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Title: Injury Incidences related to Acute-to-Chronic Workload Ratios in Taekwondo: A Prospective Study with a 3-Year Follow-Up

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Injury Incidences related to Acute-to-Chronic Workload Ratios in Taekwondo: A Prospective Study with a Three-Year Follow-Up

Abstract

Context: Although the relationship between workload and injury incidence has recently gained attention, data on the acute-to-chronic workload ratio (ACWR) and injury incidence in Taekwondo remain unavailable.

Objectives: To report the injury incidence related to the categorized ACWR, calculated using the rolling average (RA) and exponentially weighted moving average (EWMA) methods, for musculoskeletal injuries in Taekwondo.

Design: Descriptive epidemiologic study.

Setting: Data were prospectively collected through Taekwondo training facilities and competition venues.

Patients or Other Participants: A total of 110 collegiate Taekwondo players (58 females; 54 males) were studied over three consecutive seasons in 2020, 2021, and 2022.

Main Outcome Measure(s): The traumatic and gradual onset of musculoskeletal injury (rate, body location, type, mechanism, and severity) and workloads (duration of training and competitions) were recorded. ACWRs for each injury were calculated using the RA and EWMA and categorized as either high (> 1.5), relatively high (1.3 – 1.5), moderate (0.8 – 1.3), or low (< 0.8).

Results: Of the 841 injuries (training: 16 per 1,000 hours; competition: 548 per 1,000 hours), the ankle (n=86/501, 17% in traumatic) and thigh (n=106/340, 31% in gradual onset) were the most

predominantly injured body locations. Contusion (n=201/501, 40% in traumatic) and muscle cramps/spasm (n=201/501, 75% in gradual onset) were the most frequent injury types. Although the most predominant mechanism was overuse (n=331/841, 40%), 32% of the injuries (n=230/721) took > 28 days to recover from injury. The greatest number of traumatic (RA: n=224/501, 45%; EWMA: n=259/501; 52%) and gradual onset (RA: n=118/340, 35%; EWMA: n=165/340; 49%) injuries were recorded under the moderate ACWR.

Conclusions: The moderate ACWR range (0.8 – 1.3), which was considered as the "sweet spot" in team sports, was calculated to be the "danger zone" in Taekwondo. The high injury risk related workload could be used for planning training schedules.

Keywords: rolling average, exponentially weighted moving average, combat sports, training load, Kyorugi

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Key Points:

- This is the first study to explore the association between injury incidence and workload in Taekwondo over three consecutive seasons.
- To quantify the workload, the acute-to-chronic workload ratio for each injury was calculated using the rolling average and exponentially weighted moving average methods.
- Unlike team sports, traumatic and gradual onset injuries most frequently occurred in the moderate acute-to-chronic workload ratio (0.8 – 1.3).

The association between injury risk and workload has recently gained attention.[1,2] Workload can be quantified as the ratio of training loads between a recent (acute) and a preceding four-week (chronic) period.[2] This is referred to as the acute-to-chronic workload ratio (ACWR),[3] which is classified as either high (> 1.5), relatively high (1.3 – 1.5), moderate (0.8 – 1.3), or low (< 0.8).[4] Players with a high ACWR have demonstrated higher injury incidence than those with a reference range, including moderate ACWR in team sports (×3 in American football,[5] ×8 in baseball,[6] ×3 in volleyball,[7] ×3 in cricket,[3] and ×7 in soccer[8]); thus, such ranges have been proposed as the "danger zone" (> 1.5) and the "sweet spot" (0.8 – 1.3).[1]

Although available ACWR data are valuable, applying the general concepts of ACWR as injury prevention strategies remains limited owing to short follow-up periods (e.g., one season)[9-11] and the lack of variability in sport types, as most previous reports have focused on team sports.[3,5-8] Taekwondo is a global sport wherein over 200 nations participate in international events; however, the relationship between workload and the risk of injury incidence remains unknown. Due to its nature as a 1:1 combat sports, Taekwondo has a high injury incidence (e.g., 26 injuries per 1,000 hours).[12] The knee (21%),[13] ankle (14%),[14] foot (16%),[15] and thigh (17%)[12] were the most frequently injured body locations, whereas contusions (29%[13]; 48%[15]), strains (20%),[14] and muscle spasms (33%)[12] were the most frequent injury types. While most of this information was retrospectively obtained, prospectively collected data on musculoskeletal injury along with the corresponding ACWR would provide insights into injury prevention and training adaptation.

