Injuries in female and male elite taekwondo athletes: a 10-year prospective, epidemiological study of 1466 injuries sustained during 250 000 training hours

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ABSTRACT

Objectives We aimed to determine the injury patterns associated with training activities in elite South Korean taekwondo athletes training for the Olympic Games.

Methods We collected data prospectively from 2007 to 2016 at the Korea National Training Center in Seoul, South Korea. A sports injury was defined as acute or chronic musculoskeletal signs and symptoms due to taekwondo activities during training sessions. Athletes were assessed by an on-site sports medicine specialist. The elite taekwondo athletes were stratified according to sex, weight class (flyweight, featherweight, welterweight and heavyweight), injury location (body region and site) and injury severity (mild or level I, requiring treatment for 1–3 days; moderate or level II, requiring treatment for 4–7 days; or severe or level III, requiring treatment for ≥8 days).

Results Athlete exposure was 56 160 training sessions that took 249 600 hours. 1466 injuries were recorded in 283 athletes, with an average of 4.6 injuries per athlete annually. Of these, more than half (56%) were mild injuries, with most injuries occurring in the lower extremities (65.5%), followed by injuries to the trunk (16%), upper extremities (14%) and head and neck area (4%). Among these athletes, women had higher injury rates in the featherweight and welterweight categories (P≤0.0001), but there were no sex differences in other weight categories. In general, female athletes and male athletes experienced a comparable risk of injury (relative ratio: 1.55; 95% CI 0.89 to 2.68).

Conclusion In elite South Korean taekwondo athletes, most injuries occur in the lower extremities and were graded as minor. Injury severity depended on weight class.

INTRODUCTION

Taekwondo is one of several combat sports in the modern Olympic Games.[1] It originates from Korea and involves unarmed fighting styles. The competition rules for Olympic-style taekwondo allow full-contact kicking to the head and torso, as well as punching to the front of the torso.[2] Taekwondo athletes are classified into weight classes (flyweight, featherweight, welterweight and heavyweight)[3]; It is unknown whether the incidence or nature of sports injuries is influenced by weight class. Athletes go to extreme lengths (eg, saunas, fasting, laxatives and vomiting) to lose weight rapidly to be categorised into a lower weight class.[4 5] This weight cycling approach has also been associated with deaths in colleagiate wrestling.[6]

Although there are several reports regarding taekwondo-related injuries in amateur and elite athletes,[7–11] there have been no long-term studies focused on the relationship between weight class and injury severity. Most studies involve short-term follow-ups and are focused on special sporting events. Lystad *et al* reported on sports injuries in taekwondo athletes during a period of 2 years, but they only investigated amateur taekwondo athletes.[12] There is a paucity of prospective studies attempting to identify and quantify risk factors for injury.[13]

The IOC aims to develop programmes to prevent sports injuries and to help enhance the performance of Olympic athletes.[14] To collect data on the circumstances in which injuries of various severity occur, a prospective surveillance programme was initiated at the training centre in South Korea, which hosts the training of elite athletes who are expected to represent South Korea at international sporting events such as the World Championships and the Olympic Games. We aimed to analyse the specific patterns of injury for each Olympic-style weight class and to investigate potential sex-specific differences in taekwondo injuries during training.

METHODS

Study population

The present study included 283 top-ranked taekwondo athletes participating in high-level international competitions, who trained at the Korea National Training Center, between January 2007 and December 2016. This study was conducted according to the Declaration of Helsinki. The need for informed consent was waived by the ethics committee. Annually, the Korea National Training Center hosts 32 taekwondo athletes (16 male and 16 female). Four athletes of each sex, who trained at this facility for >1 year and <7 years, were included in the study for each Olympic-style weight class.

Data collection

Data regarding the match details (date and weight classes), characteristics of the athletes (name and sex) and characteristics of the injury (body region, site and severity) were recorded using daily injury report forms issued by the IOC.[15] Per the current medical definition, a sports injury was defined as acute or chronic musculoskeletal signs and symptoms owing to taekwondo activities during training sessions.[16 17] The athletes were assessed by one of three sports medicine specialists available on-site

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during the course of the study period who completed the daily injury report forms on site before referring the athletes to the clinic of the South Korean Training Center. Injury severity was assessed after treatment.

