**Type of manuscript**: Short Communication

**Title**
The incidence of concussions in male mixed martial arts competitions is related to the number of previous knockout losses and the number of matches.

**Short Title**
Concussions are related to number of previous KO losses and number of fights

**Authors**
Shinnosuke Hada* 1,2  shada@juntendo.ac.jp
4-13-21, Oomoriminami, Ota-ku, Tokyo 143-0013 JAPAN
Phone No: +81-(3)-3742-7301  Fax No: +81-(3)-3744-9310

Sungdo Kim 3
Kei Kawaguchi 4
Kazuo Kaneko 2
Muneaki Ishijima 2
Yoshimasa Tomita 1
Kazuo Isayama 5

**Affiliations**
1 Dept. of Orthopaedic surgery, Tokyo Rosai Hospital., Tokyo, JAPAN
2 Dept of Orthopaedic Surgery, Juntendo University School of Medicine ., Tokyo, JAPAN
3 Mizue Orthopedic Clinic ., Tokyo, JAPAN
4 Kawaguchi orthopedic clinic ., Shizuoka, JAPAN
5 Tama Neurosurgery Clinic ., Kanagawa, JAPAN

**Number of tables and figures**: 5

**Brief running title**
Concussions in mixed martial arts is related to previous knockout losses.
Abstract

Mixed Martial Arts (MMA) is a combat sport with a high incidence of concussions, including knockouts (KO) due to direct attacks to the head. Once a concussion occurs in a fighter, the rate of concussion recurrence increases. Therefore, participation in matches may be weakened as fighters experience repeated concussions. In this study, we investigated the relationship between the occurrence of concussions in male mixed martial arts athletes during the most recent match and their past match records. The analysis included 104 male fighters who competed in elite-level professional MMA competitions. In the most current match, 44 fighters experienced concussions and 60 fighters did not experience concussions. Previous KO losses (mean, 2.9) were significantly higher in the fighters with concussions compared with the fighters who did not suffer concussions (p < 0.0001). Concussion rates (65.0%) were significantly higher in fighters with three or more previous KO losses compared with the rates for fighters with less than 3 previous KO losses (p = 0.03). The odds ratio for the occurrence of concussions in fighters with a history of KO losses was 2.3 times that of fighters without a history of KO losses (p = 0.004). Fighters who had competed in more than 30 matches had a significantly higher incidence of concussions (60.8%) than fighters who had competed in less than 30 matches (37.0%) (P = 0.04). The occurrence of concussions in male MMA fighters is related to the number of previous KO losses and the number of matches.

Keywords: Mixed Martial Arts, Combat sports, Collision sports, Concussion, Chronic traumatic encephalopathy, Head injury.
タイトル

男子総合格闘技における脳振盪の発生率は、過去のノックアウト負けの回数と出場試合数に関連する

羽田晋之介 1,2  金成道 3 川口慶 4
金子和夫 2  石島亀章 2 富田善雅 1 諸山和男 5

所属機関
1 東京労災病院  整形外科
2 順天堂大学医学部  整形外科学講座
3 瑞江整形外科
4 かわぐち整形外科
5 多摩脳神経外科

要約

総合格闘技は打撃、投げ技、関節技など全ての攻撃が許され、頭部への直接攻撃のよるノックアウト（KO）をはじめとして脳振盪の発生率は非常に高い。一度脳振盪を起こすと再発の確率が高まるとされていることから、過去のKO負けの回数や出場試合数が多く、受傷機会が多かった選手は、頭部への衝撃に対して打たれ弱くなっていく可能性がある。本研究では男子総合格闘技選手の直近試合における脳振盪発生の有無と、当該選手の過去の戦績との関連について後ろ向き調査を行った。エリートレベルのプロ総合格闘技大会に出場した、男子104選手を対象とした。出場試合において脳振盪を受傷した群は過去のKO負けの回数が平均2.9回であり、受傷しなかった群（1.2回）に比べ有意に多かった（p<0.0001）。また、3回以上のKO負けがある選手は、脳振盪の発生率（65.0%）が1-2回の選手（40.5%）に比べ有意に高かった（p=0.03）。また、1度でもKO負けをしたことのある選手の脳振盪発生オッズ比は一度もKO負けをしたことのない選手の2.3倍であった（p=0.004）。また、過去に30試合以上出場している選手は脳振盪の発生率 60.8%と30試合未満の選手（37.0%）に比べ有意に高かった（P=0.04）。男子総合格闘技の試合における脳振盪の発生は、過去のKO負けの回数と出場試合数に関連した。
Introduction

