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Original Article

Effects of unexpectedness on the risk of head injuries in judo novices and experts

HIRONORI HAYASHI[1], KENJI ANATA[2], YOSHIHISA ISHIKAWA[3], HIDEKAZU SHODA[4]
[1] Faculty of Sport Study, Biwako Seikei Sport College, JAPAN
[2] National Institute of Technology, Ishikawa College, JAPAN
[3] Faculty of Education, Osaka kyoiku University, JAPAN
[4] School of Physical Education, Osaka University of Health and Sport Sciences, JAPAN

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Abstract
Problem Statement: Serious judo accidents in Japan have been reported worldwide since 2012. Currently, the number of serious judo-induced head injuries, such as acute subdural hematomas, is significantly reduced in Japan, indicating that the safety measures taken by the All Japan Judo Federation have been successful. However, head injuries such as concussions are still being reported, and the risk of serious head injuries remains. When a judo athlete is unexpectedly attacked, such as using a feint, Ukemi techniques to protect the head are often delayed. Thus, head injuries are more likely to occur when being thrown unexpectedly. **Purpose**: The present study clarifies the effects of unexpected conditions on the incidence of head injury in novice and expert judokas among junior high school, senior high school, and university students and elucidates the relationship between cervical muscle strength and the risk of head injury. **Approach**: Participants included 20 junior high school students (11 judo novices, 9 judo experts), 20 senior high school students (5 judo novices, 15 judo experts), and 15 university students (5 judo novices, 10 judo experts). Participants performed backward breakfalls after being pushed with a constant force under unexpected (while performing a mental addition task) and expected (not performing this task) conditions. **Results**: Among junior high school student judo novices, the maximum head angular accelerations during backward breakfalls were significantly different between the unexpected and expected conditions. The results showed that junior high school judo novices were at an extremely high risk of head injury under unexpected conditions. In the entire study population, no correlation was found between cervical muscle strength (anterior flexion) and angular acceleration of the head. **Conclusions**: To prevent head injuries, unexpected attacks, such as feints, should be avoided among junior high school judo novices.
***Key Words*: Head injury safety measures; Backward breakfall; Head angular acceleration; Cervical muscle strength; Judo novices**

Introduction

Serious judo accidents in Japan have been reported since 2012 (Krieger & Norica-Panayota Kitano, 2013). From 1983 to 2011, 118 fatalities occurred in judo club activities, mainly in junior high and high schools (Uchida, 2013). Of these, 73 (70.9%) were head injuries such as acute subdural hematoma, which are more common among novices. In addition, 18 (24.7%) deaths resulted from being thrown by Osoto-gari. There were 275 disabling accidents (Japan Judo Accident Victims Association, 2017). No fatal accidents occurred from 2012 to 2014. However, 13 serious accidents were reported from 2015 to 2019; among which was acute subdural hematoma in two elementary school students in 2019 (All Japan Judo Federation, 2019).

Serious judo-induced head injuries, such as acute subdural hematomas have significantly decreased in Japan, indicating the success of the safety measures taken by the All Japan Judo Federation (2015, 2020a). Although measures to prevent coronavirus disease 2019 (COVID 19) transmission have restricted judo practice and matches (All Japan Judo Federation, 2020b), head injuries such as concussions are still being reported (All Japan Judo Federation, 2020c, 2021, 2022). In recent years, novice-specific head trauma has also occurred among experts, suggesting a common cause of head trauma among novices and experts. The end of the COVID 19 pandemic and resumption of judo practice and matches resume are likely to reduce the risk of fatal head trauma.