The ACWR can be calculated using different methods for identifying changes in the workload. Although the gold standard has yet to be determined, the rolling average (RA) formula[8] and the exponentially weighted moving average (EWMA) formula[16] are two common

methods. Compared with the RA, the EWMA is considered to be a more sensitive calculation owing to the greater weight on the recent workload due to the attenuation of training effects over time.[11,16] Studies have recently reported the ACWR using either the RA,[17,18] EWMA,[19,20] or both methods.[21,22] Simultaneous ACWR calculations using each method would help determine the relationship between the injury risk and workload.

Therefore, this prospective descriptive epidemiologic study aimed to report the musculoskeletal injury information (number, rate, body location, type, mechanism, and severity) related to the categorized ACWR in Taekwondo over three consecutive years. Specifically, (1) the rate (e.g., per 1,000 hours of participation), body location, type, mechanism, and severity of musculoskeletal injuries; and (2) the ACWR values for each injury, calculated using both the RA and EWMA methods, were studied. We hypothesized that: (1) the thigh, muscle cramps, and overuse would be the most predominant injury location, type, and mechanism, respectively; and (2) higher (> 1.5) ACWRs would lead to higher injury incidences than relatively high (1.3 – 1.5), moderate (0.8 – 1.3), or low (< 0.8) ACWRs.

METHODS

Study Design

This is a prospective descriptive epidemiologic study in collegiate Taekwondo players. The ACWR for each musculoskeletal injury was calculated using the RA and EWMA formulas. The testing procedures of the study were approved by the University's Institutional Review Board (protocol #:_____).

Setting

Data were collected from Taekwondo training facilities and competition venues for three consecutive seasons (from January 2020 to December 2022). We employed the following definitions to ensure consistent and accurate data collection. *Musculoskeletal injury* was any musculoskeletal complaint due to participation in training and/or competition that received medical attention,[13] along with the numeric pain rating scale (NPRS) for pain perception exceeding 2 out of 10.[12] *Medical attention* was an assessment of a player's medical condition or status by athletic trainers or a medical doctor.[14] *Traumatic* was a sudden onset of the injury resulting from an identifiable event (e.g., collision between players), whereas *gradual onset* was an injury that lacked a noticeable precipitating event (e.g., tendonitis resulting from repetitive movement).[23] Players were referred to a medical doctor when (1) visible contusion or swelling was noted, or a fracture was suspected; (2) the NPRS was > 4 (out of 10) at the time of injury; (3) the NPRS had not improved; or (4) the player wanted to visit the hospital.[12] *Injury severity* was defined as the duration of the period for which a player was unable to participate in the training or competition, measured in days from the onset to recovery of the musculoskeletal injury (time bins of 0, 1 – 7, 8 – 28, and > 28 days).[23] *Training* referred to physical activities that maintained or improved sport-specific athletic skills or physical condition through the formal program of the team.[24] *Competition* was a one-to-one or team combat event wherein the players participated against other players from another team or nation.[24]

Participants

A total of 126 collegiate Taekwondo players who were enrolled in the Department of Athletics, _____ University Taekwondo rosters in 2020 (n=47), 2021 (n=38), and 2022 (n=41) initially examined starting from the first official training in the spring camp. Before data collection, we

explained the data recording procedures and data information to be collected to all players and subsequently obtained informed consent.

Variables

Participation time for training and competition, information (number, rate, body location, type, mechanism, and severity) of musculoskeletal injury (separated by traumatic and gradual onset), and the ACWR for each injury were the primary outcomes of this study. Participation time was recorded in minutes and reported in hours for the injury rate (per 1,000 hours).

