

Elucidation of the causes of head injury in judo: Is being thrown in an unexpected condition the cause of head injury?

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Abstract

Problem Statement: In Japan, head injury in judo is a serious problem. However, to our knowledge, head injury in judo has not been investigated globally, and there is a concern that head injury may become a problem in the future. Additionally, factors that cause head injuries have not been clarified, and it seems that the All Japan Judo Federation and judo coaches do not recognize that the competitive characteristic of judo, in which a participant is thrown unexpectedly, is related to the occurrence of head injuries. **Approach:** We conducted an experiment in which we pushed six university judo experts at a constant speed using an air cylinder, and had the participants perform a backward breakfall. The participants performed the backward breakfall in two patterns: the closed-eye (unexpected) and open-eye (expected) conditions. **Purpose:** Therefore, this study aimed to clarify whether being thrown unexpectedly is a risk factor for the occurrence of head injury in judo. **Results:** The results showed that the maximum angular acceleration of the head was significantly higher in the closed-eye condition than in the open-eye condition. The risk of head injury was higher in the closed-eye condition, indicating that being thrown unexpectedly is a risk factor for the occurrence of head injury in judo. Additionally, delayed reaction to a push and delayed contraction of the neck muscles may be related to head injury. **Conclusions:** Therefore, it is important to increase the speed of reaction to throws and speed of contraction of the neck muscles to prevent head injuries in judo.

Key Words: Judo, Head injury, Risk factors, Unexpected throw condition, Backward breakfall, Safety measures

Introduction

Currently, head injury in judo is a serious problem in Japan. In 1971, 20 head injuries were reported in Japan, four of which were acute subdural hematomas (Hirakawa, Hashizume, Fuchinoue, & Nakamura, 1971). In 1988, four acute subdural hematomas were reported in Japan (Nishimura et al., 1988). From 1983 to 2011, 118 fatalities were reported in junior high and high schools in Japan (Uchida, 2013). Most of these fatalities (103 cases, 87.3%) occurred during judo club activities, and 73 (70.9%) of the injuries were head injuries, such as acute subdural hematoma. In addition, it was pointed out that being thrown by “osoto-gari” was the major cause of fatalities (18 cases, 24.7%) (Uchida, 2013). Subsequently, owing to safety measures taken by the All Japan Judo Federation, there were no fatalities from 2012 to 2014. However, 13 serious accidents occurred between 2015 and 2019 (All Japan Judo Federation, 2016a, 2016b, 2016c, 2018, & 2019). Of these accidents, nine fatalities (four deaths, three disabilities, and two without disabilities) were head injuries, such as acute subdural hematoma; three fatalities were neck injuries, such as cervical dislocation and fracture (one death and two disabilities); and one fatality was a heat stroke (one death). In 2020, two serious accidents (one acute subdural hematoma and one cervical spine injury) were reported (All Japan Judo Federation, 2020a). Concussions have also been investigated since that year, and 11 cases of concussions have been reported. In particular, two elementary school students (age 10–12 years) suffered acute subdural hematoma (one death) in 2019, indicating that the problem is becoming more serious as cases of head injury extend to younger ages.

Thus, it is necessary to review the safety measures in judo because serious accidents involving injury to the head, still occur in Japan. To our knowledge, in the rest of the world, there are no reports of head injuries in judo, and they do not seem to occur, although there is no clear evidence due to the paucity of formal investigation in this regard. However, considering the competitive characteristics of judo, there is a risk of serious head injuries, and it is important to strengthen the safety measures.

Since the aforementioned report by Uchida (2013) on serious accidents in judo was made just before Budo (martial arts) began compulsorily in junior high schools, judo head injuries have become a social problem in Japan (Japan Judo Accident Victims Association, 2012; Ministry of Education, Culture, Sports, Science and Technology, 2012). This is because of the growing demand for the safety of judo among students and their parents. At the same time, many studies on head injury in judo began to be conducted.

