Effects of Different Throwing Techniques in Judo on Rotational Acceleration of Uke’s Head

Yoshihisa Ishikawa1,2, Kenji Anata3, Hironori Hayashi4, Takayuki Yokoyama5, Takashi Ono6 and Shuichi Okada7

1Faculty of Education, Osaka Kyoiku University
4-698-1, Asahigaoka, kashiwara, Osaka 582-8582, Japan
yoshihisa@cc.osaka-kyoiku.ac.jp
2Graduate School of Doctoral Program Human Development and Environment, Kobe University
3-11, Tsurukabuto, Nada-ku, Kobe, Hyogo, 657-8501, Japan
3National Institute of Technology, Ishikawa College
Kitacyujo, Tsubata, Ishikawa, 929-0392, Japan
4Biwako Seikei Sport College
1204, Kitahira, Otsu, Siga, 520-0503, Japan
5Division of Physical and Health Education, Setsunan University
17-8, Ikadanakamachi, Neyagawa, Osaka, 572-8508, Japan
6Faculty of Health and Sport Sciences, University of Tsukuba
1-1-1,Tennoudai, Tsukuba, Ibaraki, 305-8574, Japan
7Graduate School of Human Development and Environment, Kobe University
3-11, Tsurukabuto, Nada-ku, Kobe, Hyogo, 657-8501, Japan

[Received April 18, 2017; Accepted June 21, 2018; Published online July 13, 2018]

This study aimed to clarify the rotational acceleration of the head of an uke during tai-otoshi, seoi-nage, osoto-gari, and ouchi-gari when safe ukemi is performed. Eight judo club members of the National Institute of Technology (mean age, 17.5 ± 1.5 years; mean height, 173.0 ± 4.21 cm; mean weight, 72.4 ± 10.57 kg) were subjects who acted as the ukes. A subject with 8 years of experience in judo and qualified to the second dan (age, 20 years; height, 165.0 cm; weight, 70.0 kg) played the role of throwing the uke. A rotational velocity sensor was used to measure the rotational acceleration in the sagittal plane of the uke’s head. One-way analysis of variance (Friedman test) was used for the statistical analysis, and when a significant difference was observed, multiple comparison test was performed using the Bonferroni method. The results revealed that of the four throwing techniques, osoto-gari generated maximum rotational acceleration of the uke’s head. Furthermore, the maximum rotational acceleration was greater with tai-otoshi than with seoi-nage. Our results suggested that among the four throwing techniques, osoto-gari was most likely to injure the head.

Keywords: judo accident, head injury, rotational acceleration, sagittal plane, throwing technique

1. Introduction

Uchida reported that 118 fatal accidents occurred between 1983 and 2011 in judo under school management. These accidents occur more often in beginners during their first years of junior or senior high school, and the majority of these accidents occurred during after-school activities (Uchida, 2013). Injuries such as head bruising that occur because of osoto-gari are serious. In osoto-gari, the person is thrown backward. Head bruising that may result during impact can develop into an acute subdural hematoma; thus, serious accidents caused by this throwing technique are serious problems.

Against such a background, awareness regarding these risks has increased the interest in research on judo safety. Fujita et al. (2013) revealed that the sternocleidomastoid muscle must be strong to support a safe “backward breakfall.” Sannohe and Iida (2008) argued that increased falling speeds were associated with a higher likelihood of hitting the head during “backward breakfall,” even if the person who is thrown (hereafter referred to as uke) “backward hits” the tatami with one or both hands.

Hashimoto et al. (2015) and Koshida et al. (2017)
conducted throwing experiments and found that compared with ouchi-gari, osoto-gari was associated with an increased risk for serious cranial injury. However, these studies only focused on a kinematic point of view. Head traumas such as acute subdural hematoma are affected by the rotational acceleration of the head (Gennarelli and Thibault, 1982). Moreover, rotational acceleration in the sagittal plane of the head has been reported to induce an acute subdural hematoma (Gennarelli & Thibault, 1982, Ommaya & Gennarelli, 1974, Untereharnscheidt & Higgins, 1969). Thus, future studies should focus on the rotational acceleration of the uke’s head.