Judo-related head injuries have been reported overseas; the British Judo Association (2020) and the Canadian Judo Federation (Judo Canada, 2020) have established guidelines for preventing concussions. Safety measures should be continually strengthened, guided by research on the prevention of head injuries. Recent studies have revealed high risks of head injury in different judo throwing techniques (Hashimoto et al., 2015; Ishikawa et al., 2018; Koshida et al., 2012, 2017; Murayama et al., 2014); for example, Murayama et al. (2020a, 2020b) threw an anthropomorphic test device to verify the impact to the head and found that the impact of Seoi-nage, Osoto-gari, and Ouchi-gari is similar when the head hits the tatami mat. Vacca, Rosso, and Gastaldi (2020)

Corresponding Author: HIRONORI HAYASHI, E-mail: hayashi-hir@g.bss.ac.jp

experimented by throwing a human and noted that the angular velocity of the head in Ippon-Seoi-nage is greater and more dangerous than in Osoto-gari and Ouchi-gari. However, these studies have limited value regarding head injury safety as the factors causing head injury have not been clarified. Further studies are required to identify these factors and determine specific safety measures.

Studies on the causes and prevention of head injury in judo, such as those by Ishikawa et al. (2017, 2021), have revealed that a higher body weight of the thrower than that of the person being thrown is a factor in the occurrence of head injuries, with the risk of head injury increasing when the thrower is ≥ 18 kg heavier than the person being thrown. These findings suggest that practice with such a weight difference between judo athletes should be avoided. Moreover, Ishikawa et al. (2020) reported that short-term fatigue due to repetitive throwing increases the risk of head injury and implying that it is important to take appropriate rest periods even during short-term high-intensity exercise. In addition, Zhang et al. (2017) proposed a traumatic brain injury risk evaluation during Judo based on reconstruction analysis of accident cases; however, no safety measures were indicated in the study. Hayashi, Ishikawa, and Shoda (2022) proposed a safe way to apply Osoto-gari that lowers the risk of head injury.

A novel research-based perspective suggests that the characteristics of judo competitions (i.e., the occurrence of unexpected conditions) may increase the risk of head injuries (Hayashi, Anata, & Ishikawa, 2022). In judo practice and competitions, feints are sometimes used to throw an opponent. For example, an athlete may pretend to throw the opponent forward with a Seoi-nage (Daigo, 1999a), but will actually throw the opponent backward with a Kouchi-gari (Daigo, 1999b). When an attacker feints in such a way, the opponent's defensive response is delayed, which inevitably delays the Ukemi action to protect the head; thus, such feints are a factor in the occurrence of head injuries. In the experiment by Hayashi, Anata, and Ishikawa (2022), university student judo experts performed backward breakfalls while closing their eyes to reproduce the unexpected condition. The authors indicated that unexpectedness was a factor in head injury as the risk of head injury in the unexpected condition was increased. However, the study did not address three issues. First, the degree of unexpectedness is too high in their experiment because the eyes are never kept closed during judo practice and competition. Therefore, it is necessary to conduct an experiment with an appropriate degree of unexpectedness. Second, the participants were university student judo experts; this is not the age group in which head injuries frequently occur. Third, the relationship between cervical muscle strength and the risk of head injury was not examined. Since it has been pointed out that cervical muscle strength plays a major role in the prevention of head injury due to the immobilization of the head (All Japan Judo Federation, 2015, 2020a; Fujita et al., 2012), the relationship between cervical muscle strength and the risk of head injury should be examined.

Hence, the present study aimed to clarify the effects of unexpected conditions on the incidence of head injury in novice and expert judokas among junior high school, senior high school, and university students and elucidates the relationship between cervical muscle strength and the risk of head injury.

Material & methods

Study design and setting

This research was conducted at Osaka Sangyo University in September 2019. In July 2019, we recruited junior high school, senior high school, and university judo players geographically located near Osaka Sangyo University through introductions by the coach of each judo club.

Study population

In this study, we defined judo novices as individuals with a white belt and less than 1 year of judo experience; we defined judo experts as individuals with a black belt. The participants were 20 male junior high school students (13–15 years old) (11 judo novices, 9 judo experts), 20 male senior high school students (16–18 years old) (5 judo novices, 15 judo experts), and 15 male university students (19–22 years old) (5 judo novices, 10 judo experts) (Table 1). The study participants were informed of the purpose and methods of this study orally and in writing, and consent was obtained before the experiment was conducted. This study conforms to the directive of the Helsinki Declaration. The study was approved by the Research Ethics Review Committee of Biwako Seikei Sport College (Seisu No. 53).