In a human study, Hashimoto, Ishii, Okada, & Itoh (2015) reported that the “osoto-gari” throwing technique had a higher risk of head injury than “ouchi-gari” in an experiment involving throwing Japanese national team players. Koshida, Ishii, Matsuda, & Hashimoto (2017) also pointed an increased risk of head injury with the “osoto-gari” throwing technique than with the “ouchi-gari” throwing technique in an experiment involving the throwing of judo beginners. Ishikawa et al. (2018) also found that between the “tai-otoshi,” “seoi-nage,” “osoto-gari,” and “ouchi-gari” throwing techniques in throwing experiments involving university athletes, the “osoto-gari” throwing technique had the highest risk of head injury. Vacca, Rosso, & Gastaldi (2020), in an experiment involving adolescents (12 years and older) who were not judo specialists, reported that the risk of head injury was higher when the “osoto-gari” or “ouchi-gari” throwing technique was used than when the “ippon-seoi-nage” or “tai-otoshi” throwing technique was used.

In a study of anthropomorphic test devices, Murayama et al. (2013) reported that when throwing anthropomorphic test devices using the “osoto-gari” and “ouchi-gari” throwing techniques, the impact force of the throwing techniques was higher when no mat was placed under the tatami mat. In addition, Hitosugi et al. (2014) reported on the dangers of the “osoto-gari” and “ouchi-gari” throwing techniques in an experiment involving the throwing of anthropomorphic test devices. Murayama et al. (2014, 2020a) reported that when an anthropomorphic test device was thrown using the “osoto-gari” throwing technique, the head acceleration increases when the head hits the tatami mat, which is considered dangerous. Furthermore, Murayama et al. (2020b) elucidated that the mechanism of acute subdural hematoma caused by the “seoi-nage” throwing technique is that prominent angular acceleration causes marked strain and deformation of the brain surface, leading to the rupture of cortical blood vessels.

Thus, a great number of studies have examined the risk of head injury caused by throwing techniques including the “osoto-gari” throwing technique. However, even if the risk of head injury in all 67 throwing techniques (Daigo, 1999a, 1999b, 1999c) is studied, it is difficult to consider specific prevention measures as the risk of head injury is inevitably higher when the throwing and receiving techniques are inappropriate. Therefore, to prevent head injuries, it is necessary to study the causative factors.

The All Japan Judo Federation (2015, 2020b) analyzed the 2003–2014 reports of serious accidents involving head injuries. They demonstrated that many junior high school and high school beginners were thrown by the “osoto-gari” throwing technique between May and July, causing acute subdural hematoma. In addition, the federation mentioned that the head injury is related to poor breakfall skills, poor neck muscle strength, body size differences, and judo skills differences. However, these factors have been considered to be related to the incidence of head injuries, based on experience; thus, it is essential to clarify this scientifically. Recent studies have reported that fatigue and body size differences are associated with the occurrence of head injuries (Ishikawa, Anata, Hayashi, Uchimura, & Okada, 2020a, 2020b; Ishikawa et al., 2017), and head injuries may be prevented by the use of mouth guards (Shoda, Anata, Ishikawa, Uchimura, & Hayashi, 2020), but this requires further research. Therefore, it is important to elucidate the causes of head injuries and establish safety measures.

Various factors are considered to be responsible for the occurrence of head injuries, but the All Japan Judo Federation and judo coaches seem to have overlooked a fundamental factor—the competitive characteristic of judo where an athlete is caught by surprise and thrown. Judo is competitive and the opponent is not informed about the timing of throwing techniques. Alternately, when predictable external forces are applied, there is specific muscle activity in response to them (Sato & Suzuki, 1994).