Data Collection

Four athletic trainers (2020: ?? and ??; 2021 and 2022: ?? and ??) performed data collection. Researchers (?? and ??) physically calculated the descriptive statistics, injury rates, and ACWRs using a formatted spreadsheet daily (Excel 2022, Microsoft Corp., WA, USA). Injury information (body location, type, mechanism, and severity) was recorded on the basis of the Orchard Sports Injury and Illness Classification System version 13.[23] Newly incurred injuries in the study period (2020, 2021, and 2022) were recorded; thus, pre-existing injuries that had not been fully recovered in 2019 were excluded. Data during this period (March, April, May, and December 2020) were not recorded due to the public quarantine and facility shutdown caused by the COVID-19 pandemic.

Bias

We acknowledge that potential biases may exist due to using self-reporting pain perception (e.g., NPRS) and recording the data by two different athletic trainers. However, the high validity of

NPRS for assessing pain intensity, combined with rigorous data collection protocols, minimized potential biases.

Statistical Methods

The numbers, means, percentages, and 95% confidence intervals in musculoskeletal injuries were calculated for descriptive statistics. To calculate the injury rate, the number of injuries was divided by the participation time (in hours) and multiplied by 1,000 to express per 1,000 hours.

To quantify the workload, the training and competition (in minutes) duration was used.[21] To calculate the ACWR, the RA and EWMA methods were employed. For the RA ACWR, the total duration of the most recent one week (starting from the day before the injury incidence: acute) was divided by the average duration of the most recent four weeks (chronic) when an injury occurred (Equation 1).[2,8] The workload of the recent four weeks in the ACWR included the workload of the recent one week, indicating that the acute workload was included when calculating the chronic workload. For the EWMA ACWR, we calculated the EWMA values of the most recent one week (acute) and four weeks (chronic), then the acute EWMA was divided by the chronic EWMA to provide a single value (Equation 2). Based on previous studies regarding ACWRs,[1,5] we categorized the ACWR into either high (> 1.5), relatively high (1.3 – 1.5), moderate (0.8 – 1.3), or low (< 0.8).

Equation 1. $RA\ ACWR = \frac{A}{0.25\times(A+W2+W3+W4)}$

Where 'A' denotes the workload of the most recent week and A, W2, W3, and W4, indicate the last four weeks, respectively.

Equation 2. $EWMA_{today} = Load_{today} \times \lambda_a + ((1 - \lambda_a) \times EWMA_{yesterday})$

Where 'λ_a' is a value between 0 and 1 that represents the degree of decay. It is given by: $\lambda_a = 2/(N + 1)$,where 'N' is 7 days for acute and 28 days for chronic loads.

To test the agreement between the ACWR values calculated using the RA and EWMA, Pearson's correlation coefficient was performed using a statistical package (SAS 9.4, SAS Institute, Cary, USA).

RESULTS

Participants

During the data collection period, 38 players joined as freshmen, 27 graduated, and 16 dropped out (2 were injured and 14 resigned from the team). Finally, we analyzed 110 players (2020: 20 M, 21 F, career: 9.8 ± 2.7 years; 2021: 14 M, 19 F, career: 9.7 ± 2.3 years; 2022: 20 M, 16 F, career: 8.8 ± 2.0 years) for the study. Of the 110 players, 102 sustained at least one musculoskeletal injury, encompassing all 41 players in 2020, 30 out of 33 players in 2021, and 31 out of 36 players in 2022.

Injury Information

Overall (regardless of the years), 841 musculoskeletal injuries were observed (training: n=732; competition: n=109; Table 1). A higher injury rate per 1,000 hours was recorded during competition (547.7/1,000 hours), than during training (15.5/1,000 hours; Table 1).

Regardless of the years, the ankle was the most frequently injured body location (n=102/501; 20.4%), followed by foot/toe (n=86/501; 17%), finger (n=57/501; 11%), and hand (n=53/501;

11%) in traumatic injuries (Table 2). The thigh was the most predominantly injured body location (n=106/340; 31%), followed by the lumbar spine/lower back (n=74/340; 22%), lower leg (n=73/340; 22%), and foot/toe (n=32/340; 10%) in gradual onset injuries (Table 2).

