Sports Injury and Illness after Implementation of the Web-Based Surveillance System in World Taekwondo

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ABSTRACT

Context: There is a shortage of Taekwondo epidemiology studies since the rule changes introduced by World Taekwondo in 2017.

Objective: To describe injury and illness patterns at the Muju 2017 World Taekwondo Championships (WTC) following the implementation of the web-based surveillance system by World Taekwondo.

Design: Prospective cohort study.

Setting: All injuries and illnesses were recorded during the 2017 WTC using a web-based system developed by the International Olympic Committee.

Patients or Other Participants: 971 athletes who participated in the 2017 WTC.

Main Outcome Measure(s): A profiles and mechanisms of injury and illness in the 2017 WTC.

Results: We analyzed total 131 injuries and 26 illnesses, corresponding to an overall clinical incidence of 13.5 ((95% confidence interval (CI): 11.2–15.8)) injuries and 2.7 (95% CI: 1.6–3.7) illnesses per 100 athletes, and an overall incidence rate of 19.3 (95% CI: 16.0–22.6) injuries and 3.8 (95% CI: 2.4–5.3) illnesses per 1,000 athlete-days, respectively. Most injuries occurred in the lower extremities (46.6%, n=61), of which knee injuries were most frequent (19.8%, n=26). Among the head and trunk injuries (29.8%, n=39), face injuries (22.1%, n=29) were most frequent, whereas among upper extremity injuries (23.7%, n=31), finger injuries (6.1%, n=8) were most frequent. Contusions (33.6%, n=44) were the most frequent injury type, followed by
fractures and ligament ruptures/sprains. The most common injury mechanism was in contact
with another athlete (74.0%, n=97), whereas the least common was concussions (n=5). The
major affected system was the respiratory system (30.8%, n=8), with major symptoms being pain
(42.3%, n=11) and fever (26.9%, n=7). Environmental factors were the most common cause of
illness (57.7%, n=15).

Conclusion: The web-based surveillance system used at the 2017 WTC revealed that 13.5/100
athletes (77.8/1,000 athlete-exposures, 13.9/100 minute-exposures) had new or recurrent
injuries, whereas 2.7/100 athletes became ill.

Keywords: taekwondo, epidemiologic studies, incidence, injury prevention, web-based
surveillance system

Key points:

• The clinical incidence of injury and illness following the implementation of the web-
based surveillance systems revealed 13.5 injuries and 2.7 illnesses per 100 athletes,
during the 2017 WTC.

• The knee and the ankle were the most common injury sites in the lower extremities
(46.6%).

• The injury rate after the introduction of the PSS (protector and scoring system) showed a
significant drop. Currently, the most common injury types, sites, and causes are (1) 33.6%
contusion, face, 15 contacts; (2) 23.7% fractures, fingers, 6 contacts; and (3) 16.0%
ligament ruptures, knees, 10 contacts and/or noncontact, respectively.

• Implementing the web-based injury and illness surveillance system at the WTC will
allow for a more careful investigation of injury trends over time, including the evaluation of such things as rule changes.
Introduction

Of all the 28 Olympic sports, taekwondo has been among the top five sports with the highest injury incidence across the last three Olympic Games (Beijing 2008, London 2012, and Rio 2016).¹⁻³ These results prompted the International Olympic Committee (IOC) to address the safety of taekwondo athletes.³ Since the last Olympic Games in Rio, competition rules and scoring systems have been adjusted and additional physical protection has been mandated.⁴ These rules were implemented at the 2017 World Taekwondo Championships (2017 WTC) in Muju, promoted by World Taekwondo (WT).⁵ The injury rate at the 1999 Edmonton WTC was 19.5%; however, this was before implementing the competition rule changes and standard injury and illness surveillance system.⁶