Prospective human subject research on head injuries is associated with obvious ethical issues. Therefore, Murayama et al. (2014) performed an experiment wherein an anthropomorphic test device was thrown to mimic the impact to the back of the head to compare the effects of osoto-gari and ouchi-gari with or without a mat laid out under the tatami. The maximum simulated translational acceleration of the head was lower for both throws when a mat was used. However, the study focused on osoto-gari and ouchi-gari, which involve throwing the uke backward. Thus, it is also necessary to collect data regarding rotational acceleration of the head during other techniques such as tai-otoshi and seoi-nage, which involve throwing the uke forward.

Sudden backward head rotation increases the risk for acute subdural hematoma without bruising (All Japan Judo Federation, 2016). Noji (2011) indicated that concussions occur without head bruising, and in environments with high risks for concussion, an acute subdural hematoma tends to occur because of severe acceleration injury; however, conventional views state that an acute subdural hematoma occurs when the head bruises (Kubota, 2002), which is an inaccurate assumption. Therefore, future research should assess the rotational acceleration of the uke’s head even in situations where the head is not bruised.

Therefore, this study aimed to clarify the rotational acceleration of the uke’s head during skilled backward and forward throwing when safe ukemi was performed.

2. Methods

2.1. Subjects

Subjects were informed in writing regarding the study purpose and methods, and all subjects and their parents provided informed consent before any study procedures. Next, to ensure safety, an individual with 12 years of experience in teaching judo, who was qualified to the fifth dan, and who possessed the A-level instructor certification from the Public Interest Incorporation Foundation All Japan Judo Federation confirmed in advance that the breakfalls and throwing techniques performed were correct for both the uke and thrower (hereinafter, referred to as tori).

Table 1 shows data such as height, weight, years of judo experience, and rank of the uke. Judo accidents frequently occur among beginners such as junior high school first graders and high school first graders. Considering the current judo safety measures, it is desirable to conduct experiments that target these novices. However, throwing a beginner poses a high risk for injury and is difficult to implement. Thus, we selected an uke and eight judo club members (mean age, 17.5 ± 1.5 years; mean height, 173.0 ± 4.21 cm; mean weight, 72.4 ± 10.57 kg) from the National Institute of Technology.

Ishii et al. (2018) found that throwing kinematics varied depending on the skill level. In addition, individuals have considerable interpersonal variability with respect to throwing techniques. It is reasonable to assume that these technical variations affect the rotational acceleration generated at the uke’s head. Therefore, in this study, to minimize the variability,
the tori selected was an athlete with 8 years of experience in judo and who was qualified to the second dan (age, 20 years; height, 165.0 cm; weight, 70.0 kg). This study was conducted with the approval of the management committee (equivalent to an ethics committee) of the National Institute of Technology, Nagano College.

2.2. Assessed trial techniques

We selected tai-otoshi, seoi-nage, osoto-gari, and ouchi-gari as the trial techniques because seoi-nage, osoto-gari, and ouchi-gari are associated with the highest number of accidents. Furthermore, tai-otoshi is listed in the Course of Study (Mext, 2008, 2009) and is taught at a relatively early stage.

Daigo (1999b) described tai-otoshi as follows: the tori breaks the balance of the uke to the uke’s right front corner, the tori turns to step in front of the uke’s right foot with the tori’s right foot and then uses the action of both hands to pull the uke down, and finally throws the uke over the tori’s leg [Figure 1(a)]. Seoi-nage was described as follows: the tori breaks the uke’s balance to the uke’s front or right front corner, the tori then pivots to counterclockwise while allowing the elbow of the tori’s right arm to bend and come under the uke’s right armpit, then the tori carries the uke onto the back and throws the uke over the right shoulder [Figure 1(b)]. Daigo (1999a) described osoto-gari as follows: the tori breaks the balance of the uke to the uke’s rear or right rear corner to shift most of the uke’s weight onto the uke’s right heel and then the tori sweeps out the uke’s right leg with the tori’s right leg [Figure 1(c)]. Ouchi-gari was described as follows: the tori sweeps out the uke’s left leg from the inner side with the tori’s right leg to throw the uke backward [Figure 1(d)].