Regardless of the years, contusion was the most frequent injury type (n=201/501; 40%), followed by sprain (n=190/501; 38%), strain (n=53/501; 11%), and laceration (n=20/501; 4.0%) in traumatic injuries (Table 3). Muscle cramps/spasms were the most frequent injury type (n=256/340; 75%), followed by tendinosis (n=38/340; 11%), strain (n=18/340; 5%), and other (n=18/340; 5%) in gradual onset injuries (Table 3).

Regardless of the years, overuse was the most predominant injury mechanism (n=337/841; 40%), followed by contact with another athlete (n=331/841; 39%), contact with a stagnant object (n=125/841; 159%), and non-contact trauma (n=26/841; 3%; Table 4).

Injury severity was assessed in 721 of 841 injuries (86%), whereas 120 injuries were not followed up due to quarantine or restriction caused by the COVID-19 pandemic or individual infections. Overall, severe (> 28 days; n=230/721; 32%) injuries were the most predominant, followed by slight (0 – 1 day; n=214/721; 30%) and moderate (8 – 28 days; 28%) injuries. Severe injuries were 12 fold greater than minimal (2 – 3 days) injuries (Table 5).

ACWR

Overall (regardless of the years and injury type), the injuries most frequently occurred in the moderate ACWR (0.8 – 1.3), as calculated using the RA (n=342/841; 41%) and EWMA (n=424/841; 50%; Table 6; Figure 1). Traumatic injuries (n=501/841) most frequently occurred in the moderate ACWR, as calculated by the RA (n=224/501; 45%) and EWMA (n=259/501; 52%; Table 6). Gradual onset injuries (n=340/841) most frequently occurred in the range of

moderate ACWR, as calculated by the RA (n=118/340; 35%) and EWMA (165/340; 49%; Table 6).

Pearson's correlation coefficient test revealed that there was a strong correlation between the RA and EWMA ACWR (r=0.83; p<0.001; Figure 1D).

DISCUSSION

This is the first study on the injury information with the ACWR in Taekwondo. Our hypothesis that the thigh, muscle cramps, and gradual onset would be the characteristics of musculoskeletal injury was supported by our results and mostly consistent with previous data.[12,14] The largest number of musculoskeletal injuries (60% in traumatic; 40% in gradual onset) occurred under the moderate ACWR (0.8 – 1.3), rather than the high ACWR (> 1.5), which does not support our second hypothesis (Table 6). This finding is interesting as the moderate ACWR is considered the "sweet spot" in several team sports.[7,20,21] Our data offer critical guidance for tailoring injury prevention strategies to workload-based training schedules in Taekwondo and other combat sports. Furthermore, our data suggest that the relationship between injury risk and workload can depend on the sport type.

Regarding injury rates, our results showed a higher rate of injury during competition (548/1,000 hours) than during training (16/1,000 hours), which is in line with the results of a previous study (1,072/1,000 hours; training: 22/1,000 hours).[12] Taekwondo players during competition typically participate in several consecutive matches in a day with a relatively short resting period.[25] Furthermore, most Taekwondo players experience the burden of controlling their body weight within short periods (up to 19 days),[26] which influences hydration and overall conditioning status.[27] This aggressive weight loss increase the injury risk during competition.[28]

Additionally, following the rules of the Taekwondo competition, players actively compete against unexpected attacks from each other; such conditions could generate a high injury incidence rate in the competition.