Injury reports from previous games, including the Olympics, and other epidemiological studies have had several drawbacks. First, these reports do not comply with the standardized reporting protocols (i.e., they do not report the exposure time at each competition).³,⁷ Second, because injuries and illnesses were reported by the venue’s medical staff or team physicians, there might have been some bias in reporting and diagnosis.³ Third, many medical staff hired by organizing committees (OCs) lacked sufficient knowledge and were not specialized in sports-related injuries.⁶ Therefore, prospective epidemiological studies are necessary at the Olympics and World Championships to assess the risk factors associated with, and to more accurately diagnose, athlete injuries and illnesses.⁷⁻⁹

In 2016, WT changed the competition scoring rules, which possibly results in more aggressive match styles than those observed under the previous competition scoring rules.⁴ The new competition rules have been reported to affect the location, type, mechanism, and incidence
of competition-related injuries because taekwondo athletes changing their game strategies and
subsequent training methods.\textsuperscript{7,10} This was resulted in the WT developing and initiating a web-
based injury and illness surveillance system in 2017 to identify athlete injuries and illnesses
caused by changes to new competition rules. Also, the medical and statistics committee of WT
taught medical staff about the web-based injury and illness surveillance system, emergency
manual, and on-site ultrasound use for more accurate diagnosis.

In this study, we aimed to analyze the incidence and patterns of injuries and illnesses that
occurred during the 2017 WTC following the implementation of the web-based surveillance
system by WT. Injury and illness surveillance conducted in this study can be the first step toward
designing an injury-prevention program based on the new competition rules and the protector
and scoring system (PSS) now in use. At the 2017 WTC, the PSS consisted of a chest protector
and electronic headgear to fully automate the scoring system; however, at the London and
Beijing Olympics, PSS did not include a headgear.\textsuperscript{3}

**Methods**

In this prospective cohort study, we modified the IOC injury and illness surveillance system
for better compatibility with taekwondo,\textsuperscript{3} which was implemented during the 2017 WTC that
was held over 7 days from June 24, 2017 to June 30, 2017 in Muju, South Korea.

We enrolled all taekwondo athletes who participated in the 2017 WTC and collected data
across 929 scheduled games; 87 matches did not commence because the athletes either failed to
pass the weight restrictions or withdrew from the competition.

We used two methods to collect data. First, we asked all national team physicians to report
the daily occurrence of new injuries and illnesses either on paper and/or using an online database
(XXX.com) approved by WT. Second, we collected injury and illness data from athletes who had ever been treated by OCs medical staff supervised by WT medical officers for any injury or illness at the venue’s medical center and/or specialists at designated hospitals organized by the Muju Taekwondo OCs. At five taekwondo courts, we had five sports medicine specialists (MD) and five athletic trainers (AT), one MD and one AT per each court. We received additional detailed information to the venue medical staff regarding the mechanism of injury and recorded the injury-related information and the affected area. The MD and AT were responsible for monitoring all injuries and the possibility of injury occurrence at the entry and exit points of each court. We kept a Mindray M7 ver. 2015 (Mindray North America, Mahwah, NJ, USA) portable ultrasound machine at the venue’s medical room for accurate injury diagnosis. We recorded injury data on-site and from any designated local hospitals to which the injured taekwondo athlete was transferred. The medical staff also signed the medical information release form for all injured athletes. We have received approval from the XXX University Institutional Review Board to declare ethics on the athlete’s injury and illness data (IRB no. XXX).

We modeled a paper and an online form based on those used during Rio Olympics 2016. We used the designed paper and form to report injuries and illnesses. We designed each injury or illness as new (we did not record preexisting or not fully rehabilitated conditions) or recurring (athletes having returned to full participation after a previous condition) musculoskeletal complaints, concussions, or other medical conditions (injuries or illnesses) that occurred during the competition/training at the 2017 WTC and that received medical attention, regardless of the consequences with respect to absence from the competition or training. As in the previous Olympic epidemiological study, in cases where a single incident caused multiple injury types, only the most severe diagnosis was recorded and retained, as determined by the research team on
the basis of all available clinical data for analysis.\textsuperscript{2} We defined the severities of injury and illness by the time loss from competition/training of <1, 1–3, 4–7, or >7 days, and we estimated the categorization only according to the nature of the injury at the time of diagnosis.\textsuperscript{3,12,13}

