TRUNK BIOMECHANICS DURING BREAKFALL FOR OSOTO-GARI AND ITS ASSOCIATION WITH JUDO-RELATED HEAD INJURY RISK IN NOVICE JUDOKAS

Sentaro Koshida[1], Takanori Ishii[2], Tadamitsu Matsuda[3], Toshihiko Hashimoto[4]

Faculty of Health Sciences, Ryotokuji University, Urayasu, Japan[1]
Centre of Liberal Arts Education, Ryotokuji University, Urayasu, Japan[2]
Faculty of Social Work Studies, Jyosai International University, Togane, Japan[3]
Tokyo Metropolitan University, Tokyo, Japan[4]

The incidence of head injuries in novice judo practitioners is of increasing public concern in Japan. This study investigated the correlation between trunk biomechanics and judo-related head injury risk in novice judokas with the aim of developing effective injury prevention strategies. Thirty-one novice judokas volunteered to participate the study. Three-dimensional motion analysis of the osoto-gari breakfall was performed. A multiple regression analysis was used to test the correlation between trunk biomechanics and possible head injury risk. We found a significant correlation between the trunk COM velocity and the peak neck angular momentum (F = 13.29, df = 3, P < 0.001, r = 0.77). The result suggests that controlling the trunk COM angular velocity may play an important role in judo-related head injury prevention for novice judokas.

KEYWORDS: martial arts, head injury prevention, motion analysis

INTRODUCTION: Previous epidemiological studies reported that most severe head injuries sustained during judo occur in young novice judokas (Kamitani et al, 2013) It has also been indicated that such severe judo-related injuries frequently caused by striking the occipital region to the judo mat when thrown backward with osoto-gari, one of the judo throw techniques. Therefore, avoiding the head contact by performing breakfall safely is considered to directly lead to prevention of injuries.

Previous studies suggest that poor neck stability may be associated with the greater risk of judo-related head injuries. Koshida et al (2017a) demonstrated that the peak angular momentum of the head-cervical segment in the sagittal plane during the breakfall motion was significantly greater among novice judokas than the experts. This result suggests that novice judokas may stabilize their neck motion poorly when being thrown, which potentially increases the risk of the direct head contact. Therefore, it seems reasonable to implement cervical strength exercises into its prevention paradigm for the novice judokas. However, the interpretation warrants careful consideration. Recently, Koshida et al (2017b) also reported that no significant correlation was found between peak isometric strength of cervical flexion and the peak neck angular momentum during the breakfall in judo beginners, suggesting that cervical strength alone may not be a single contributing factor for the neck stability during the breakfall.

In the breakfall motion for osoto-gari, a judoka’s body is rotated backward in the air first. Consequently, the upper limbs and the trunk are grounded in this order, and the head reaches the lowest point on the vertical axis, indicating that the impact of trunk segment will affect the neck stability during the breakfall. However, the trunk biomechanics in the breakfall motion and its association with judo-related head injury remain to be elucidated. Therefore, the present study aimed to investigate the trunk segment biomechanics during the breakfall for osoto-gari and the correlation with biomechanical parameters that potentially reflect the risk of judo-related head injuries.

METHODS: Thirty-one novice judokas (22 men and nine women) were recruited at a local university. The novice judokas had not participated in judo competitions but had attended at least 10 sessions of a judo course. No participants had experienced any previous and/or current mild and/or major head or neck trauma. The participants gave their written informed