Mixed martial arts (MMA) is a combat sport in which strikes, throws, submissions, and other attacks are allowed in all phases. The frequency of injuries is high in MMA\(^1\). Since 2000, unified rules have gradually been followed; MMA competition is maturing. Matches are decided by knockout (KO) when the opponent is knocked unconscious by a strike, a technical knockout (TKO) is declared when the referee stops a match because the opponent is unable to fight, tapped out (TO) by submission or choked, or a time out decision. With the establishment of the MMA Official Committee (JMOC) in Japan in 2018, there is a need for medical validation and intervention for MMA. Current data suggest that head injury rates among MMA athletes are as high as 228.7 for every 1000 athlete-exposures, which is significantly higher than most collision sports like hockey and football\(^2\)\(^3\). Repeated concussions may progress to chronic traumatic encephalopathy (CTE)\(^4\). CTE is known as “punch drunk” in boxing. The accumulation of damage due to KO losses and multiple concussions leads to delayed brain dysfunction, including mood disorders, memory impairment, depression, and dementia. The number of matches is a risk factor for CTE\(^5\)\(^6\). In addition, repeated concussions have a short-term effects; once an injury occurs, the next one is more likely to occur\(^6\)\(^7\). Before the development of clinical features of CTE, many authors anecdotally report a preclinical stage of impairment, whereby some boxers began to “soften up”\(^8\). Boxers experienced preclinical symptoms, described as a “groggy state” by one author, after several years of boxing or a large number of bouts (30–60). Boxers in this state become increasingly vulnerable to blows, are readily knocked down, and take longer to recover following bouts\(^6\)\(^9\). In other words, the accumulation of head damage has a significant impact on
the performance and athletic longevity of active athletes; however, the number of KO losses required for concussions to occur again is unclear. In this study, we retrospectively investigated the relationship between the occurrence of concussions and the past fighting records of active MMA fighters.

Materials and Methods

This study included 104 male fighters who competed in elite-level professional mixed martial arts competitions in Japan. The occurrence of concussions in the last one match was determined. The diagnosis of concussion was based on the presence of any of the following symptoms after an impact to the head: confirmed loss of consciousness, suspected loss of consciousness, convulsions, tonic posturing, balance disturbance or ataxia, clearly dazed, disorientation in time, place, and person, definite confusion, definite behavioral changes, or oculomotor signs (e.g., spontaneous nystagmus). The concussion diagnosis was confirmed by the official doctor during matches, a post-match medical check, or video check\(^{10}\). The past match records of the fighters were examined and information on the number of matches, wins and losses, and the number of KO losses (including TKO losses due to head blows) was compiled.

Fighters were divided into two groups: a concussions group and a non-concussion group, according to if the fighter experienced a concussion in the most recent match. The past results were compared between the two groups using independent t-tests. The fighters were divided into groups based on the number of past KO losses and the concussion rates in the most recent matches were compared using one-way analysis of variance and chi-square tests. The odds ratio for the occurrence of concussion in fighters with a history of KO losses was calculated by comparing the fighters with a history of
KOs to fighters without a history of KO losses. The concussion rates were calculated for 0–9, 10–19, 20–29, 30+ matches and compared between the two groups of more or less than 30 games using chi-square tests. P values < 0.05 were considered significant. This study was conducted in compliance with the Declaration of Helsinki. This study was approved by the Ethics Committee of Tokyo Rosai Hospital. (approval number: 29-22).