We assessed taekwondo-related injury and illness variables using univariate analysis and descriptive statistics. Injury and illness rates were calculated after evaluating the overall competition and/or training, with the clinical incidence as injuries and illnesses per 100 athletes during the 2017 WTC.\textsuperscript{3,14} Additionally, we calculated the number of injuries or illnesses per 1,000 athlete-days, where athlete-days represents the total number of athletes multiplied by 7 days.\textsuperscript{2,3} Moreover, incidence rate (IR) of competition was expressed as the number of injuries per 1,000 athlete-exposures (AEs, where one exposure is one athlete participating in one match) and per 1,000 minute-exposures (MEs, where 1 min of exposure is one athlete participating in a match for 1 min).\textsuperscript{7,14} IR of competition match was the average injury risk for one individual athlete per 1,000 AEs \([\text{no. of injuries/\text{no. of total AEs in match}}] \times 1,000\),\textsuperscript{14,15} whereas that of competition minutes was the average injury risk for one individual athlete per 1,000 min of exposure \([\text{no. of injuries/\text{no. of total MEs in match}}] \times 1,000\).\textsuperscript{7,14} The competitions at the WTC comprised three rounds of 2 min, each with a 1-min break.\textsuperscript{4} We calculated the total MEs in each match using only the actual fight time.\textsuperscript{7} We calculated the incidence rate ratio (IRR) and 95% confidence intervals (CIs) to measure the strength of the associations between males and females.\textsuperscript{14} The IRR for a male to female was calculated as a rate value per 1000/AEs. We performed all statistical analyses using SPSS v24.0 (IBM Corp., Armonk, NY, USA) and considered significant if two-tailed p-values were < 0.05.

**Results**

In total, 971 athletes participated in the 2017 WTC. Of them, 593 (61%) were males and 378
(39%) were females, with an average age of 22.9 (23.3 and 22.3, respectively) years. There were 842 matches and 4,716 MEs to competitions during the 2017 WTC. The largest weight division was <68 kg for males and <57 kg for females.

We recorded total 131 injuries and 26 illnesses, with an overall clinical incidence of 13.5 injuries (95% CI: 11.2–15.8) and 2.7 illnesses (95% CI: 1.6–3.7) per 100 athletes. This corresponds to 19.3 injuries (95% CI: 16.0–22.6) and 3.8 illnesses (95% CI: 2.4–5.3) per 1,000 athlete-days (Table 1). On an average, 8.9% (n = 86) of all athletes sustained at least one injury and 2.0% (n = 19) experienced an illness.

During the competition, we recorded 77.8 (95% CI: 64.5–91.1) injuries per 1,000 AEs with significantly higher rates in males (90.0/1,000 AEs, 95% CI: 71.4–108.6) than in females (59.9/1,000 AEs, 95% CI: 41.6–78.3). Furthermore, the total injuries per 1,000 MEs were 13.9 (95% CI: 11.5–16.3), with higher rates observed in males (16.6/1,000 MEs, 95% CI: 13.1–20.0) than in females (10.3/1,000 MEs, 95% CI: 7.1–13.4). We observed that male athletes were at a higher risk of sustaining injuries during competition than female athletes (IRR: 1.50; 95% CI: 1.04–2.17). Also, the illness incidence rate ratios in males and females athletes were similar (IRR: 1.10; 95% CI: 0.50–2.41) (Table 1).

For male athletes, our results showed that the weight division with the highest number of injuries was <68 kg (21.1%, n = 19); however, the highest injury rate per 1,000 AEs was in the weight division of >87 kg (155.6/1,000 AEs). For female athletes, the weight division with the highest number of injuries was <62 kg (29.3%, n = 12); however, the highest injury rate per 1,000 AEs was in the weight division of >73 kg (161.8/1,000 AEs).