Regarding injury information, our results demonstrated that the most frequently injured body locations in traumatic and gradual onset injuries were the ankle (20%) and thigh (31%), respectively (Table 2); contusion (40%) and muscle spasms (75%) were the most predominant injury types in traumatic and gradual onset injuries, respectively (Table 3); the most prevalent injury mechanism was overuse (40%: Table 4); approximately 60% of injuries required more than a week for recovery (Table 5). Previous studies have reported that the knee (21%),[13] ankle (14%),[14] foot (16%),[15] and thigh (17%)[12] were the most injured body locations, whereas contusion (29%[13]; 48%[15]), strain (20%),[14] and muscle spasms (33%)[12] were the most frequent injury types. Additionally, 'moderate (8 – 28 days)' was the most frequent injury severity.[12] Our results are generally consistent with those of previous studies.[12,14] Players are frequently exposed to physical contact during defensive and offensive maneuvers. Furthermore, players mostly use kicking skills, which require a high level of accuracy, efficiency, and coordination of lower extremity muscles, to achieve higher scores in Taekwondo (kicking yields a score of 2 – 5).[12] Therefore, the likelihood of colliding with other players or training equipment as well as repetitive usage of their legs may be higher. A noticeable discrepancy in injury severity was observed: there were 210 slight severe injuries compared to only 4 in the same category in 2021 and 2022. Due to the prohibition of official competitions and the quarantine resulting from COVID-19, most training programs primarily focused on conditioning training or individual exercises rather than tactical contact practices, such as scrimmage sparring. Therefore, players were naturally exposed to injuries caused by repetitive muscle use. This may be linked with a

large number of gradual onset injuries in 2020 (234/393 injuries, 60%, Table 3) and the category of 'overuse' injuries in 2020 (234/393 injuries, 60%). Since access to athletic training rooms was considerably restricted in 2020, players may have experienced difficulties in managing their physical condition (e.g. residual pain and accumulated fatigue) through therapeutic modalities or prophylactic taping. We believe that the training environment may have contributed to the discrepancy in injury characteristics between 2020 and other years.

In our study, players had mostly been trained under the moderate ACWR (Figure 1). Compared with the highest number of injuries recorded in the moderate ACWR (0.8 – 1.3), as calculated using the RA and EWMA methods, the remaining injuries were distributed across the other ACWR ranges (Table 6). Based on our data, we cannot suggest the least vulnerable workload range. The musculoskeletal injury least frequently occurred in 0.8 – 1.2 in football,[5,20] 0.8 – 1.0 in rugby,[16] 0.8 – 1.5 in soccer,[9] 1.0 – 1.5 in cricket,[3] and approximately 1.0 in volleyball.[7] In team sports, maintaining moderate workload causes fewer injuries; however, this does not appear to be the case in Taekwondo. These conflicting results might be attributed to the type of sports. Unlike team sports, Taekwondo is an individual, combat, and weight-categorized sport with no clearcut season periods (e.g., competition every 4 – 6 weeks year-round) and a high requirement for cardiorespiratory fitness, anaerobic fitness, flexibility, and maximum dynamic strength. Therefore, a periodization strategy may be different from that in team sports.[29] Players in Taekwondo repeatedly and continuously control their body weight and prepare for competition.[26] Hence, training responses regarding injury prevention may have been applied differently; subsequently, the most vulnerable range of the ACWR was observed differently. Previously, a U-shape (mixed data from cricket[3] and rugby[31]), positive linear (soccer[11] and football[20]), and negative linear (runners[22]) relationship were reported. Along with these

inconsistency, our results also suggest that the application of ACWR should consider the type of sports.

Both the RA and EWMA methods determined that the greatest injury incidences occurred in the moderate ACWR (0.8 – 1.3). As previously reported,[32] a strong relationship (r=0.83) existed between the two formulas. Consistent with previous data,[32] overall ACWR values from the EWMA formula tended to be lower than those from the RA in our study, due to the differences in weighting between acute and chronic workloads. For example, in our ACWR data when resuming training after a few weeks of break, the ACWR values on day 42 in Figure 1A are much different (RA: 2.4; EWMA: 0.5). Therefore, the number of injuries observed might be distributed in the lower categories (e.g., n=235/841 in high RA ACWR vs. n=102/841 in high EWMA ACWR), resulting in the differences. Participation times for the training or competition were used for quantifying the workload, which is common in previous studies.[3,7,11] Instead of solely using participation time, several studies[3,7,9] have adopted quantifying the workload by multiplying the duration by the rate of perceived exertion (RPE). The discrepancy in workload definitions between the present and previous studies may contribute to the observed inconsistencies. However, we collected the data within the same institution for three consecutive years. Taekwondo players do not play specific positions but perform approximately the same practice drills with the same participation times; therefore, lesser variations in the quantity and quality of the training and conditioning program would diminish the aforementioned potential limitations. The data in 2020 included a shutdown period due to the COVID-19 pandemic, which made an irregular basis of training or competition schedules of the year. During the shutdown period, players maintained the provided training routine by themselves despite the prohibited opening of the official competition. The quarantine during this period prevented athletic trainers