Results

The average age of the 104 fighters was 31.2 (±5.5) years, the average height was 174.9 (±8.7) cm, the average weight was 75.2 (±22.3) kg, the average number of matches was 21.6 (±11.9), the average winning percentage was 73.9% (±15.6), and the average number of KO losses was 1.9 (±2.0). Age (32.8 vs. 30.1, P = 0.01), the number of matches (24.7 vs. 19.3, P = 0.02), the number of losses (7.6 vs. 4.7, P = 0.001), and KO losses (2.9 vs. 1.2, P < 0.001) were significantly higher in the concussion group (n=44) than in the non-concussion group (n=60). The winning percentage did not reach statistical significance (P = 0.19) (Table 1). Of the 35 fighters with no previous KO losses, 8 (22.9%) had concussions; 15 (40.5%) of the 37 fighters with 1–2 KO losses had concussions, and 21 (65.0%) of the 32 fighters with 3 or more KO losses had concussions. The incidence of concussions increased significantly with the number of KO losses (P = 0.04). All fighters with six or more KO losses had concussions (Figures 1 and 2).

The odds of concussion occurrence for fighters with at least one KO loss was 2.3 times higher (95% CI: 0.96–4.90, P = 0.004) than the occurrence in fighters with no KO losses. The odds of concussions for fighters with three or more KO losses was 2.8 times higher (95% CI: 1.03–3.25, p < 0.001) than the occurrence in fighters with no KO
losses. Of the 19 fighters who had competed in 0–9 matches in the past, 7 (36.8%) had concussions. Similarly, 11 of 32 (34.3%) fighters who had competed in 10–19 matches had concussions, 12 of 30 (40.0%) fighters who had competed in 20–29 matches had concussions, and 14 of 23 (60.8%) fighters who had competed in 30 or more matches had concussions (Table 2). Concussion rates were significantly higher in the group of fighters who had competed in more than 30 matches (60.8%) than in the group who had competed in fewer than 30 matches (37.0%, \( P = 0.04 \)) (Figure 3).

**Discussion**

The results of this study revealed that the incidence of concussions was higher in fighters with more than three previous KO losses and in those who had competed in more than 30 fights. The reason why the concussion rate increases with the number of past KO losses is that almost all KO losses are concussions, and players with many past KO losses are also players with many concussion injuries. Athletes who suffered a concussion have a four-fold increase in the rate of recurrence\(^7\). These findings suggest that the accumulation of concussion damage due to KO losses may cause structural and functional changes in the brain, progressing to the “groggy state.” Concussions increase the possibility of repeating the negative chain of events, leading to CTE. Considering how the number of matches is involved, it is possible that a large number of matches is associated with the accumulation of small amounts of damage. In boxing, the number of fights during the active period is considered to be a risk factor for the occurrence of CTE after retirement\(^6\)\(^{11}\). In support of this fact, in a longitudinal cohort study of MMA fighters and boxers, the average number of punches a fighter received to the head per match was 58(MMA) and 175(boxing), and the volume of the thalamus and caudate...
nucleus on head MRI decreased at an average of about 0.3%(MMA) and 0.4%(boxing) per match. The initial symptoms of CTE appeared more in fighters who participated more frequently in competitions\(^4\). In other words, these findings suggest that repeated minor impacts from blows to the head with little subjective symptoms may also lead to damage accumulation, in addition to obvious concussions caused by KO losses.

Concussions in MMA tend to be focused only on the serious symptoms, such as second impact syndrome and acute subdural hematoma\(^11\), and the long-term risks, such as CTE after retirement. In addition to these problems, if a fighter suffers repeated concussions, including KO losses, during the course of his career, his fighting style and competitiveness will be greatly affected. If a fighter is in a "groggy state," it is difficult to return to his previous state. For example, a fighter who was good at striking is more likely to be knocked down in a punching rally. The damage caused by head trauma accumulates, and in order for fighters to live a stable active for a long time and to stay healthy after retirement, it is necessary to work on a daily basis to minimize head damage and to inform fighters about the importance of care after a KO loss or concussion.