Measurement methods

We measured participants' head angular accelerations in the sagittal plane (around the *x*-axis) using a headgear device (D3O headgear, Budogear Corp., Japan) with a triaxial angular rate sensor (MVP-RF8-GC, MicroStone Corp., Japan). We set the sampling frequency of the triaxial angular rate sensor to 200 Hz and performed the calibration. In addition, participants' age, height, weight, judo degree, years of judo experience, cervical muscle strength (anterior flexion), and cervical muscle strength (posterior flexion) were recorded. We used a manual weight gauge (Movi MT100, SAKAImed Corp., Japan) to measure cervical muscle strength. The head is anchored by the cervical muscles, and the sternocleidomastoid muscles are critical for the safe performance of a backward breakfall (Fujita et al., 2012). Participants were immobilized with the shoulders in a supine position and were asked to lie with their backs on the bed; both their shoulders were fixed at the end of the bed according to the methods described by Okada et al. (1991), Fujita et al. (2012), and Ishikawa et al. (2021). Next, a manual weight gauge was applied to the participant's eyebrows and occipital region, and cervical flexion (anterior and posterior) was performed.

Since it is not safe to throw a person in an unexpected condition, we decided to have the participants perform backward breakfalls instead of throwing them. Participants performed backward breakfalls after being pushed by a device generating a constant force of 1094 N at a speed of 200 mm/s with (hereafter referred to as "unexpected condition") or without (hereafter referred to as "expected condition") being distracted by a mental addition task (Fig. 1).

Table 1. Characteristics of the study population (n = 55)

Measurement items	Junior high school (n = 20)		Senior high school (n = 20)		University (n = 15)	
	Novices (n = 11)	Experts (n = 9)	Novices (n = 5)	Experts (n = 15)	Novices (n = 5)	Experts (n = 10)
Age (years)	13.2 (±0.4)	14.2 (±0.7)	15.6 (±0.5)	16.9 (±0.9)	21.8 (±0.4)	19.6 (±0.8)
Body height (cm)	158.5 (±6.5)	169.3 (±2.6)	170.8 (±4.5)	171.2 (±4.9)	177.0 (±2.7)	173.0 (±8.8)
Body weight (kg)	50.1 (±6.7)	65.8 (±12.1)	65.4 (±6.4)	70.6 (±12.6)	65.6 (±6.4)	88.2 (±25.3)
Judo degree (dan)	0	1 (±0)	0	1.3 (±0.5)	0	2 (±0)
Judo experience (years)	0.8 (±0.9)	3.5 (±1.7)	0.4 (±0.0)	8.3 (±4.5)	0	11.2 (±3.7)
Cervical muscle strength, anterior flexion (kg)	6.4 (±1.6)	10.7 (±2.3)	8.4 (±2.1)	12.4 (±4.4)	10.1 (±2.1)	17.5 (±5.9)
Cervical muscle strength, posterior flexion (kg)	14.6 (±1.9)	21.1 (±2.4)	21.0 (±4.7)	24.8 (±4.7)	18.7 (±1.8)	29.8 (±3.2)

Data are presented as the mean (±standard deviation).