In contact sports, unintentional disturbances may cause sports injuries, such as elbow dislocation, despite the presence of sufficient muscle strength. This is largely due to the magnitude of the impact force of the disturbance, but it is also related to the delay in reaction to the unexpected disturbance. In other words, it has been pointed out that the risk of sports injury increases if the response to an unexpected disturbance is delayed, even in the presence of sufficient muscle strength (Kimura et al., 1993). This suggests that the competitive characteristic of judo, such as throwing an opponent unexpectedly, may be related to the occurrence of head injury. However, as mentioned above, throwing an opponent unexpectedly is not included as a factor of head injury in the report by the All Japan Judo Federation, and no research has clarified this subject. Therefore, the purpose of this study was to clarify whether being thrown unexpectedly is related to the occurrence of head injury, and to propose a preventive measure against head injury.

Materials and Methods

Participants

Six experts of the university male judo club participated in the study (mean age: 19.5 ± 0.6 years, mean height: 169.8 ± 7.9 cm, mean weight: 81.4 ± 16.4 kg, mean dan: 2.0 ± 0 dans, mean years of judo experience: 13.5 ± 2.2 years). To account for the effect of body weight, the six participants were selected from each of the six of the seven classes in judo competition (the 60-, 66-, 73-, 81-, 90-, and 100-kg categories). The purpose and methods of this study were explained to the participants both in writing and orally, and their verbal and written consent was obtained before the experiment was performed. Consent was also obtained from the guardians of underage participants. This study was approved by the research ethics review of the Biwako Seikei University of Sport Sciences (Seisu No. 53).

Experimental procedure

Since it is unsafe to throw a participant unexpectedly, we instructed the participants to perform a backward breakfall, instead of being thrown. To clarify that being thrown unexpectedly is a factor for the occurrence of head injury, the participants were pushed in closed-eye and open-eye conditions and were made to perform a backward breakfall. To accurately measure the effect of being pushed unexpectedly, we kept the pushing force and speed constant. In this study, an air cylinder (MDBL50-900Z, SMC) was used to push the participant in the mid-back position (Fig. 1). The position of the participant was adjusted by touching the chest with the air cylinder using a rubber pad. To push the participant, the air cylinder was ejected at a pressure of 0.7 MPa, which is a theoretical value of 1374 N.

