gari onto the judo mat by one male tester (the thrower: age 41 years, height 1.70 m, weight 65.0 kg) who had over 20 years' experience in judo (with a 3rd degree blackbelt).

Three-dimensional marker trajectory data (500 Hz) were obtained with a 12-camera Mac3D motion analysis system (Motion Analysis Corp., Santa Rosa, CA, USA) and were then low-pass filtered through a Butterworth digital filter at a cut-off frequency of 6 Hz. The neck angles in the sagittal, frontal, and horizontal plane were calculated as measurement variables in this study; the directions of neck flexion, neck lateral flexion to the right, and neck rotation to the left were defined as positive values. We also obtained the peak angular momentum of neck motion in three motion plane as well as the peak resultant angular momentum observed after the right hand hit the judo mat. The angular momentum was represented as an absolute value in this study. The biomechanical variables were computed with a MATLAB program (The Mathworks Inc., Natick, MA, USA). We analysed the breakfall motion 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 along the vertical axis. The kinematic data were normalized to 100% to facilitate group comparison.

We also measured peak isometric neck flexion strength (N: Newton) using a handheld dynamometer. First, a participant was instructed to lie on the treatment table in the supine position with neck flexion angle at 30 degree. The tester placed the handheld dynamometer and applied a force manually onto the forehead of the participant. The applied force increased gradually by the tester and the peak value was obtained when the participant failed to maintain the neck angle at the starting position. The data collection of the neck strength was performed twice consecutively. When there was a more than 10% difference in measurement values between the first and second measurement, we repeated the test for the third time. The averaged data was then used for further analysis.

We first analysed the neck angle-time data in a qualitative manner. The angle curves of neck motion in three sagittal, frontal, and horizontal plane were visually observed by an experienced athletic trainer / judokas who had more than 15 years of experiences.
For the comparison of the peak neck angular momentum in the three motion plane, Mauchly's sphericity test was conducted to confirm the sphericity of the variance within the kinematic data. After the sphericity was confirmed, a repeated one-way analysis of variance (ANOVA) was performed, followed by Holm's test for multiple comparison. When the sphericity of the variables was rejected, degrees of freedom were adjusted using Greenhouse–Geisser epsilon. Its effect size was also calculated using eta squared.
Finally, Peason's product moment correlation coefficient was performed to demonstrate the association between peak resultant neck angular momentum and neck flexion strength. All statistical analyses were performed with R, a free statistical software package (http://www.gnu.org/).Statistical significance was set at 0.05 in this study.

RESULTS: The mean (SD: standard deviation) age, height, weight, and judo experience of the novice judokas were as follows: 20.1 (0.94) years; 1.70 (0.07) m; 68.6 (8.1) kg.
The mean (SD) of the whole motion time and the timing at hand contact in the breakfall was 0.71(0.09) s and 79.5(8.2) % mark respectively. Neck flexion angle started increasing from the beginning and reached at its peak approximately 80 to 85% mark followed by the abrupt neck extension to the end of the motion. In addition, neck lateral flexion increased gradually toward left side from the beginning until and around 80% mark, and then the direction of motion was changed to the right flexion. Finally, the neck rotation started at rotation angle of about 20° to the right and then gradually rotating to the left until 80% mark, followed by the change of direction towards the right direction (Figure 2).