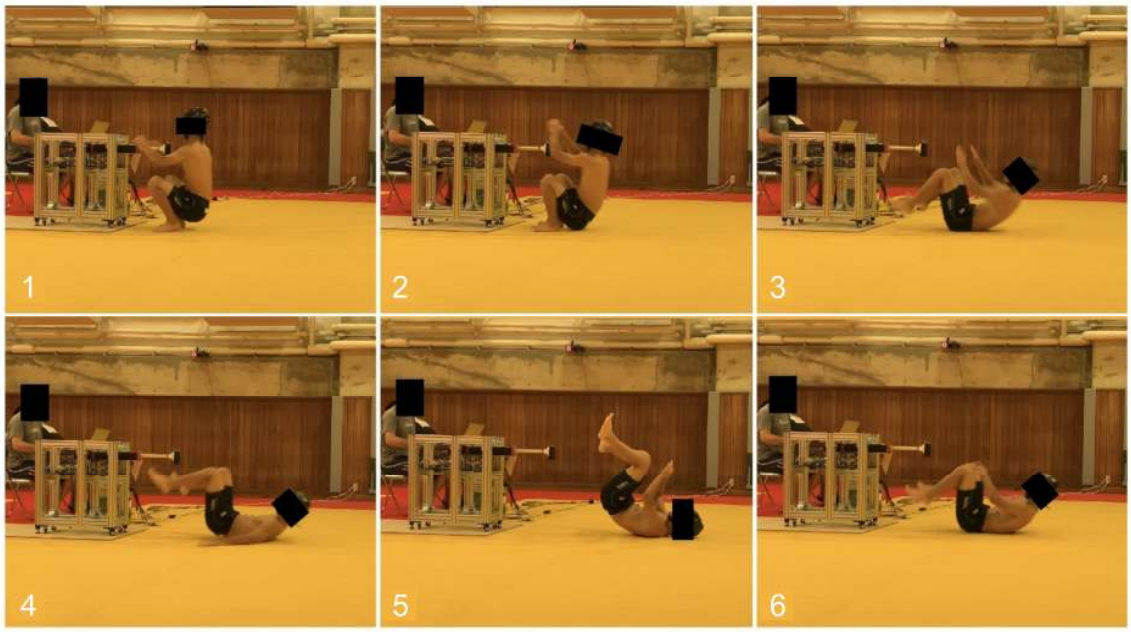

Fig 1. Example of a backward breakfall

Statistical analysis

The maximum head angular acceleration values recorded during backward breakfalls under the unexpected and expected conditions were compared for each skill level in each age group. We calculated the maximum head angular acceleration from the mean value of three backward breakfall attempts. We used the nonparametric Wilcoxon's signed rank test for statistical analysis after tests for normality (Shapiro–Wilk test) indicated non-normal data distributions. Given that cervical muscle strength (anterior flexion) is closely related to the prevention of head injury, the correlation between cervical muscle strength (anterior flexion) and angular acceleration of the head was analyzed using Spearman's rank correlation coefficient, a nonparametric test. The level of significance was set to < 5%. We used Cohen's r to calculate the effect size, which was categorized as small (0.1–0.3), medium (0.3–0.5), or large (> 0.5). Analyses were performed with the IBM SPSS Statistics ver.20.0 (IBM Corp., Armonk, NY, USA) statistical software.

Results

Among junior high school student judo novices, the maximum head angular accelerations during backward breakfalls were significantly different between the unexpected and expected conditions ($p < 0.01$, $r = 0.57$). By contrast, among junior high school student judo experts, the maximum head angular acceleration values during backward breakfalls showed no significant differences between the unexpected and expected conditions (Fig. 2).

The maximum head angular acceleration values when senior high school student judo novices performed backward breakfalls in the unexpected and expected conditions demonstrated no significant differences. The maximum head angular accelerations when senior high school judo experts performed backward breakfalls in the unexpected and expected conditions were compared, and no significant difference was found (Fig. 2).

The maximum head angular accelerations when university student judo novices performed backward breakfalls in the unexpected and expected conditions were also compared; again, no significant difference was detected. Similarly, no significant difference was identified among university students who were judo experts (Fig. 2).

No correlation was found between cervical muscle strength (anterior flexion) and head angular acceleration in all participants and subgroups (Table 2).