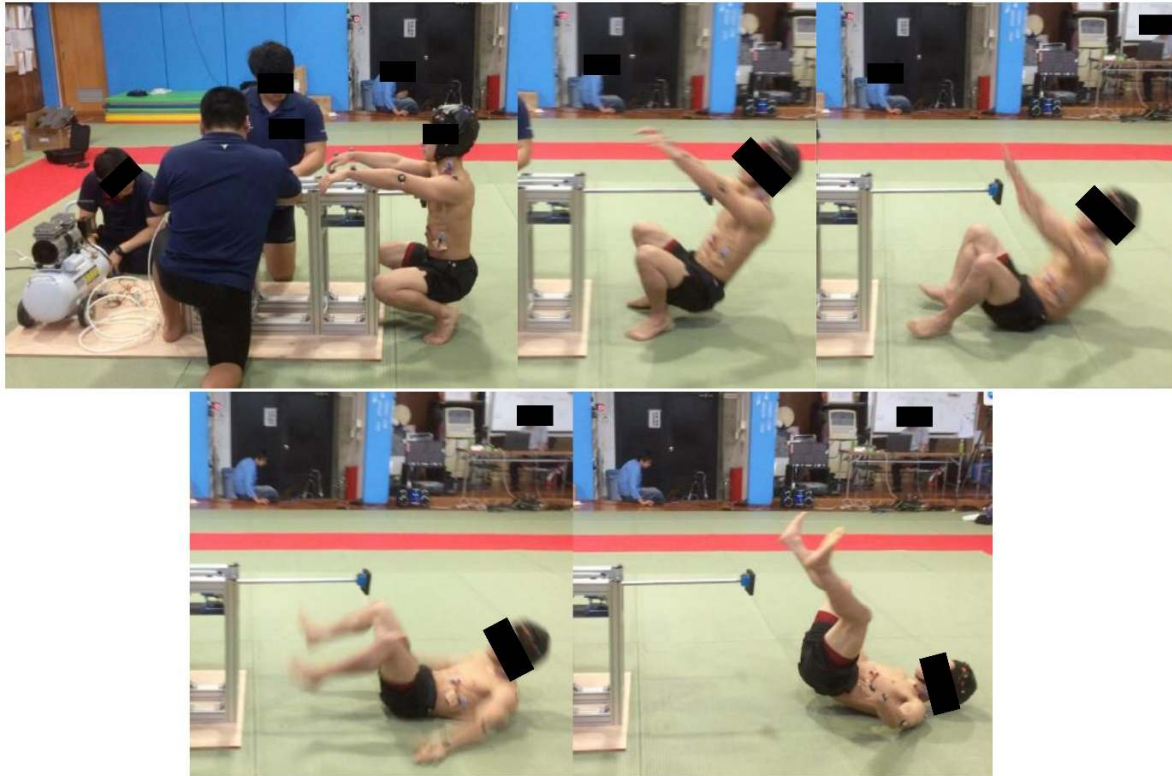


Figure 1. The experiment of backward breakfall

Measurement method

In this study, we measured the participants' head angular acceleration and head extension angle in the sagittal plane (around the x-axis) (Fig. 2); it has been shown that angular acceleration in the sagittal plane is closely related to head injury (Gennarelli & Thibault, 1982; Ommaya & Gennarelli, 1974). Moreover, we performed this measurement because head injury occurs when a person who is unable to perform a backward breakfall and strikes the back of the head (All Japan Judo Federation, 2015, 2020b).

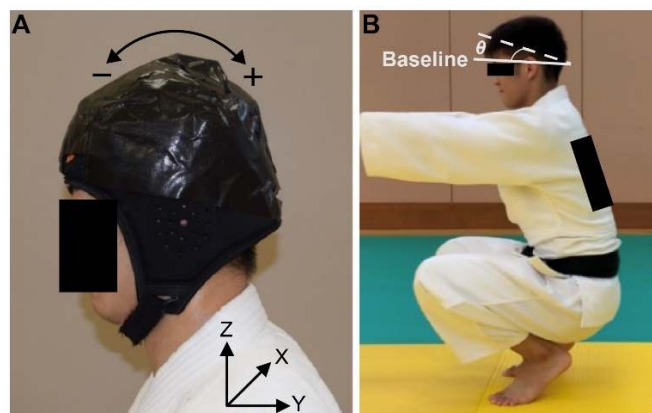


Figure 2. (A) Definition of x-axis head angular acceleration. (B) Definition of head extension angle, θ

Head angular acceleration was measured by numerically differentiating the angular velocity obtained from attaching a three-axis angular velocity sensor (MVP-RF8-GC, MicroStone, Inc.) to the headgear; the sampling frequency of the three-axis angular velocity sensor was set to 200 Hz, and calibration was performed. For safety reasons, the participant wore a headgear (d3o, LAB) and performed each of the three backward breakfalls in the closed-eye and open-eye conditions.

The head extension angle was measured using motion capture (Motion Analysis, Corp., CA, USA). The head extension angle was measured from the movement of a plane passing through three markers attached to the center of the frontal region and the right and left sides of the temporal region. The head extension angle was calculated as the difference between the angle of the plane when the participant was pushed and the angle of the plane in the mid-back position before the participant was pushed (Fig. 2B).

Statistical analysis

The values of head angular acceleration and head extension angle were the average values of the three backward breakfalls. For the head extension angle, the initial angle was calculated as 0°. Next, we compared the maximum angular acceleration of the head in the closed-eye and open-eye conditions and the head extension angle in the closed-eye and open-eye conditions. An example of the transition of head extension angle between the closed-eye and open-eye conditions is shown.

For statistical processing, the Wilcoxon signed-rank test (for non-parametric variables) was used. The level of statistical significance was set at $p < 0.05$. Cohen's r was used to calculate the effect size. The effect size was evaluated as small (0.1–0.3), medium (0.3–0.5), or large (>0.5) using SPSS Statistics ver. 20.0 (Armonk, NY: IBM Corp.).