Operational definitions

Multiple injuries in a single athlete were classified according to the affected body region (ie, knee sprains were catalogued under injuries of the knee, whereas ankle sprains were catalogued under injuries of the ankle, regardless of whether the two injuries occurred during the same incident or during separate incidents). The data were stratified according to Olympic-style weight class (flyweight: <58 kg for men, <49 kg for women; featherweight: <68 kg for men, <57 kg for women; welterweight: <80 kg for men, <67 kg for women; heavyweight: >80 kg for men, >67 kg for women), sex and location of the injury. The injury severity was classified as follows: mild injury: requiring 1–3 days of treatment (level I); moderate injury: requiring 4–7 days of treatment (level II); and severe injury: requiring 8 or more days of treatment (level III).[18 19]

The injury location was classified based on the practice of the IOC.[4] We defined the following affected body regions and injury sites: head and neck area (head, face and neck/cervical spine), upper extremity (shoulder/clavicle, upper arms, elbow, forearm, wrist, hand, finger and thumb), trunk (sternum/ribs, thoracic spine/upper back, abdomen, lumbar spine/lower back and pelvic/sacrum/buttock) and lower extremity (hip, groin, thigh, knee, lower leg, Achilles tendon, ankle and foot/toe).[14 20]

Statistical analysis

The examined variables included sex, weight class, injury location (body region and site) and injury severity. Descriptive statistics were used to examine injury patterns. To compare injury severity and location between groups based on weight class or sex, χ^2 tests were applied. Injury rates were calculated as the number of injuries per year, the number of injuries per 1000 hours of training and the number of injuries per 1000 athlete exposures (AE). The total number of training hours was calculated based on the average time (hours/day×days/week×weeks/year) that the athletes spent at the training centre. One AE was defined as participation in one training session. Injury risk was expressed in terms of the relative injury rate (RR) with 95% CIs. The groups were compared in terms of various statistics. All statistical analyses were performed using SPSS V.24.0 for Windows, and the significance level was set at a P value less than 0.05.

RESULTS

A total of 283 athletes >18 years of age were included in the study. Athletes trained an average of 4 hours/day, 5 days a week. Over the course of a year, the athletes were present at the training centre for 9 months (39 weeks), totalling 780 hours of training per year. The athletes participated in nine training sessions for each period of 2 weeks (4.5 training sessions per week), totalling 175.5 AE per year. Thus, athlete exposure was 56 160 training sessions that took 249 600 hours.

Injury rates

A total of 1466 injuries were recorded during the study period, without differentiating between acute and overuse injuries. The total injury rate per athlete was 4.6 injuries/year, with a significant difference between male and female athletes and among weight classes in terms of distribution of injuries per injury severity. Compared with men, women had higher injury rates for the featherweight and welterweight categories, whereas no significant differences were noted between the sexes for the flyweight or heavyweight categories.

In terms of training hours, the overall injury rate was 5.9 injuries/1000 hours of training, with lower rates among flyweight and heavyweight athletes than among featherweight and welterweight athletes. However, this difference was not significant (RR=1.66, 95% CI 0.73 to 3.81) (table 1).

In terms of exposure, the overall injury rate was 26.1 injuries/1000 AE, with lower rates in male athletes (20.5 vs 31.7 injuries/1000 AE; RR=1.55, 95% CI 0.89 to 2.68) (table 2). However, no significant differences in injury rates were noted between male and female athletes competing in the flyweight or heavyweight categories, whereas male featherweight and welterweight athletes had significantly lower injury rates than those noted for their female counterparts (featherweight: RR=1.82, 95% CI 1.05 to 3.14; welterweight: RR=2.27, 95% CI 1.41 to 3.68) (table 2).

Table 1 IR per 1000 hours of training for each weight classes

	1000 hours IR		
Weight class	Men IR (95% CI)	Women IR (95% CI)	RR (95% CI)
Flyweight	4.5 (2.87 to 6.04)	4.3 (2.71 to 5.88)	M ref. 1.05 (0.28 to 3.91)
Featherweight	4.4 (2.77 –to 5.95)	7.9 (6.36 to 9.54)	W ref. 1.80 (0.56 to 5.74)
Welterweight	5.2 (3.60 to 6.78)	11.8 (10.24 to 13.42)	W ref. 2.27 (0.81 to 6.34)
Heavyweight	4.5 (2.90 to 6.08)	4.4 (2.83 to 6.01)	M ref. 1.02 (0.28 to 3.79)
Total	4.6 (1.44 to 7.80)	7.1 (3.94 to 10.30)	W ref. 1.54 (0.48 to 4.97)

IR: sports injuries/1000 hours of training (1000 hours).
M, men; IR, incidence rate; RR, relative ratio; W, women.