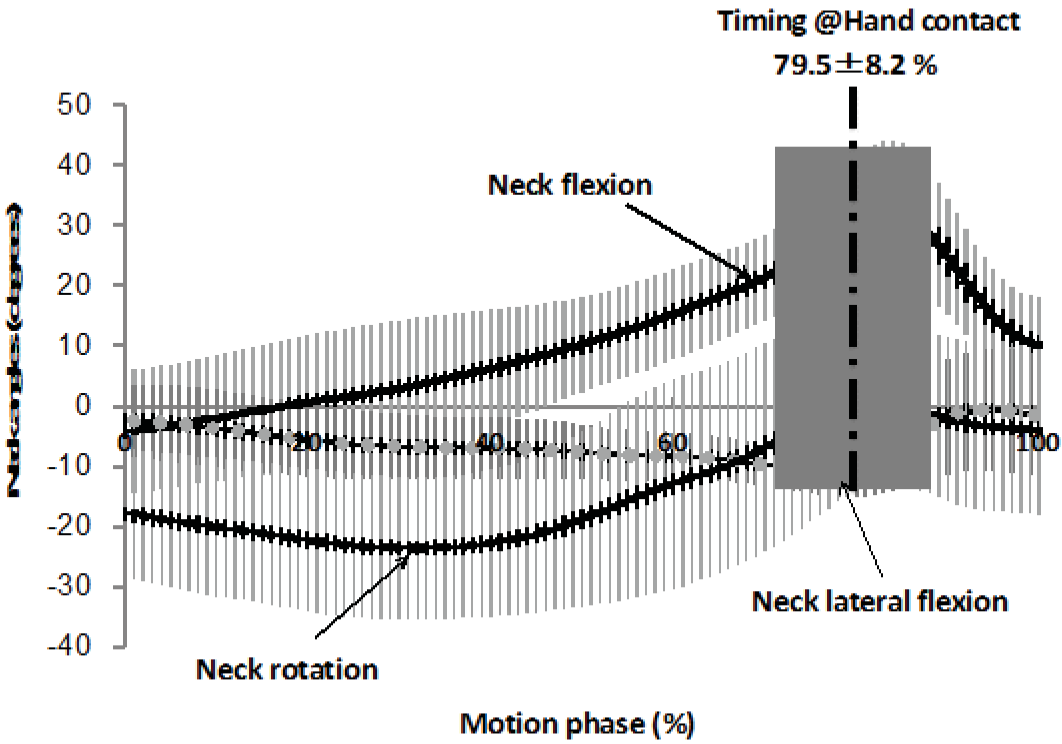

Figure 2: Mean angle–time plots of neck in the sagittal, frontal, and horizontal planes during breakfall for osoto-gari. The vertical lines represent standard deviation

Mean (SD) peak angular momentum were 1.24 (0.40) $kg \cdot m^2 \cdot s^{-1}$ in the sagittal plane, 0.36 (0.20) $kg \cdot m^2 \cdot s^{-1}$ in the frontal plane, and 0.41 $kg \cdot m^2 \cdot s^{-1}$ in the horizontal plane. In addition, mean (SD) peak resultant neck angular momentum was 1.32 (0.44) $kg \cdot m^2 \cdot s^{-1}$. Finally, mean (SD) peak neck flexion strength was 125.3 (29.8) N. A one way ANOVA demonstrated that there was significant difference among the peak values of the three planes (F = 186.15, df = 1.56, $P < 0.001$, $\eta^2 = 0.64$). In addition, the multiple comparison test demonstrated that the peak momentum in the sagittal plane was significantly greater than those in the frontal and horizontal plane, whereas there was no significant difference in the peak momentum between the frontal and the horizontal plane. Finally, there was no significant linear relationship between the peak neck strength and the peak resultant neck momentum in this study ($P < 0.05$)

DISCUSSION: The present study revealed that the neck motion in the breakfall for osoto-gari is not single plane motion, but rather multi-plane motion. The angle-time curve in the sagittal plane showed the similar change to the one demonstrated previously by Koshida et al (2016). In addition, neck angle curves in both the frontal and horizontal plane also showed the change of approximately 10 to 30 degrees throughout the entire breakfall motion. Especially, neck extension, right lateral flexion and rotation occurred simultaneously after the timing of hand contact at approximately 80% mark in the motion.

Although the statistical analysis showed that peak angular momentum in sagittal plane was significantly greater than the peak values in other planes, the frontal and horizontal angular momentum also showed that approximately 30% of the peak flexion momentum, suggesting that not only sagittal plane motion, but we also need to pay a closer attention to the other plane motion.

Interestingly, the neck flexion strength was not significantly correlated to the peak resultant neck momentum. The result suggests that neck flexion strength alone may not be able to predict the risk of head injuries in novice judokas. The result also suggests that, in order for novice judokas to prevent judo-related head injuries from occurring, neck strength may need to assess / improved multidrectionally.

This study was not without limitations. Although most head injuries occur during grappling, we did not obtain the motion data in such situations because of the limited measurement environment. We speculate that the progress of sensor technologies may enable us to elucidate breakfall biomechanics in real grappling situations in the near future.

CONCLUSION: We demonstrated that neck motion occurs in sagittal, frontal, and horizontal plane during the breakfall motion. In addition, although the peak neck angular momentum in sagittal plane showed the greatest value, the peak values of the other planes were not also negligible. Finally, there was no significant linear relationship between neck strength and the biomechanical parameters that reflects the risk of judo-related head injury.

REFERENCES:

Kamitani, T., Nimura, Y., Nagahiro, S., Miyazaki, S., & Tomatsu, T. (2013). Catastrophic head and neck injuries in judo players in Japan from 2003 to 2010. *The American Journal of Sports Medicine*, 41, 1915–1921.

Koshida, S., Matsuda, T., Ishii, T., & Hashimoto, T. (2016). Kinematics of judo breakfall for osoto-gari: Considerations for head injury prevention. *Journal of Sports Sciences*, 21, 1-7.

Koshida, S., Matsuda, T., Ishii, T., & Hashimoto, T. (2014) Biomechanics of judo backward breakfall: Comparison between novice and experienced judokas. *Archives of Budo*, 10, 187–194.

Acknowledgement

The study was supported by JSPS KAKENHI # 16k01668. The authors would like to thank all the participants for their contribution during the data collection. We also extend our appreciation to NAC image technology Inc., for their supports.