Results

The maximum angular acceleration of the head in the closed-eye condition ($419.7 \pm 247.2 \text{ rad/s}^2$) was significantly higher than that in the open-eye condition ($331.0 \pm 167.0 \text{ rad/s}^2$) (Fig. 3A, $p < 0.05$, $r = 0.58$). There was no significant difference in the head extension angle between the closed-eye conditions ($93.8^\circ \pm 16.0^\circ$) and the open-eye conditions ($86.0^\circ \pm 14.2^\circ$) (Fig. 3B, *n.s.*, $r = 0.29$). Fig. 4 shows an example of the transition of the head extension angle and backward breakfall posture.

The participant's neck is bent forward in reaction to the pushing force of the extruder on his chest, and the head extension angle decreased the most (approximately -15° for both conditions, Fig. 4A). Thereafter, the head of both participants fell backward, and the head extension angle increased rapidly. When the participant's back touched the tatami mat, the increase in head extension angle temporarily stopped (closed-eye condition: approximately 40° , open-eye condition: approximately 20° , Fig. 4B). However, the head fell further backward, and the head extension angle reached its maximum (closed-eye condition: approximately 80° , open-eye condition: approximately 70° , Fig. 4C).

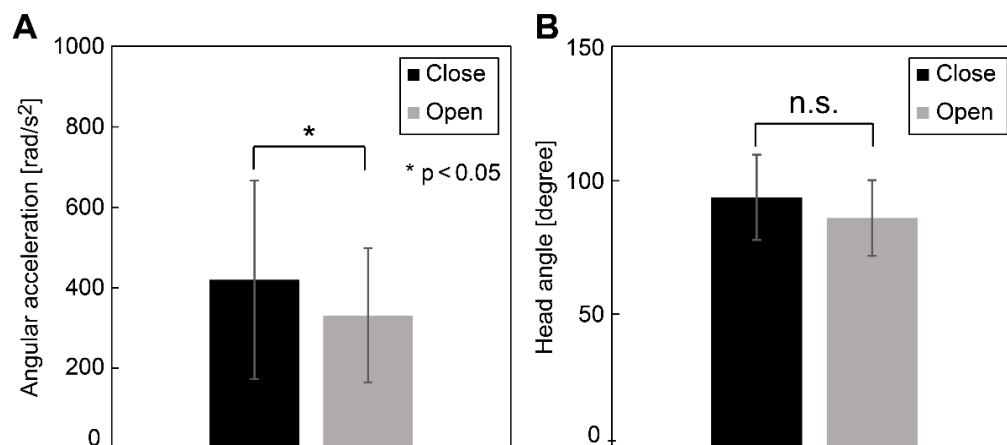


Figure 3. Results of (A) x-axis head angular acceleration. (B) Change in head extension angle calculated with the initial angle as 0°. * $p < 0.05$ (statistical analysis was performed using the Wilcoxon signed-rank test)