consent after of the purpose and risks of the study were explained to them. The study protocol was approved by the institutional ethics committee.
Forty-one 2.5 cm diameter reflective markers were placed on bilateral anatomical landmarks as Koshida et al (2017a). Participants were instructed to wear judo clothes on the top of tight-fitting spandex shirts and shorts that were designed to allow visibility of the attached markers and headgear to ensure safety during the measurements.
The osoto-gari involves the thrower pushing a participant with the hands, sweeping out his supporting leg, and throwing him backward. The participants performed a breakfall motion by curling his neck and trunk upward and using the arm and hand action (Figure 1). The measurement protocol included three breakfall motions in response to be thrown with osoto-gari. The participants were thrown by one experienced male third degree black belt judoka who had more than 20 years of experience. No participant hit his head during the measurements. Three-dimensional marker trajectory data (500 Hz) during the breakfall motion were obtained with a 12-camera Mac3D motion analysis system (Motion Analysis Corp., Santa Rosa, CA, USA). The motion data were filtered through a Butterworth low-pass digital filter at a cut-off frequency of 6 Hz.
The angular velocity of the centre of mass (COM) of the trunk segment in three-dimensional motion plane were computed with a customised MATLAB program (The Mathworks Inc., Natick, MA, USA). In addition, a resultant angular momentum of head-cervical segment for the neck joint centre was chosen as a biomechanical parameter that potentially reflects the judo-related head injury risk.
The breakfall motion was cropped from the time that the thrower's leg first touched the participant to the time when the head of the participant was at the lowest position on the vertical axis. The kinematic data were normalised to 100% and then divided into 10% slices to facilitate the group comparisons. Because the thrower is a left-handed style (see Figure 1), the participant's body was supposed to rotate backward in the sagittal plane, left in the frontal plane, and right in the horizontal plane when being thrown with osoto-gari; therefore, we decided to express these directions as positive values in this study.

Figure 1: Breakfall motion for osoto-gari

All statistical analyses were performed with free statistical software R.version1.33.18 for Macintosh. A multiple regression analysis was performed to test for the correlation between peak resultant neck angular momentum and trunk COM angular velocities in three motion planes during the breakfall motion for osoto-gari (P < 0.05). In addition, the trunk COM angular velocity and resultant neck angular momentum changes over time were analysed qualitatively.

RESULTS: The mean (standard deviation: SD) age, height, body mass of the participants were 20.9 (0.9) years, 1.67 (0.08) m, 64.9 (9.2) kg, respectively.
Figure 2 illustrates the trunk COM angular velocity and resultant neck angular momentum changes over time. Trunk horizontal rotation predominantly occurs during the early phase of the breakfall motion until approximately the 60% mark. Abrupt changes of the angular velocity were then observed both in the sagittal and horizontal plane motion followed by the

frontal plane motion. The highest value of the peak resultant momentum of the head-neck segment was observed at approximately the 90% mark of the breakfall motion.