from collecting data. Therefore, the training and competition schedules over the three-year study period (2020, 2021, and 2022) might have been inconsistent. However, such a phenomenon was inevitable; therefore, we believe that our results sufficiently reflected realistic data.

CONCLUSION

This prospective cohort study is the first to report on the relationship between workload and injury incidence, as determined by participation times for training and competition, in Taekwondo. Of the 841 musculoskeletal injuries (16 per 1,000 hours in training; 548 per 1,000 hours in competition), the RA and EWMA methods determined that the highest injury incidences occurred in the moderate ACWR (0.8 – 1.3). This pattern was consistent when the injury types were classified into traumatic vs. gradual onset. However, as the ACWR and its relation to high injury risk varied across different types of sports, we suggest caution in the use of our data.

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388 **Figure Captions**

389 Figure 1. Acute-to-chronic workload ratio (ACWR) over the study period (1,092 days). The
390 ACWR is zero either due to the COVID-19 lockdowns or short breaks. (A) Changes in the
391 ACWR as calculated using the rolling average (RA) and the exponentially weighted moving
392 average (EWMA) methods. (B) The correlation between the RA and EWMA (r=0.83, p<0.0001).
393 Changes in the ACWR as calculated by the RA (C) and the EWMA methods (D), and the number
394 of injuries observed. Green markers represent injuries that occurred under the moderate ACWR
395 (0.8 – 1.3), the gray area).

Table 1. Injury Rates by Years

Year	Event	Participation time (hour)	No. of injury (n)	Rate per 1,000 hours (95% CIs)
2020	Training	10,234	392	38.3 (34.5, 42.1)
	Competition	5	1	-
	Overall	10,239	393	38.4 (34.6, 42.2)
2021	Training	16,207	186	11.5 (9.8, 13.1)
	Competition	98	51	521.3 (378.2, 664.3)
	Overall	16,304	237	14.5 (12.7, 16.4)
2022	Training	20,832	154	7.4 (6.2, 8.6)
	Competition	96	57	592.3 (438.6, 746.1)
	Overall	20,929	211	10.1 (8.7, 11.4)
Total	Training	47,273	732	15.5 (14.4, 16.6)
	Competition	199	109	547.7 (444.9, 650.6)
	Overall	47,472	841	17.7 (16.5, 18.9)