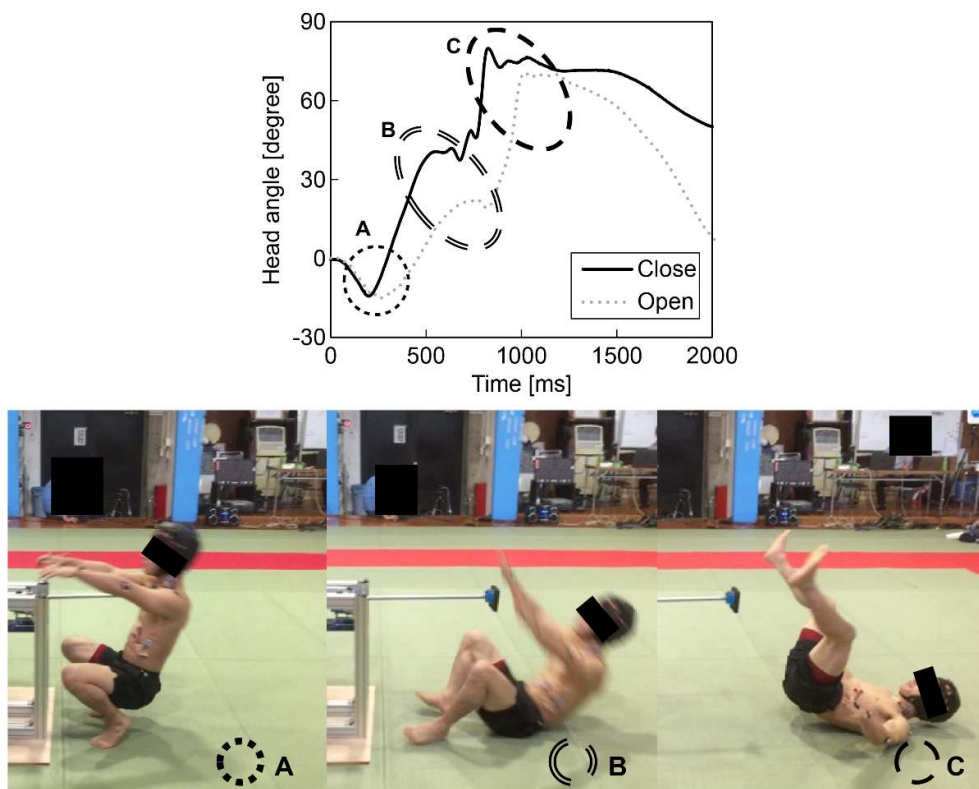


Figure 4. Results of an example of the transition of head extension angle calculated with the initial angle as 0°. (A) The push scene. (B) The scene where the waist and back begin to hit the tatami mats. (C) The scene where the participant's head is closely approaching the tatami mat.

Discussion

The maximum angular acceleration of the head when the participant was pushed in the closed-eye condition and when the participant performed a backward breakfall was higher than that in the open-eye condition, indicating that the risk of head injury was higher when the participant was thrown unexpectedly (Fig. 3A). Thus, our results demonstrate that being thrown unexpectedly is a risk factor for the occurrence of head injury in judo.

As a safety measure to prevent head injuries in judo, it was proposed that the neck muscles should be strengthened (All Japan Judo Federation, 2015; Iteya, 2012; Okada et al., 1991) since the cervical muscle strength is related to the backward breakfall movement (Fujita et al., 2013). In addition, it was considered that the strength of the neck muscles in novice students in junior high school and high school, who are more predisposed to head injuries, is low. However, the cervical muscle strength of the skilled university students was estimated to be high. Further, it was reported that the cervical muscle strength of skilled university students (17.5 kg forward bending) is two to three times greater than that of junior high school (6.4 kg forward bending) and high school (8.4 kg forward bending) students (Hayashi, Anata, Uchimura, Shoda, & Ishikawa, 2020a, 2020b).

There are two possible reasons why the maximum angular acceleration of the head in the closed-eye condition increased and the risk of head injury increased, despite the appreciable neck muscle strength of the skilled university students. The first is a delay in the response to a pushing force, because regardless of the strength of the cervical muscles, if the response to a pushing force is delayed, subsequent contraction of the cervical muscles would also be delayed. This delay in response can be confirmed by the fact that the angle of head extension in the closed-eye condition increased more rapidly than in the open-eye condition (from approximately -15° to approximately 40° and from approximately -15° to approximately 20°, respectively, Fig. 4). The second possible reason is a delay in the contraction of the cervical muscle. This is because regardless of how fast a person responds to a pushing force or how strong the neck muscles are, if there is a delay in contraction of the neck muscles, the speed at which the head falls backward will increase. Therefore, in the closed-eye condition, it seems plausible that the preparation for the backward breakfall movement was delayed and subsequent contraction of the neck muscle was also delayed. In contrast, in the open-eye condition, reaction to the push and contraction of the neck muscles was not delayed and the speed at which the head fell backward was reduced. Moreover, the maximum angular acceleration of the head did not increase.