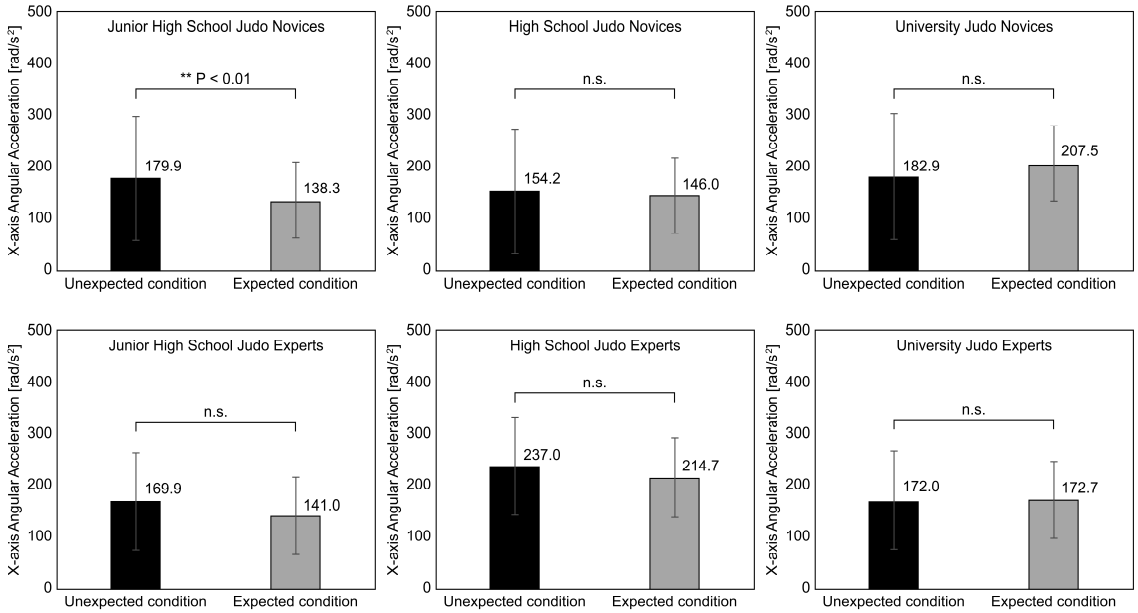

Fig 2. Comparison of the maximum *x*-axis head angular acceleration values between the unexpected and expected conditions in the different study subgroups. n.s., not significant

Table 2. Associations between cervical muscle strength (anterior flexion) and *x*-axis angular acceleration

Student categories	Judo level	R^2	
		Unexpected condition	Expected condition
Junior high school	Novices	0.125	0.099
	Experts	0.000	0.029
Senior high school	Novices	0.053	0.102
	Experts	0.122	0.105
University	Novices	0.229	0.029
	Experts	0.072	0.010
All		0.000	0.009

Discussion

This study evaluated the effects of unexpected conditions on head injuries in novice and expert judokas among junior high school, senior high school, and university students and clarified the relationship between cervical muscle strength (anterior flexion) and the risk of head injuries. We found that among the assessed groups, only junior high school student judo novices showed significant differences in the maximum head

angular accelerations during backward breakfalls between the unexpected and expected conditions. No significant differences between these conditions were noted in the other participant groups. No correlations were observed between cervical muscle strength (anterior flexion) and head angular acceleration in all participants and subgroups.

Hayashi, Anata, and Ishikawa (2022) previously examined the maximum angular acceleration of the head among university student judo experts during backward breakfalls under unexpected and expected conditions and reported that the maximum head angular acceleration was significantly increased under unexpected conditions. In the present study, the same experiment was conducted on university student judo experts; however, no significant difference was found between the unexpected and expected conditions.

Two reasons might account for this. First, the force pushing the participants in the present experiment (1094 N) was weaker than that in the experiment by Hayashi, Anata, and Ishikawa (2022) (1374 N), and this might have slowed the speed of the backward fall in the present study. Second, since the degree of unexpectedness was lower in the current study than that employed under the closed-eye condition in the previous study, participants could perceive the moment of being pushed more rapidly in the present study and, thus, were able to better control the speed at which they fell backward. We believe that these reasons contribute to the lack of significant differences in the maximum head angular acceleration values between the unexpected and expected conditions when junior high school judo experts, senior high school judo novices and experts, and university student judo novices performed backward breakfalls.