2.3. Measurement method

In this study, the axes at the head were defined as follows: the left–right direction was the X axis, the anterior–posterior direction was the Y axis, and the superior–inferior direction was the Z axis (Figure 2). Acute subdural hematoma, which is one of the head injuries resulting from judo accidents, is said to be caused by the rotational acceleration in the sagittal plane, or about the X axis in this study. Therefore, in this study, we measured the rotational acceleration about the X axis at the head of the uke for different throwing techniques. The rotational acceleration about the X axis at the head of the uke was measured by numerically differentiating the rotational velocity about the X axis obtained from a triaxial rotational velocity sensor (MVP-RF 8-GC, manufactured by MicroStone, hereinafter referred as “sensor”). In this study, the forehead direction was denoted as “−” and the back head direction was denoted as “+” (the arrow in Figure 2). The

![Figure 1](image-url)  Throwing techniques.
sensor was attached with a double-sided tape to the top of the headgear (d3o LAB, London, UK) and was fixed from above with a curing tape. The uke wore the headgear fitted with the sensor on top to measure the rotational acceleration. Next, after setting the sampling frequency of the sensor to 5 milliseconds using a personal computer, the uke was instructed to stand straight to calibrate the sensor. After setting-up the sensor, the tori threw the uke using a specified throwing technique. Each throwing technique was performed thrice in the order shown in Table 2. Before the experiment, the tori was instructed to throw the uke as he normally would, and the uke was asked to receive the throw as he normally would.

After completing the throwing techniques, we confirmed with the uke and tori whether the uke’s head touched the tori’s leg during the throw. If there was contact, the experiment was repeated to obtain accurate data until three successful throws were completed. The average value of these three values was taken as the analysis target.

2.4. Statistical analysis

Data were analyzed using one-way analysis of variance (ANOVA; Friedman test, which is a non-parametric statistical method). When a significant difference was confirmed, multiple comparison test by Bonferroni method was performed for each technique. The statistical significance level was set at p values of <0.05. Moreover, the effect size was calculated using Cohen’s d (Cohen, 1988). The effect sizes were assessed using Cohen’s d as trivial (<0.1), small (0.1-0.3), medium (0.3-0.5), and large (>0.5).

3. Results

The maximum rotational acceleration in the sagittal plane (about the X axis) of the head was compared when performing tai-otoshi, seoi-nage, osoto-gari, and ochi-gari.

One-way ANOVA results revealed a significant difference in the maximum rotational acceleration with regard to each throwing technique (p<0.01). Multiple comparison test results showed that the maximum rotational acceleration was significantly greater with osoto-gari than the tai-otoshi (p<0.01; r=0.89), seoi-nage (p<0.01; r=0.89), and ochi-gari (p<0.01; r=0.89). Furthermore, the maximum rotational acceleration was significantly greater with tai-otoshi than with seoi-nage (p<0.01; r=0.84). The maximum rotational acceleration was significantly greater with ochi-gari than with seoi-nage (p<0.05; r=0.64; Figure 3).

4. Discussion

Of the four throwing techniques, the maximum rotational acceleration of the uke's head during osoto-gari was the highest.

The maximum rotational acceleration was greater with osoto-gari than with ochi-gari. Hashimoto et al. (2015) noted that compared with osoto-gari, in ochi-gari, the area and time of contact between the upper limb and tatami was greater when the uke was thrown, which decreases the vertical velocity of the head. Furthermore, in contrast to osoto-gari in which the uke is thrown such that the upper body falls directly downward, in ochi-gari, the uke is thrown such that the lower body falls first. We believe that the maximum rotational acceleration of the head was greater with osoto-gari than with ochi-gari because in osoto-gari, the head was more vulnerable to a strong impact because the upper body landed on the tatami first.
The maximum rotational acceleration of the uke’s head was greater with osoto-gari than with tai-otoshi or seoi-nage. Magara & Takumiya (1977) reported that when thrown with osoto-gari and seoi-nage, the uke lands on the tatami on his arm, upper body, and lower body in that order. Based on this, it can be inferred that the body parts land in the same order as that with tai-otoshi, which is classified in the same group as seoi-nage. Therefore, in osoto-gari, tai-otoshi, and seoi-nage, body contact is made with the tatami in the same order. In contrast, osoto-gari produces a high-magnitude force by coupling of forces (Daigo, 1999a). Therefore, osoto-gari is associated with a higher maximum rotational acceleration of the head than either tai-otoshi or seoi-nage.