Ishikawa, Anata, Hayashi, Uchimura, & Okada (2020a) conducted an experiment in which 15 male university judo club members were asked to perform high-intensity exercises and were then thrown with the "osoto-gari" throwing technique. The authors reported that fatigue caused by high-intensity exercise did not reduce the neck muscle strength, but significantly increased the maximum angular acceleration of the head. The

authors concluded that this was because fatigue slowed down the speed at which neck muscles contracted. In the present study, it was inferred that the delay in the contraction of the neck muscle was closely related to the occurrence of head injury in judo. However, since the speed of cervical muscle contraction was not measured in both studies, it is essential to clarify the relationship between the speed of cervical muscle contraction and the angular acceleration of the head using electromyography in the future.

Moreover, since the maximum angular acceleration of the head was higher in the closed-eye condition than in the open-eye condition, it is expected that the head extension angle would also be greater in the closed-eye condition than in the open-eye condition. However, no significant differences were found in this study. We believe that the reason for this is that the participants were judo experts, and because judo experts can instantly contract their cervical muscles to suppress head swing even if the angular velocity of the head increases rapidly due to delayed reaction to a push in the closed-eye condition. This phenomenon can further be explained by the fact that, immediately after the participant is pushed by the extruder (Fig. 4A), the head extension angle in the closed-eye condition increases to approximately 40°, but the head extension angle in the open-eye condition increases to only approximately 20° (Fig. 4B), and then the head extension angles in both conditions remain the same at approximately 50° (Fig. 4C).

The All Japan Judo Federation pointed out that poor breakfall skills was a factor in the occurrence of head injuries, as head injuries occurred more frequently in the junior high school and high school beginners. Assuming that the delayed reaction to throwing techniques and delayed contraction of the neck muscles are considered breakfall skills, it would be easy to understand that, from the results of this study, head injuries are more frequent in beginners since experts have a prompt response to throwing techniques and can instantly contract their cervical muscle to perform a backward breakfall, and are less likely to hit their heads on the tatami mat. Conversely, novices often hit their head on the tatami mat because of their delayed response to throwing techniques and their inability to instantly contract their cervical muscles to perform a backward breakfall. Therefore, to reduce the risk of head injury in judo, it is desirable to actively introduce training in which an athlete is pushed by another person and the athlete instantly performs a backward breakfall. Moreover, it has been pointed out that to enhance reactivity to disturbances in various contact sports, it is necessary for athletes to learn tasks that allow them to react as quickly and strongly as possible to unexpected disturbances (Kimura et al., 1993). Therefore, it is necessary to develop backward breakfall training that incorporates unexpected conditions, while considering safety.

In this study, however, we did not measure the angular acceleration and extension angle of the head of beginners; thus, we could not make inferences based on a comparison with the angular acceleration and extension angle of the head of experts. In addition, we did not demonstrate the effects of training for instantaneous backward breakfall after a push or the effects of training for backward breakfall, including conditions of an unexpected push. It is necessary to verify these points in the future. Although there was no significant difference in the head extension angle between the closed- and open-eye conditions, the effect size (r) was 0.29, which is close to the medium level. Therefore, it is predicted that a significant difference in head extension angle between the closed- and open-eye conditions will be observed by increasing the number of participants and the pushing force of participants in future studies.

Conclusions

1. The maximum angular acceleration of the head was significantly higher in the closed-eye condition (419.7 rad/s²) than in the open-eye condition (331.0 rad/s²) ($p < 0.05$).
2. There were no significant differences in the head extension angles of university judo experts when they were pushed for a backward breakfall (*n.s.*) between closed-eye (93.8°) and open-eye (86.0°) conditions.
3. In judo, being thrown unexpectedly is a risk factor for head injury, which may be related to delayed reaction to the throwing technique and delayed contraction of the neck muscle.
4. To prevent head injuries in judo, it is important to increase the speed of reaction to throws and speed of contraction of the neck muscle.

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Declaration of Interest Statement

The authors declare that there is no conflict of interest.

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