Important measures to prevent damage accumulation include (1) recognition of the importance of concussions, (2) avoidance of preventable damage accumulation, (3) appropriate diagnosis, (4) appropriate rest periods, and (5) return to work at appropriate times\(^5\). However, the reality is that these measured cannot be thoroughly implemented. Thanks to JMOC, refereeing techniques and safety awareness have been improved in recent years, and the opportunities to receive preventable blows such as chase after KO have been considerably reduced in high-level competitions. Hopefully, this trend will spread to all competitions. When sparring in practice, hitting in the head with full force
should be avoided, as this will cause damage to both parties; full force should be limited
to a minimum number of rounds. In the future, in addition to the number of fights and
the number of KOs and concussions, the "number of blows to the head" counted in
conjunction with the recently evolving fight analysis system may be utilized as an
important indicator.

Concussion is an injury that all ringside physicians should be familiar with,
regardless of their specialty. Medical professionals should share a unified knowledge of
diagnosis and response. Graduated return-to-play programs for MMA injuries have been
published recently\(^1\), and following these program is the standard at present. Even if the
fighter wins, the graduated return-to-play steps should be followed when the fighter is
downed or when the fighter feels a shock to the brain. Regarding the timing of return to
competition, medical suspension\(^2\) is in effect in some competitions, and wider
application should be considered in Japan. In addition, although the decision to retire is
made by the athlete himself/herself, the results of this study show 100% of athletes
experience concussions if they experience 6 or more KO losses. Information should be
provided to athletes with a high number of KO losses about the high risk of concussion
re-injury and CTE if the athlete continues to compete.

Although the lack of established imaging methods for concussion and early CTE is
also problematic, recent studies have shown that magnetic resonance spectroscopy\(^2\)
evaluation methods for concussion and early CTE and non-specific and age-related
findings, such as high signal changes in cerebral white matter on general FLAIR and
T2* imaging, are associated with concussion occurrence and cognitive function\(^3\). As
for treatment, an effective method of active intervention has not been established.

Recent findings have shown that hyperbaric oxygen therapy, which is often used to treat
In the future, the establishment of a smooth network of doctors, ring doctors, neurosurgeons, and neurologists affiliated with fighters and gyms, in parallel with information provision and educational activities for fighters and related parties would be ideal. Based on the results of this study, studies should be continued to ensure the safety of fighters, prevent performance deterioration, extend the active careers of fighters, and stabilize second careers for fighters. There may be a need to consider regulation changes for concussions in MMA in the future, as there are in other sports.

**Contributions**

SH, KK, SK, KK, MI and KI conceptualized the study design and protocol, and determined the study institutions. SH and YT collected and assembled the data. SH carried out the analysis and interpretation of data. SH drafted the manuscript. All authors have critically reviewed, revised and approved the manuscript.

**Conflicts of Interest**

All authors declare that there is no conflict of interest regarding this article.

**Acknowledgments**

We would like to express our sincere gratitude to Associate Professor Tomoki Matsumiya of Seiwa University for his advice on the competition rules, the members of JMOC for their contribution to the development of the competition management, and CEO Nobuyuki Sakakibara and Mr. Keiichi Sasahara of RIZIN FF for their
understanding of this research. Finally, we would like to thank Itaru Morohashi, Yukou Ohara, Eiji Iwasaki, Yoshiyuki Tomita, Moritoshi Yanase, and Haruka Yanase, and all the other medical staff for working with us.

References


7) Zemper ED. Two-year prospective study of relative risk of a second cerebral


therapy for post concussion symptoms: issues may affect the results. Med Gas Res 5:

15) Huang L, Obenaus A, Hamer M, Zhang JH. 2016. Neuroprotective effect of
hyperbaric oxygen therapy in a juvenile rat model of repetitive mild traumatic brain
### Table 1

Comparison of past match records with and without concussion in the most recent one match