Our results showed that lower extremities (n = 61, 46.6%) were most commonly injured,
with the knee (n = 26, 19.8% of the total injuries) being the most frequently injured area, followed by the ankle (n = 12, 9.2%). In the head and trunk region (n = 39, 29.8%), the face was the most frequently injured area (n = 29, 22.1%), followed by the head (n = 3, 2.3%). Moreover, in the upper extremities (n = 31, 23.7%), the fingers were the most frequently injured area (n = 8, 6.1%), followed by the hand (n = 7, 5.3%).

In our study, contusions/hematomas/bruises were the most common injury types (n=44, 33.6%), followed by fractures (n=31, 23.7%), ligamentous ruptures/sprains (n=21, 16.0%), and muscle ruptures/strains (n=14, 10.7%) (Table 2A). The face was the most common site for a contusion/hematoma/bruise, which occurred primarily due to contact with the opponent during offensive/defensive moves. The fingers, forearms, and wrists were the most common site of fractures due to contact with the opponent during defense blocking, whereas the knees and ankles were the most common sites for ligamentous ruptures/sprains or muscle rupture/strain due to contact and/or non-contact. Of the five reported cases of concussions, three were mild, and fortunately, the other two athletes who were transported to the hospital sustained an injury that resulted in no time loss from the competition (Table 2B).

As shown in Figure 1, we observed that the most common injury mechanism was contact with another athlete (n = 97, 74.0%), followed by noncontact (n = 18, 13.7%), which included injuries from footwork during offensive/defensive moves and from avoiding contact. Males were more prone to contact injuries from opponents, whereas females were more prone to noncontact injuries. Twelve (9.2%) athletes were unsure of the cause of their injuries in terms of contact or noncontact with their opponent.

Of all injuries, we estimated that 34.4% (n = 45) would result in no time loss from
competition/training; 65.6% (n = 86) and 17.6% (n = 23) of injuries would result in an absence from competition/training for 1–3 days; 17.6% (n = 23), for 4–7 days; and 30.5% (n = 40), for >7 days. Furthermore, we classified 48.1% (n = 63) of injuries as severe, with an estimated time loss of >7 days from competition/training. These injuries comprised 31 fractures, 21 ligament sprains/ruptures, 10 muscle and tendon strains/ruptures, and 1 multiple contusion (Table 2A).

Among all athletes with injuries and illnesses, we transferred 27 athletes (19 injuries, eight illnesses) to hospitals for a more thorough examination after a primary checkup in the field medical office.

Our results showed that 8 (30.8%) and 5 (19.2%) illnesses were affected the respiratory system and the gastrointestinal system, respectively. The major symptoms were pain (n = 11, 42.3%) and fever (n = 7, 26.9%). Environmental factors (i.e., humidity or climate) were the most common cause of illness (n = 15, 57.7%), followed by infections (n = 10, 38.5%) (Table 3).

Discussion

Our study aimed to analyze injuries and illnesses after the implementation of the web-based surveillance system at the 2017 WTC. Our results showed that 8.9% and 2.0% of all 971 taekwondo athletes suffered at least one injury or illness during the 2017 WTC, with an overall clinical incidence of 13.5 injuries and 2.7 illnesses per 100 athletes. Among both males and females, heavy-weight athletes had a higher injury rate than the low-weight athletes, which is believed to be a result of their ability to create a more powerful impact.

Overall, we found that the injury incidence rates at the 2017 WTC (77.8/1,000 AEs and 13.9/1,000 MEs) were lower than that at the 1999 WTC (108.1/1,000 AEs and 12.2/1,000 MEs) and Rio 2016 (100/1,000 AEs and 16.8/1,000 MEs). Although the competition rules at the 2017
WTC and Rio 2016 were the same, the injury incidence rates were different, 77.8/1,000 AEs versus 100/1,000 AEs. Likewise, the injury incidence rates in the competitions at the 2017 WTC were lower than those at Beijing 2008 (114.9/1000AEs)\(^1\) and London 2012 (164.5/1000AEs).\(^2\)

Several combat sports associations have published data on injury rates during their national/world championships.\(^8\) The injury rate at the 2017 WTC (77.8/1,000 AEs and 13.9/1,000 MEs) was higher than that at the 2013 World Karate Championships in Guadalajara (53.3/1,000 AEs and 23.7/1,000 MEs) and at the 2015 World Karate Championships in Jakarta (23.2/1,000 AEs and 9.2/1,000 MEs).\(^8\)

At the 2017 WTC, PSS consisted of a chest protector and electronic headgear to fully automate the scoring system.\(^5\) We believe that because the electronic headgear sensor requires only a slight contact between the foot sensor and the headgear to register a scored point, the athletes do not have to deliver kicks with a force higher than that used previously to score head kicks.