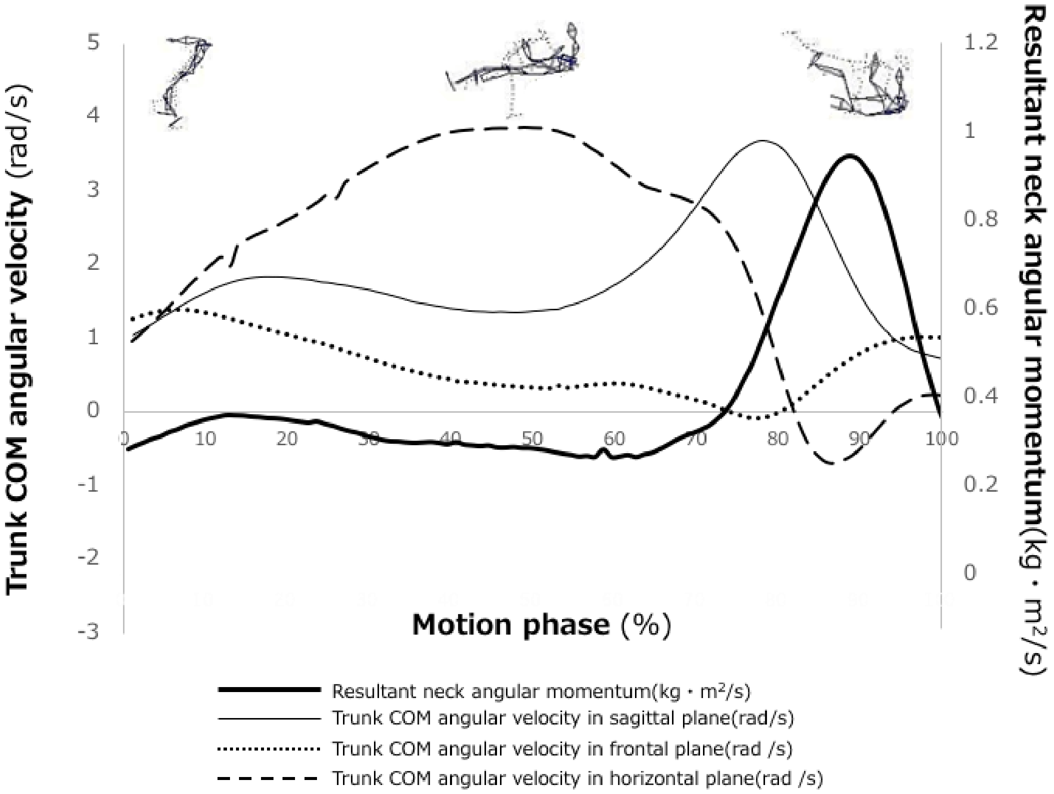

Figure 2: Mean trunk COM angular velocity and resultant neck angular momentum changes during breakfall for osoto-gari (N = 31)

Mean (SD) peak trunk velocity in sagittal, frontal and horizontal planes were 4.86 (1.24) rad/s, 1.80 (0.53) rad/s and 0.49 (0.81) rad/s respectively. In addition, mean (SD) peak neck angular momentum was 1.19 (0.44) m・kg^2/s. A multiple regression analysis demonstrated there was a significant correlation between the peak trunk angular velocity in the three motion planes and the peak resultant momentum of the head-neck segment (F = 13.29, df = 3, P < 0.001, r = 0.77). Partial correlation coefficients also revealed that peak trunk angular velocity in each motion plane was significantly correlated to the peak angular momentum (sagittal plane: t = 4.61, P < 0.001, adjusted partial r = 0.61, frontal plane: t = -2.20, P = 0.04, adjusted partial r = -0.32, horizontal plane: t = 2.44, P = 0.02, adjusted partial r =0.38) (Figure 3).

DISCUSSION: The present study indicated that trunk biomechanics during the breakfall for osoto-gari may be associated with the judo-related head injury risk. Of all the motion planes, the peak trunk rotation velocity in the sagittal plane may be the greatest contributor to the magnitude of peak neck angular momentum during the motion. Koshida et al (2017a) demonstrated that the novice judokas were likely to take a more flexed posture than the experienced judokas, especially from the middle to late phase of the break motion, indicating that such flexed posture may reflect the skill level of the breakfall. From the view of biomechanics, the flexed posture may lead to greater angular velocity due to the possible decrease of the moment arm distance around the trunk COM, Therefore, maintaining a straight posture during the breakfall motion may help judokas to lower the trunk angular velocity when being thrown, leading to a reduced risk of judo-related head injuries associated with osoto-gari.
In addition, the qualitative analysis revealed that the breakfall is not a single plane motion, but a multi-planar motion. In particular, the movement in the horizontal plane predominantly

occurred in the initial stage. Furthermore, the horizontal plane motion seems to be linked with the following sagittal plane motion. We speculated that such kinematic linkage also reflected the skill level of judokas as well as the head injury risk. In future studies, a comparison of trunk motions will be necessary between skilled and unskilled judokas to prove this hypothesis.