Injury location and severity

Injuries occurred most commonly in the lower extremity (65.5%), followed by the trunk (16.2%), upper extremity (14.1%) and head and neck area (4.2%), with similar distributions of affected body regions in male and female athletes (P=0.98) for all weight categories. The ankle, knee, foot/toe, lumbar spine/lower back and thigh were the most common injury sites (table 3).

Table 2 IR per 1000 athlete exposures (AE) for each weight classes

	1000 hours IR		
Weight class	Men IR (95% CI)	Women IR (95% CI)	RR (95% CI)
Flyweight	19.8 (18.03 to 21.57)	19.1 (17.32 to 20.85)	M ref. 1.04 (0.56 to 1.93)
Featherweight	19.4 (17.61 to 21.14)	35.3 (33.56 to 37.09)	W ref. 1.82 (1.05 to 3.14)
Welterweight	23.1 (21.31 to 24.84)	52.6 (50.80 to 54.33)	W ref. 2.28 (1.41 to 3.68)
Heavyweight	19.9 (18.18 to 21.71)	19.7 (17.89 to 21.42)	M ref. 1.01 (0.55 to 1.87)
Total	20.5 (19.67 to 21.43)	31.7 (30.78 to 32.54)	W ref. 1.55 (0.89 to 2.68)

Incidence rate: sports injuries/1000 AE.
IR, incidence rate; RR, relative ratio.

Table 3 Injury location (body region and site) in elite Korean taekwondo athletes