Table 2. Distribution of Injured Body Location

Body location	No. of injuries (%)							
	Traumatic (n=501)				Gradual onset (n=340)			
	Total	2020	2021	2022	Total	2020	2021	2022
Face (including eye, ear, nose)	16 (3.2)	10 (6.3)	6 (3.6)	0	0	0	0	0
Head	9 (1.8)	0	0	9 (5.1)	0	0	0	0
Neck / cervical spine	0	0	0	0	6 (1.8)	5 (2.1)	1 (1.4)	0
Thoracic spine / upper back	0	0	0	0	1(0.3)	0	1 (1.4)	0
Sternum / ribs	2 (0.4)	0	0	2 (1.1)	0	0	0	0
Abdomen	0	0	0	0	0	0	0	0
Lumbar spine / lower back	5 (1.0)	0	1 (0.6)	4 (2.3)	74 (21.8)	54 (23.1)	14 (19.4)	6 (17.6)
Pelvis / sacrum / buttock	6 (1.2)	4 (2.5)	2 (1.2)	0	8 (2.4)	5 (2.1)	2 (2.8)	1 (2.9)
Shoulder / clavicular	1 (0.2)	0	0	1 (0.6)	19 (5.6)	16 (6.8)	3 (4.2)	0
Upper arm	2 (0.4)	0	1 (0.6)	1 (0.6)	1 (0.3)	0	0	1 (2.9)
Elbow	9 (1.8)	5 (3.1)	1 (0.6)	3 (1.7)	1 (0.3)	0	0	1 (2.9)
Forearm	8 (1.6)	4 (2.5)	1 (0.6)	3 (1.7)	0	0	0	0
Wrist	34 (6.8)	16 (10.1)	15 (9.1)	3 (1.7)	0	0	0	0
Hand	53 (10.6)	12 (7.5)	9 (5.5)	32 (18.1)	0	0	0	0
Finger	57 (11.4)	16 (10.1)	38 (23.0)	3 (1.7)	0	0	0	0
Hip / groin (adductor)	6 (1.2)	1 (0.6)	0	5 (2.8)	4 (1.2)	3 (1.3)	1 (1.4)	0
Thigh	41 (8.2)	3 (1.9)	9 (5.5)	29 (16.4)	106 (31.2)	78 (33.3)	20 (27.8)	8 (23.5)
Knee	43 (8.6)	11 (6.9)	16 (9.7)	16 (9.0)	11 (3.2)	4 (1.7)	5 (6.9)	2 (5.9)
Lower leg	21 (4.2)	3 (1.9)	9 (5.5)	9 (5.1)	73 (21.5)	57 (24.4)	10 (13.9)	6 (17.6)
Ankle	102 (20.4)	42 (26.4)	29 (17.6)	31 (17.5)	4 (1.2)	2 (0.9)	2 (2.8)	0
Foot / toe	86 (17.2)	32 (20.1)	28 (17.0)	26 (14.7)	32 (9.4)	10 (4.3)	13 (18.1)	9 (26.5)
Total	501	159	165	177	340	234	72	34

Table 3. Distribution of Injury Type

Type	No. of injuries (%)							
	Traumatic (n=501)				Gradual onset (n=340)			
	Total	2020	2021	2022	Total	2020	2021	2022
Concussion	0	0	0	0	0	0	0	0
Fracture (trauma, stress, other bone injuries)	23 (4.6)	8 (5.0)	5 (3.0)	10 (5.6)	4 (1.2)	0	3 (4.2)	1 (2.9)
Dislocation, subluxation	8 (1.6)	1 (0.6)	4 (2.4)	3 (1.7)	0	0	0	0
Sprain (ligamentous rupture)	190 (37.9)	85 (53.5)	55 (33.3)	50 (28.2)	2 (0.6)	0	2 (2.8)	0
Strain (muscle rupture, tear, tendon rupture)	53 (10.6)	1 (0.6)	11 (6.7)	41 (23.2)	18 (5.3)	2 (0.9)	10 (13.9)	6 (17.6)
Meniscus, cartilage	1 (0.2)	0	0	1 (0.6)	1 (0.3)	0	1 (1.4)	0
Contusion, hematoma, bruise	201 (40.1)	51 (32.1)	85 (51.5)	65 (36.7)	0	0	0	0
Tendinosis	1 (0.2)	1 (0.6)	0	0	38 (11.2)	12 (5.1)	14 (19.4)	12 (35.3)
Arthritis / synovitis / bursitis	1 (0.2)	0	1 (0.6)	0	0	0	0	0
Impingement	0	0	0	0	1 (0.3)	1 (0.4)	0	0
Laceration, abrasion, skin lesion	20 (4.0)	10 (6.3)	4 (2.4)	6 (3.4)	0	0	0	0
Dental injury, broken tooth	1 (0.2)	1 (0.6)	0	0	0	0	0	0
Nerve injury / spinal cord injury	0	0	0	0	2 (0.6)	2 (0.9)	0	0
Muscle cramps, spasm, DOMS	1 (0.2)	0	0	1 (0.6)	256 (75.3)	207 (88.5)	39 (54.2)	10 (29.4)
Other	1 (0.2)	1 (0.6)	0	0	18 (5.3)	10 (4.3)	3 (4.2)	5 (14.7)
Total	501	159	165	177	340	234	72	34