Interestingly, in this study the severe injuries were the fractures of either the ankles or fingers, whereas the mild injuries were the contusions of the face, all of which occurred from contact with an opponent. Moreover, we noted that ligamentous ruptures or sprains and musculotendinous injuries (ruptures, tears, strains, or tendinosis) to the knee or ankle were common. These occurred both with and without opponent contact. Furthermore, many ligament injuries in the ankle and knee occurred due to kicking of the leg. We believe that the use of an electronic headgear, which automates the scoring of head kicks, was responsible for fewer concussions (five mild concussion cases).\(^16\)

We found that the results of a literature review\(^7\) of eight studies (data from 5,856 male and
2,126 female athletes) were similar to those of our study regarding injury rates, such as those in
the lower extremities (48.3/1,000 AEs), head and trunk region (34.8/1,000 AEs), and upper
extremities (16.7/1,000 AEs). Additionally, the rates of contusions/abrasions/lacerations
(65.4/1,000 AEs), sprains/strains (19.0/1,000 AEs), and fractures (9.7/1,000 AEs) were similar to
those previously reported (7,509 males and 2,852 females). 7

Similar to previous studies, 6,7 the most frequent types of injury in this study were
musculoskeletal contusions, sprains, and bone fractures. Therefore, we suggest that it is
important to improve protective equipment, such as headgears, forearm pads, and shin protectors,
to prevent contact injuries to the face, fingers, knees, and ankles. 17–19 For noncontact injuries, we
recommend additional neuromuscular exercises and chronic injury management as part of the
athletes’ training regimen. 20,21

At the 2017 WTC, we estimated that 65% of the injuries would result in time loss from
competition/training for at least 1 day, which was higher than that recorded at Rio 2016 (40%)
and London 2012 (35%). Taekwondo athletes at the 2017 WTC sustained more injuries of higher
severity than those at Rio 2016 or London 2012.

At the 2017 WTC, we found that the injury severity (48.1%, n = 63) was in the order of bone
fractures > ligament ruptures/sprains > muscle and tendon ruptures, which was similar to that at
the Olympics or other taekwondo competitions. 13,22,23 With a high number of severe injuries, we
suggest that it is critical for the athletes’ safety that competitions maintain a regular injury and
illness surveillance system to continuously identify and prevent serious injuries, evaluate and
improve protective equipment, and test injury-prevention programs implementation. 7,16

The injury mechanisms in taekwondo competitions are similar among weight divisions and
between genders.\textsuperscript{24} Reportedly, the injury mechanisms at national taekwondo events, such as the Canadian National Championships, Thailand National Championships, and Greek National Championships, were similar, occurring mostly from contact with the opponent.\textsuperscript{15,25,26} At the 2017 WTC, we observed that a majority of the contact injuries were acute, whereas noncontact and overuse injuries with a sudden onset accounted for 14.5\% of overall injuries. The contact between athletes caused majority of injuries; thus, to reduce them, training of the athletes should include techniques to improve the efficiency and safety of blocking and avoidance techniques.\textsuperscript{6,16}

Moreover, we suggest that to prevent severe knee and ankle noncontact injuries, neuromuscular and proprioceptive training should be conducted.\textsuperscript{20,27}