	No (%)							
	Men				Women			
Site	Flyweight	Featherweight	Welterweight	Heavyweight	Flyweight	Featherweight	Welterweight	Heavyweight
Head	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)
Face	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)
Neck/cervical spine	6 (4.3)	7 (5.1)	8 (4.9)	4 (2.9)	2 (1.5)	11 (4.4)	20 (5.4)	3 (2.2)
Head and neck	6 (4.3)	7 (5.1)	8 (4.9)	4 (2.9)	2 (1.5)	11 (4.4)	20 (5.4)	3 (2.2)
Shoulder/clavicle	3 (2.2)	4 (2.9)	10 (6.2)	7 (5.0)	6 (4.5)	11 (4.4)	15 (4.1)	7 (5.1)
Upper arms	1 (0.7)	1 (0.7)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	2 (0.5)	1 (0.7)
Elbow	4 (2.9)	N/A (0.0)	2 (1.2)	1 (0.7)	N/A (0.0)	3 (1.2)	4 (1.1)	2 (1.4)
Forearm	1 (0.7)	N/A (0.0)	1 (0.6)	N/A (0.0)	N/A (0.0)	N/A (0.0)	3 (0.8)	2 (1.4)
Wrist	1 (0.7)	4 (2.9)	N/A (0.0)	5 (3.6)	2 (1.5)	7 (2.8)	8 (2.2)	4 (2.9)
Hand	5 (3.6)	2 (1.5)	5 (3.1)	4 (2.9)	2 (1.2)	5 (2.0)	10 (2.7)	3 (2.2)
Finger	4 (2.9)	6 (4.4)	3 (1.9)	4 (2.9)	4 (3.0)	7 (2.8)	12 (3.3)	2 (1.4)
Thumb	2 (1.4)	1 (0.7)	1 (0.6)	N/A (0.0)	1 (0.7)	N/A (0.0)	2 (0.5)	N/A (0.0)
Upper extremity	21 (15.1)	18 (13.1)	22 (13.6)	21 (15.0)	15 (11.2)	33 (13.3)	56 (15.2)	21 (15.2)
Sternum/ribs	1 (0.7)	2 (1.5)	N/A (0.0)	N/A (0.0)	1 (0.7)	1 (0.4	2 (0.5)	N/A (0.0)
Thoracic spine/upper back	9 (6.5)	1 (0.7)	6 (3.7)	3 (2.1)	3 (2.2)	4 (1.6)	4 (1.1)	4 (2.9)
Abdomen	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	N/A (0.0)	2 (0.5)	N/A (0.0)
Lumbar spine/lower back	16 (11.5)	13 (9.6)	14 (8.6)	16 (11.4)	13 (9.7)	24 (9.7)	38 (10.3)	15 (10.9)
Pelvic/sacrum/buttock	3 (2.2)	2 (1.5)	4 (2.5)	5 (3.6)	3 (2.2)	11 (4.4)	15 (4.1)	3 (2.2)
Trunk	29 (20.9)	18 (13.1)	24 (14.8)	24 (17.1)	20 (14.9)	40 (16.1)	61 (16.5)	22 (15.9)
Hip	2 (1.4)	N/A (0.0)	2 (1.2)	N/A (0.0)	N/A (0.0)	3 (1.2)	7 (1.9)	4 (2.9)
Groin	N/A (0.0)	2 (1.5)	1 (0.6)	1 (0.7)	N/A (0.0)	2 (0.8)	1 (0.3)	3 (2.2)
Thigh	16 (11.5)	13 (9.6)	19 (11.7)	10 (7.1)	12 (9.0)	28 (11.3)	33 (8.9)	14 (10.1)
Knee	23 (16.5)	25 (18.4)	22 (13.6)	17 (12.1)	22 (16.4)	28 (11.3)	41 (11.1)	15 (10.9)
Lower Leg	7 (5.0)	9 (6.6)	10 (6.2)	14 (10.0)	17 (12.7)	26 (10.5)	43 (11.7)	9 (6.5)
Achilles tendon	2 (1.4)	3 (2.2)	5 (3.1)	7 (5.0)	4 (3.0)	10 (4.0)	16 (4.3)	7 (5.1)
Ankle	25 (18.0)	28 (20.6)	28 (17.3)	27 (19.3)	24 (17.9)	43 (17.3)	57 (15.4)	26 (18.8)
Foot/toe	8 (5.8)	13 (9.6)	21 (13.0)	15 (10.7)	18 (13.4)	24 (9.7)	34 (9.2)	14 (10.1)
Lower extremity	83 (59.7)	93 (68.5)	108 (66.7)	91 (65.0)	97 (72.4)	164 (66.1)	232 (62.9)	92 (66.7)
Total	139	136	162	140	134	248	369	138

Data provided as absolute incidence and frequency of injury at a specific site or in a specific body region, relative to the total number of injuries noted over the entire observation period.

For all weight classes, more than half of the injuries (56.5%) were level I (minor severity), followed by level II and level III injuries with an overall prevalence of 22.9% and 20.6%, respectively (table 4). In both men and women, weight class significantly influenced the injury severity ($P<0.001$ and $P=0.022$, respectively). Specifically, among male athletes: level I injuries occurred most commonly in the welterweight category, followed by flyweight, heavyweight and featherweight; level II injuries occurred most commonly in the welterweight category, followed by heavyweight, featherweight and flyweight; level III injuries occurred most commonly in the featherweight category, followed by flyweight and heavyweight with equal injury rates and then by welterweight. However, among female athletes, injuries of any severity occurred most commonly in the welterweight category, followed by featherweight, flyweight and heavyweight. The injury severity also varied

Table 4 Injury severity and affected weight class

	No (%)					
	Men			Women		
Weight class	Level I	Level II	Level III	Level I	Level II	Level III
Flyweight	92 (26.4)	16 (15.2)	31 (25.0)	76 (15.8)	40 (17.4)	18 (10.1)
Featherweight	75 (21.6)	20 (19.0)	41 (33.1)	138 (28.7)	67 (29.1)	43 (24.2)
Welterweight	94 (27.0)	47 (44.8)	21 (16.9)	194 (40.3)	81 (35.2)	94 (52.8)
Heavyweight	87 (25.0)	22 (21.0)	31 (25.0)	73 (15.2)	42 (18.3)	23 (12.9)
Total	348	105	124	481	230	178

Data provided as absolute incidence and frequency of injury in a specific body region, relative to the total number of injuries noted over the entire observation period. Injury severity was defined as: mild or level I injury, requiring treatment for 1–3 days; moderate or level II injury, requiring treatment for 4–7 days; and severe or level III injury, requiring treatment for ≥8 days.