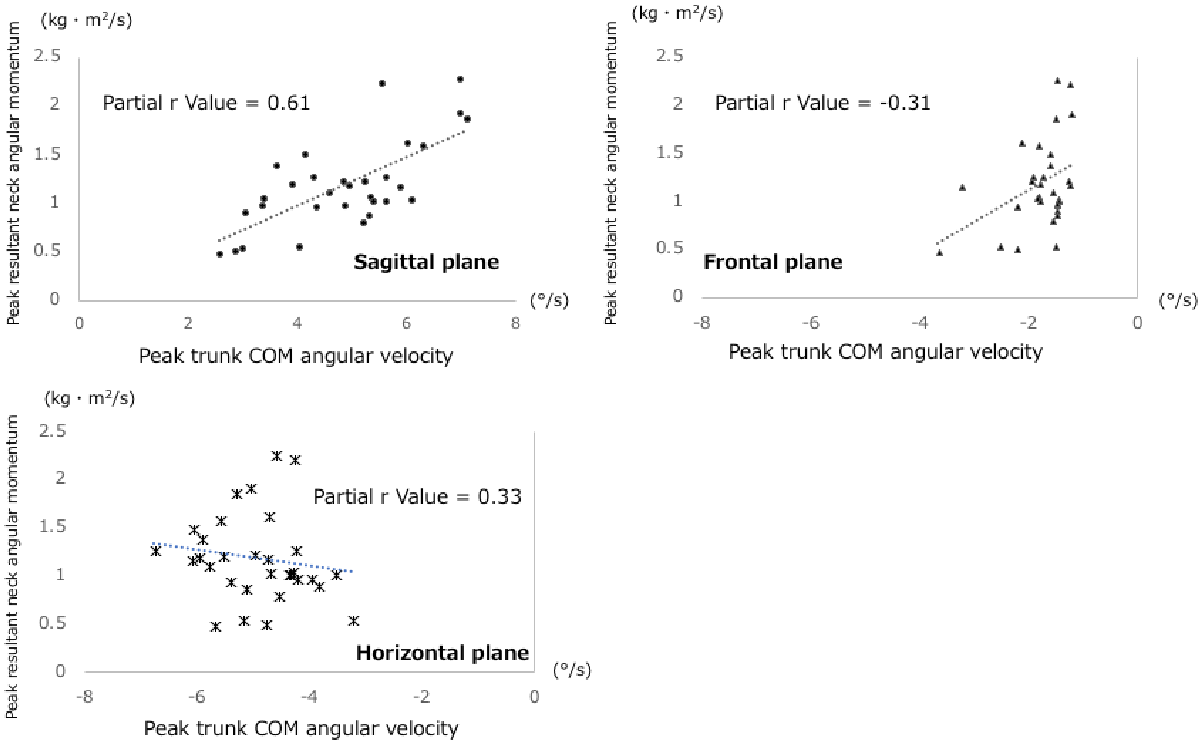

Figure 3: A correlation diagram between peak resultant neck momentum and peak trunk COM angular velocity in sagittal, frontal, and horizontal plane (N = 31).

CONCLUSION: The present study demonstrated that there was a significant correlation between the trunk COM angular velocity in all three motion planes and the biomechanical parameter that potentially reflects the judo-related head injury risk. Trunk motion control during the breakfall may play a crucial role in judo-related head injury prevention in novice judokas.

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. doi:10.1177/0363546513490662.

Koshida, S., Ishii, T., Matsuda, T., & Hashimoto, T. (2017a). Kinematics of judo breakfall for osoto-gari: consideration for head injury prevention. Journal of Sports Sciences, 35, 1059–1065. doi: 10.1080/02640414.2016.1210194.

Koshida, S., Ishii, T., Matsuda, T., & Hashimoto, T. (2017b). Three-dimensional neck kinematics during breakfall for osoto-gari and its association with neck strength in novice judokas. Proceedings of 35th International Conference on Biomechanics in Sports, 35, 408–411.

ACKNOWLEDGEMENTS: The authors would like to thank NAC image technology Inc., for their technical support. The work was supported by the JSPS KAKENHI [number 16k01668].