At the 2017 WTC, the IR of the illnesses was relatively low compared with the injury rate. The overall percentage of athletes with illnesses at the 2017 WTC (3\%) was lower than that at Rio 2016 (5\%), Sochi 2014 (8\%), and London 2012 (7\%).\textsuperscript{2,3,13} As in previous World Championships and Olympics, the majority of illnesses at the 2017 WTC were caused by an environmental change (i.e., humidity or climate) or a respiratory/gastrointestinal system infection. The overall rates were similar to those observed in IAAF World Athletics Championships 2009, London Olympic Games 2012, and Rio Olympic Games 2016.\textsuperscript{2,3,28} We hypothesize that these illnesses were caused by a combination of long flights and environmental and climatic changes, further compounded by high demands to limit food and water because of the weigh-ins before the competition.\textsuperscript{7,13,28}

In our study, the methods used to research the injury and illness surveillance system are based on IOC’s recommendations. First, we used the WTC online electronic system for rapid collection and accurate coding of injury and disease data in all medical offices. Second, continuous recommendations by and education of WT staff are necessary to support and
encourage team physicians in each country to efficiently use the system. Third, it is important to have correct medical equipment at on-site medical offices to accurately diagnose the injuries.

Fourth, it is important to minimize errors while entering data in the system. Fifth, the athlete’s risk exposure time (number and minutes of match games) should be included instead of expressing injuries according to the athlete, such as the method used in Olympics research.\textsuperscript{3,29}

We conducted this study with a web-based injury and illness surveillance system that more accurately diagnosed injuries occurring in the field using ultrasound during the 2017 WTC. Due to the fact that MDs and ATs, who specialize in sports-related injuries, were included on-site, we specialized out study more highly than other studies. The injury and illness surveillance system is ideal for use at large world championships for observing the effect of any changes within the competition, such as new PSS or rules, because it can alter the injury profiles and game strategies. However, our study has some limitations, including intentionally/unintentionally missing injury/illness reporting during competition/training and only occasional clarity of the mechanisms and severity of injury and illness occurring at a competition (recall bias). The issues surrounding injury severity are based on estimated time loss rather than the actual time loss. Moreover, we recorded only the most severe injury when an athlete presented with multiple injuries; this might have resulted in underestimating the injury incidence and overestimating the severity of injuries.

Conclusion

Sports injury and illness following the implementation of the web-based surveillance system at the 2017 WTC resulted in a new or recurrent injury clinical incidence of 13.5/100 athletes and an illness clinical incidence of 2.7/100 athletes. Continuous athlete injury and illness surveillance
is recommended at all international and domestic taekwondo competitions in the future to collect
more epidemiological information to inform the development of effective injury-prevention
measures.
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Figure legend

Figure 1. Injury mechanisms at the competition at the Muju WTC 2017
Table 1. Injury and illness rates at the Muju WTC¹ 2017

| Variables                              | Male   | Female  | Total   |
|----------------------------------------|--------|---------|---------|
| Participating athletes (no.)           | 593    | 378     | 971     |
| Athlete-days (no.)                     | 4,151  | 2,646   | 6,797   |
| Athlete-exposures (no.)                | 1,000  | 684     | 1,684   |
| Minute-exposures (min.)                | 5,434  | 3,996   | 9,430   |
| Injuries in competition (no.)          | 90     | 41      | 131     |
| Injury clinical incidence/100 athletes | 15.2 (12.0–18.3) | 10.8 (7.5–14.2) | 13.5 (11.2–15.8) |
| Injury incidence rate/1,000 athlete-days | 21.7 (17.2–26.2) | 15.5 (10.8–20.2) | 19.3 (16.0–22.6) |
| Injury incidence rate/1,000 AEs        | 90.0 (71.4–108.6) | 39.9 (41.6–78.3) | 77.8 (64.5–91.1) |
| Injury incidence rate/1,000 MEs        | 16.6 (13.1–20.0) | 10.3 (7.1–13.4) | 13.9 (11.5–16.3) |
| **Injury IRR/1,000 AEs**               | 1.50 (1.04–2.17) | 1.00     | -       |
| Illnesses in competition (no.)         | 16     | 10      | 26      |
| Illness clinical incidence/100 athletes | 2.7 (1.4–4.0)  | 2.6 (1.0–4.3)  | 2.7 (1.6–3.7)  |
| Illness incidence rate/1,000 athlete-days | 3.9 (2.0–5.7) | 3.8 (1.4–6.1) | 3.8 (2.4–5.3) |
| **Illness incidence rate/1,000 AEs**   | 16.0 (8.2–23.8) | 14.6 (5.6–23.7) | 15.4 (9.5–21.4) |
| **Illness IRR/1,000 AEs**              | 1.10 (0.50–2.41) | 1.00     | -       |