The maximum rotational acceleration of the uke’s head was greater with tai-otoshi than with seoi-nage. As shown in Figure 1, tai-otoshi features no contact between the tori’s back and the uke’s lower back and front side. The speed of tai-otoshi does not decelerate because of a lack of friction. In contrast, the speed of seoi-nage is reduced because it includes loading on the back, i.e., owing to the friction that occurs during contact between the tori and uke. This apparently explains why the rotational acceleration of the head was greater with tai-otoshi than with seoi-nage.

The maximum rotational acceleration was greater with ouchi-gari than with seoi-nage. Ouchi-gari brings the lower body into contact with the tatami after sweeping out the legs. In contrast, seoi-nage involves carrying the weight on the back and then throwing it over the shoulder on the tatami from the upper body. Because of this, there was a difference in the maximum rotational acceleration of the head owing to the difference in the contact order of the body with the tatami.

In this study, the maximum rotational acceleration generated was 368.3 rad/s² with tai-otoshi, 276.2 rad/s² with seoi-nage, 693.2 rad/s² with osoto-gari, and 401.6 rad/s² with ouchi-gari. Om-maya (1984) indicated that a rotational acceleration of 4500 rad/s² was required to cause a concussion even among adults who are most prone to concussions. Given this, the probability of a concussion is low when ukemi is performed.

In contrast, Hitosugi et al. (2014) conducted an experiment in which a judo expert threw an anthropometric test device via osoto-gari and ouchi-gari. They then measured the rotational acceleration of the head of an anthropometric test device during each throwing technique. The maximum rotational acceleration generated was 3315 rad/s² with osoto-gari and 1328 rad/s² with ouchi-gari. These accelerations were sufficiently lower than those produced in the study by Hitosugi et al. (2014). This disparity was greatly affected by the presence or absence of head bruising. Therefore, preventing head bruising and reducing rotational acceleration are important. Ukemi may be an effective method because it is an action to prevent the occurrence of head bruising by striking the arm against the tatami and pulling the jaw (All Japan Judo Federation, 2016). In addition, using a brain and skull collision model, Aiba et al. (2012) demonstrated the effects of head protection at the time of a collision while collapsing backward. Therefore using protective equipment also helps...
prevent accident-related injuries.

In this study, variability with regard to the tori and uke was limited, whereas in reality, the combination of tori and uke vary. It is important to consider the influence of physical differences (e.g., height and weight) between the tori and uke, level of throwing techniques used by the tori, and the preparation technique of the uke (difference between controlled practice and free practice) on the rotational acceleration of the uke’s head.

Future research is necessary to clarify why the rotational acceleration of the head increases in osoto-gari. To achieve this, it is necessary to investigate the relationship between the whole-body behavior of the uke during the throwing technique and acceleration of its head.

5. Conclusions

This study attempted to elucidate the rotational acceleration in the sagittal plane of the uke’s head during throw maneuvers. The acceleration occurs as the uke is thrown via tai-otoshi, seoi-nage, osoto-gari, and ouchi-gari. These results showed that of the four throwing techniques, osoto-gari generated the greatest maximum rotational acceleration of the uke’s head. The maximum rotational acceleration was greater with tai-otoshi than with seoi-nage. Our results suggested that among the four throwing techniques, osoto-gari was most likely to injure the head.

Acknowledgement

This study was conducted with the help of the Mizuno Sports Promotion Foundation. We would hereby like to express our appreciation for this support.

References


Mext (2009). Kontou gakkou gakushu shidou youryou kaisetsu to kaihukou no biroku. (in Japanese)


The Effects of Judo Throwing Techniques on the Uke’s Head

Name: Yoshihisa Ishikawa

Affiliation: Faculty of Education, Osaka Kyoiku University

Address: 4-698-1, Asahigaoka, kashiwara, Osaka 582-8582, Japan

Brief Biographical History:
1998-2002 School of Health and Physical Education, University of Tsukuba
2006-2008 Graduate School of Master’s Program in Health and Sport Sciences, University of Tsukuba
2008-2011 Researcher, Faculty of Health and Sport Sciences, University of Tsukuba
2011-2015 Lecturer, National Institute of Technology, Nagano College
2015-Present Lecturer, Faculty of Education, Osaka Kyoiku University
2018-Present Graduate School of Doctoral Program Human Development and Environment, Kobe University

Main Works:

Degree:
Master

Membership in Learned Societies:
• Japanese Academy of Budo
• Japanese Society of Physical Education, Health and Sport Sciences
• Japanese Society of Education and Health Science
• Japanese Society of Sport Psychology