The maximum head angular acceleration showed significant differences when junior high school judo novices performed backward breakfalls under the unexpected and expected conditions; this may be because the cervical muscle strength of junior high school judo novices was weak and their proficiency (judo experience) in backward breakfalls, which facilitates the protection of the head, was not sufficient (Table 1). However, cervical muscle strength (anterior flexion) was not correlated with head angle acceleration in any of the study groups, meaning that the cause of the observed difference is not the weakness of cervical muscle strength among junior high school judo novices but rather a lack of proficiency in backward breakfalls.

The fact that the maximum head angular acceleration was elevated despite the weak pushing force and the low degree of unexpectedness in this experiment means that junior high school judo novices are at an extremely high risk of a head injuries. The All Japan Judo Federation (2020a) reported the following case numbers for acute subdural hematomas in 2003–2019: 16, two, and three in first-, second-, and third-year junior high school students, respectively; and 13, five, and one in first-, second-, and third-year high school students, respectively. Furthermore, the incidence of acute subdural hematoma was higher among judo novices.

Since most of the 11 junior high school judo novices enrolled in the present study were first-year junior high school students (9/11), the risk of head injury is highest among first-year junior high school novices. Therefore, head injuries in junior high school judo novices can be prevented by not attacking them using feints or other means that catch them off-guard.

Hayashi, Anata, and Ishikawa (2022) reported that skilled university student judokas had a faster reaction to throws and could instantly contract their cervical muscles to perform backward breakfalls, resulting in fewer hits to the heads on the tatami mats. The authors pointed out that the heads of judo novices often hit the tatami mats due to the delayed reaction to throwing maneuvers and the inability to instantly contract the cervical muscles while performing backward breakfalls. The slow speed of contraction of the cervical muscles may have influenced the elevation in the maximum head angular acceleration of junior high school judo novices during the unexpected condition in the present study. Therefore, the speed of contraction of the cervical muscles is one of the factors in the proficiency of backward breakfalls, which is congruent with the results of the study by Ishikawa et al. (2020) showing that a slow speed of contraction of the cervical muscles may influence the rise in the maximum head angular acceleration.

Our data suggest that the cervical muscle strength of skilled judokas is much higher than that of judo novices. Recent studies also report that head injuries occur in skilled judo athletes with strong cervical muscles (All Japan Judo Federation, 2020c, 2021, 2022); this study suggests that head injuries in judo are not only related to cervical muscle strength but also the speed of cervical muscle contraction. It is important to measure the speed of cervical muscle contraction in future studies on head injuries in judo athletes.

The present study is not without limitations. We did not measure the speed of cervical muscle contraction in the present study; hence, further investigations are warranted to verify these results.

Conclusions

The present study clarifies the effects of unexpected conditions on the incidence of head injury in novice and expert judokas among junior high school, senior high school, and university students and elucidates the relationship between cervical muscle strength and the risk of head injury. Participants performed backward breakfalls after being pushed with a constant force under unexpected (while performing a mental addition task) and expected (not performing this task) conditions. As a result, the following was found.

1. Among junior high school student judo novices, the maximum head angular accelerations during backward breakfalls were significantly different between the unexpected and expected conditions. By contrast, among

junior high school student judo experts, the maximum head angular acceleration values during backward breakfalls showed no significant differences between the unexpected and expected conditions.

2. The maximum head angular acceleration values when senior high school student judo novices performed backward breakfalls in the unexpected and expected conditions demonstrated no significant differences. The maximum head angular accelerations when senior high school judo experts performed backward breakfalls in the unexpected and expected conditions were compared, and no significant difference was found.
3. The maximum head angular accelerations when university student judo novices performed backward breakfalls in the unexpected and expected conditions were also compared; again, no significant difference was detected. Similarly, no significant difference was identified among university students who were judo experts.
4. No correlation was found between cervical muscle strength (anterior flexion) and head angular acceleration in all participants and subgroups.

Therefore, under unexpected conditions, junior high school judo novices are at extremely high risk of head injury. To prevent head injuries, unexpected attacks, such as feints, should be avoided among junior high school judo novices.

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Conflicts of interest

The authors report that there are no competing interests to declare.

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