¹World Taekwondo Championships; ²number; ³minute; ⁴95% confidence interval; ⁵athlete-exposures; ⁶minute-exposures; ⁷incidence rate ratio
| Injury Type       | N (% of total) | Injured body part | Injured body part | Injured body part |
|------------------|----------------|------------------|------------------|------------------|
|                  | Male           | Injury site (N)   | Female           | Injury site (N)   | Total           | Injury site (N) |
| Contusion/       | 30 (33.3)      | Face (9),        | 14 (34.1)        | Face (7),        | 44 (33.6)       | Face (16),      |
| Hematoma/       |                | Thigh (4),       |                  | Thigh (2),       |                  | Thigh (6),      |
| Bruise          |                | Pelvic (2),      |                  | Foot/toe (2),    |                  | Foot/toe (3),   |
|                 |                | Foot/toe (1)     |                  | Hand (1)         |                  | Pelvic (2),     |
|                 |                | Neck (1),        |                  |                  |                  | Hand (2),       |
|                 |                | Ribs (1),        |                  |                  |                  | Neck (1),       |
|                 |                | Forearm (1),     |                  |                  |                  | Ribs (1),       |
|                 |                | Hand (1),        |                  |                  |                  | Forearm (1),    |
|                 |                | Lumbar (1),      |                  |                  |                  | Lumbar (1),     |
|                 |                | Hip (1),         |                  |                  |                  | Hip (1),        |
|                 |                | Groin (1),       |                  |                  |                  | Groin (1),      |
|                 |                | Ankle (1)        |                  |                  |                  | Ankle (1)       |
| Fracture        | 22 (24.4)      | Finger (4),      | 9 (22.0)         | Finger (2),      | 31 (23.7)       | Finger (6),     |
|                 |                | Ankle (4),       |                  | Face (2),        |                  | Face (5),       |
|                 |                | Face (3),        |                  | Ankle (1)        |                  | Ankle (5),      |
|                 |                | Knee (3),        |                  | Knee (1),        |                  | Knee (4),       |
|                 |                | Hand (2),        |                  | Hand (1),        |                  | Hand (3),       |
|                 |                | Thumb (2),       |                  | Thumb (1),       |                  | Thumb (3),      |
|                 |                | Forearm (2),     |                  | Wrist (1)        |                  | Forearm (2),    |
|                 |                | Wrist (1),       |                  |                  |                  | Wrist (2),      |
|                 |                | Ribs (1)         |                  |                  |                  | Ribs (1)        |
| Ligamentous Rupture/Sprain | Knee (5), Ankle (5), Thumb (2), Hand (1), Finger (1) | 14(15.6) | 7(17.1) | Knee (5), Ankle (1), Thumb (1) | 21(16.0) | Knee (10), Ankle (6), Thumb (3), Hand (1), Finger (1) |
|---|---|---|---|---|---|---|
| Muscle Rupture/Strain/Tendinosis | Knee (3), Thigh (2), Wrist (1), Hip (1), Lower leg (1), Foot/toe (1) | 9(10.0) | 5(12.2) | Hand (1), Knee (1), Thigh (1), Lower leg (1), Hand (1), Finger (1), Hip (1), Foot/toe (1) | 14(10.7) | Knee (4), Thigh (3), Lower leg (2), Wrist (1), Hand (1), Finger (1), Hip (1), Foot/toe (1) |
### Table 2B. Continued From Previous Page