<table>
<thead>
<tr>
<th></th>
<th>All Fighter (n=104)</th>
<th>Concussion (n=44)</th>
<th>Non-concussion (n=60)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>31.2 ± 5.5</td>
<td>32.8 ± 5.5</td>
<td>30.1 ± 5.3</td>
<td>0.01</td>
</tr>
<tr>
<td>Matches (n)</td>
<td>21.6 ± 11.9</td>
<td>24.7 ± 14.0</td>
<td>19.3 ± 9.4</td>
<td>0.02</td>
</tr>
<tr>
<td>Wins (n)</td>
<td>15.7 ± 8.5</td>
<td>17.2 ± 9.7</td>
<td>14.7 ± 7.4</td>
<td>0.16</td>
</tr>
<tr>
<td>Losses (n)</td>
<td>5.9 ± 4.6</td>
<td>7.6 ± 5.2</td>
<td>4.7 ± 3.8</td>
<td>0.001</td>
</tr>
<tr>
<td>Winning rates (%)</td>
<td>73.9 ± 15.6</td>
<td>71.6 ± 13.2</td>
<td>75.6 ± 17.0</td>
<td>0.19</td>
</tr>
<tr>
<td>KO wins (n)</td>
<td>6.1 ± 4.5</td>
<td>5.8 ± 4.1</td>
<td>6.3 ± 4.8</td>
<td>0.56</td>
</tr>
<tr>
<td>KO defeats (n)</td>
<td>1.9 ± 2.0</td>
<td>2.9 ± 2.4</td>
<td>1.2 ± 1.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>KO Winning rates (%)</td>
<td>43.3 ± 30.3</td>
<td>37.7 ± 22.5</td>
<td>47.4 ± 34.7</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Mean ± SD
Independent t-test
Figure 1

Concussion rates and number of past KO losses

<table>
<thead>
<tr>
<th>Past KO Losses (n)</th>
<th>Concussion rates(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8 (22.9%)</td>
</tr>
<tr>
<td>1</td>
<td>7 (47.1%)</td>
</tr>
<tr>
<td>2</td>
<td>8 (36.3%)</td>
</tr>
<tr>
<td>3</td>
<td>4 (57.1%)</td>
</tr>
<tr>
<td>4</td>
<td>3 (100%)</td>
</tr>
<tr>
<td>5</td>
<td>6 (85.7%)</td>
</tr>
<tr>
<td>6</td>
<td>5 (100%)</td>
</tr>
<tr>
<td>7</td>
<td>1 (100%)</td>
</tr>
<tr>
<td>10</td>
<td>1 (100%)</td>
</tr>
</tbody>
</table>
Figure 2

Comparison of concussion rates by number of past KO losses

<table>
<thead>
<tr>
<th>Past KO losses (n)</th>
<th>Concussion Rates (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>22.9% (8/35)</td>
<td>0.09**</td>
</tr>
<tr>
<td>1-2</td>
<td>40.5% (15/37)</td>
<td>0.04*</td>
</tr>
<tr>
<td>3-</td>
<td>65.0% (21/32)</td>
<td>0.03**</td>
</tr>
</tbody>
</table>

*one-way analysis of variance  
**chi-square test
### Table 2

Concussion rates and number of past matches

<table>
<thead>
<tr>
<th>Past matches (n)</th>
<th>All Fighter (n)</th>
<th>Concussion (n)</th>
<th>Non-concussion (n)</th>
<th>Concussion Rates(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9</td>
<td>19</td>
<td>7</td>
<td>12</td>
<td>36.8</td>
</tr>
<tr>
<td>10-19</td>
<td>32</td>
<td>11</td>
<td>21</td>
<td>34.3</td>
</tr>
<tr>
<td>20-29</td>
<td>30</td>
<td>12</td>
<td>18</td>
<td>40.0</td>
</tr>
<tr>
<td>30-</td>
<td>23</td>
<td>14</td>
<td>9</td>
<td>60.8</td>
</tr>
</tbody>
</table>
Comparison of concussion rates by number of past matches

![Bar graph showing concussion rates](image)

- **0-30** matches: 37.0% (30/81)
- **30+** matches: 60.8% (14/23)

Chi-square test $P=0.04$