Table 4. Distribution of Injury Mechanisms

	No. of injuries (%)			
Injury mechanism	Total	2020	2021	2022
Overuse	337 (40.1)	234 (59.5)	69 (29.1)	34 (16.1)
Non-contact trauma	26 (3.1)	2 (0.5)	0	24 (11.4)
Recurrence of previous injury	3 (0.4)	0	3 (1.3)	0
Contact with another athlete	331 (39.4)	88 (22.4)	127 (53.6)	116 (55.0)
Contact with moving object	18 (2.1)	8 (2.0)	3 (1.3)	7 (3.3)
Contact with stagnant object	125 (14.9)	60 (15.3)	35 (14.8)	30 (14.2)
Violation of rules	0	0	0	0
Field or play conditions	0	0	0	0
Weather conditions	0	0	0	0
Equipment failure	0	0	0	0
Other	1 (0.1)	1 (0.3)	0	0
Total	841	393	237	211

Note. A combination of ‘overuse’ and ‘recurrence of previous injury’ was expressed as ‘gradual onset’ throughout the body, table 2, table 3, and table 6.

Table 5. Distribution of Injury Severity

	No. of injuries (%)			
	Total	2020	2021	2022
Less than 1 week				
Slight (0 – 1 day)	214 (29.7)	210 (59.5)	3 (1.5)	1 (0.6)
Minimal (2 – 3 days)	19 (2.6)	1 (0.3)	13 (6.7)	5 (2.9)
Mild (4 – 7 days)	56 (7.8)	3 (0.8)	38 (19.6)	15 (8.6)
More than 1 week				
Moderate (8 – 28 days)	202 (28.0)	44 (12.5)	82 (42.3)	76 (43.7)
Severe (> 28 days)	230 (31.9)	95 (26.9)	58 (29.9)	77 (44.3)
Total	721	353	194	174

Note. Injury severity was calculated among 721 injuries (out of 841 injuries over three years; 85.7%). 120 injuries could not be followed up due to the quarantine resulting from the COVID-19 cluster or individual infection.

Table 6. Number of Injuries (%) under the Categorised ACWR

		No. of injuries (%)								
		Overall	Traumatic (n=501)				Gradual onset (n=340)			
			Total	2020	2021	2022	Total	2020	2021	2022
< 0.8	RA	165 (20)	89 (18)	16 (10)	29 (18)	44 (25)	76 (22)	57 (24)	15 (21)	4 (12)
	EWMA	183 (22)	115 (23)	23 (14)	38 (23)	54 (31)	68 (20)	50 (21)	15 (21)	3 (9)
0.8 to 1.3	RA	342 (41)	224 (45)	51 (32)	84 (51)	89 (50)	118 (35)	59 (25)	43 (60)	16 (47)
	EWMA	424 (50)	259 (52)	65 (41)	105 (64)	89 (50)	165 (49)	92 (39)	51 (71)	22 (65)
1.3 to 1.5	RA	99 (12)	61 (12)	36 (23)	15 (9)	10 (6)	38 (11)	32 (14)	4 (6)	2 (6)
	EWMA	132 (16)	77 (15)	43 (27)	15 (9)	19 (11)	55 (16)	44 (19)	3 (4)	8 (24)
> 1.5	RA	235 (28)	127 (25)	56 (35)	37 (22)	34 (19)	108 (32)	86 (37)	10 (14)	12 (35)
	EWMA	102 (12)	50 (10)	28 (18)	7 (4)	15 (8)	52 (15)	48 (21)	3 (4)	1 (3)
Total		841	501	159	165	177	340	234	72	34

Note. ACWR: acute-to-chronic workload ratio; RA: rolling average; EWMA: exponentially weighted moving average; Overall: regardless of injury type