| Injury Type                | N (%) of total | Male | Injury site (N) | Female | Injury site (N) | Total | Injury site (N) |
|----------------------------|----------------|------|----------------|--------|----------------|-------|----------------|
| Laceration/ Abrasion/ Skin lesion |                 |      |                |        |                |       |                |
| Concussion                 | 4(4.4)         | Head/brain (4) | 1(2.4) | Head/brain (1) | 5(3.8) | Head/brain (5) |
| Lesion of meniscus         | 2(2.2)         | Knee (1), Wrist (1) | 1(2.4) | Knee (1) | 3(2.3) | Knee (2), Wrist (1) |
| Dislocation/ Subluxation   | 1(1.1)         | Shoulder (1) | 1(2.4) | Knee (1) | 2(1.5) | Shoulder (1), Knee (1) |
| Arthritis/ Synovitis/ Bursitis |           | Wrist (1) |       | - | 1(0.8) | Wrist (1) |
| Other bone injuries        | 1(1.1)         | Knee (1) | 0(0.0) | - | 1(0.8) | Knee (1) |
| Muscle cramps/ Spasm       | 1(1.1)         | Upper back (1) | 0(0.0) | - | 1(0.8) | Upper back (1) |
| Nerve/ Spinal cord injuries |     | Forearm (1) | 1(2.4) | - | 1(0.8) | Forearm (1) |
| Other                      | 0(0.0)         | Face (1) | 1(2.4) | - | 1(0.8) | Face (1) |
| Total                      | 90(100)        | -    | 41(100) | - | 131(100) | - |
Table 3. The affected systems, main symptoms, and causes of illnesses at the Muju WTC* 2017

| Affected system                        | N (% of total illnesses) |
|----------------------------------------|---------------------------|
|                                        | Male (n=16) | Female (n=10) | Total (n=26) |
| Respiratory/ear, nose, throat          | 6 (37.5)    | 5 (50.0)      | 11 (42.3)    |
| Gastrointestinal                       | 4 (25.0)    | 1 (10.0)      | 5 (19.2)     |
| Urogenital/gynecological               | 0 (0)       | 1 (10.0)      | 1 (3.8)      |
| Allergic/immunological                 | 1 (6.3)     | 1 (10.0)      | 2 (7.7)      |
| Metabolic/endocrinology                | 1 (6.3)     | 1 (10.0)      | 2 (7.7)      |
| Musculoskeletal                        | 1 (6.3)     | 1 (10.0)      | 2 (7.7)      |
| Dental                                 | 2 (12.5)    | 0 (0)         | 2 (7.7)      |
| No answer                              | 1 (6.3)     | 0 (0)         | 1 (3.8)      |

| Main symptom                           | N (% of total illnesses) |
|----------------------------------------|---------------------------|
|                                        | Male (n=16) | Female (n=10) | Total (n=26) |
| Fever                                  | 4 (25.0)    | 3 (30.0)      | 7 (26.9)     |
| Pain                                   | 7 (43.8)    | 4 (40.0)      | 11 (42.3)    |
| Diarrhea, vomiting                     | 1 (6.3)     | 2 (20.0)      | 3 (11.5)     |
| Hyperthermia                           | 1 (6.3)     | 0 (0)         | 1 (3.8)      |
| Dehydration                            | 1 (6.3)     | 1 (10.0)      | 2 (7.7)      |
| Lethargy, dizziness                    | 1 (6.3)     | 0 (0)         | 1 (3.8)      |
| No answer                              | 1 (6.3)     | 0 (0)         | 1 (3.8)      |

| Cause of illness                       | N (% of total illnesses) |
|----------------------------------------|---------------------------|
|                                        | Male (n=16) | Female (n=10) | Total (n=26) |
| Infection                              | 6 (37.5)    | 4 (40.0)      | 10 (38.5)    |
| Environmental                          | 9 (56.3)    | 6 (60.0)      | 15 (57.7)    |
| No answer | 1 (6.3) | 0 (0) | 1 (3.8) |
|-----------|---------|-------|---------|

^World Taekwondo Championships
Figure 1. Injury mechanisms at the competition at the Muju WTC 2017