Table 5 Statics results of injury in elite Korean taekwondo athletes

	No (%)					
Injury	**Level I**	**Level II**	**Level III**	**df**	**χ^2**	**P value**
Men						
Flyweight	92 (26.4)	16 (15.2)	31 (25.0)	6	27.123	P<0.001
Featherweight	75 (21.6)	20 (19.0)	41 (33.1)			
Welterweight	94 (27.0)	47 (44.8)	21 (16.9)			
Heavyweight	87 (25.0)	22 (21.0)	31 (25.0)			
Women						
Flyweight	76 (15.8)	40 (17.4)	18 (10.1)	6	14.775	P=0.022
Featherweight	138 (28.7)	67 (29.1)	43 (24.2)			
Welterweight	194 (40.3)	81 (35.2)	94 (52.8)			
Heavyweight	73 (15.2)	42 (18.3)	23 (12.9)			
Men						
Head and neck	19 (5.5)	6 (5.7)	N/A (0.0)	6	38.104	P<0.001
Upper extremity	62 (17.8)	15 (14.3)	5 (4.0)			
Trunk	68 (19.5)	16 (15.2)	11 (8.9)			
Lower extremity	199 (57.2)	68 (64.8)	108 (87.1)			
Women						
Head and neck	26 (5.4)	7 (3.0)	3 (1.7)	6	35.705	P<0.001
Upper extremity	85 (17.7)	28 (12.2)	12 (6.7)			
Trunk	88 (18.3)	39 (17.0)	16 (9.0)			
Lower extremity	282 (58.6)	156 (67.8)	147 (82.6)			
Flyweight						
Head and neck	5 (3.0)	3 (5.4)	N/A (0.0)	6	14.553	P=0.024
Upper extremity	25 (14.9)	9 (16.1)	2 (4.1)			
Trunk	36 (21.4)	9 (16.1)	4 (8.2)			
Lower extremity	102 (60.7)	35 (62.5)	180 (87.8)			
Featherweight						
Head and neck	12 (5.6)	5 (5.7)	1 (1.2)	6	24.970	P<0.001
Upper extremity	41 (19.2)	8 (9.2)	2 (2.4)			
Trunk	33 (15.5)	16 (18.4)	9 (10.7)			
Lower extremity	127 (59.6)	58 (66.7)	72 (85.7)			
Welterweight						
Head and neck	22 (7.6)	4 (3.1)	2 (1.7)	6	18.858	P=0.004
Upper extremity	48 (16.7)	17 (13.3)	13 (11.3)			
Trunk	54 (18.8)	20 (15.6)	11 (9.6)			
Lower extremity	164 (56.9)	87 (68.0)	89 (77.4)			
Heavyweight						
Head and neck	6 (3.8)	1 (1.6)	N/A (0.0)	6	29.218	P<0.001
Upper extremity	33 (20.6)	9 (14.1)	N/A (0.0)			
Trunk	33 (20.6)	10 (15.6)	3 (5.6)			
Lower extremity	88 (55.0)	44 (68.8)	51 (94.4)			

Data provided as absolute incidence and frequency of injury in a specific body region, relative to the total number of injuries noted over the entire observation period. Injury severity was defined as: mild or level I injury, requiring treatment for 1–3 days; moderate or level II injury, requiring treatment for 4–7 days; and severe or level III injury, requiring treatment for ≥8 days.

with body region in both male athletes (P<0.001) and female athletes (P<0.001) (table 5). Moreover, the weight categories differed significantly in terms of distribution of injuries with a certain severity in various body regions (table 5).

DISCUSSION

We aimed to better understand the pattern of sports injuries among elite South Korean taekwondo athletes by assessing the association between injury rate, location and severity based on sex and weight class. Previous prospective studies conducted on elite South Korean taekwondo athletes focused only on injuries occurring prior to or during special sporting events.[21 22] Although differences in the study design preclude a direct comparison between our results and those of previous studies, there were similarities regarding male and female injury rates/1000 AE (our study: 39.4 vs 60.6; previously reported: 44.4 vs 55.6). While there were differences regarding total injuries/1000 AE (our study: 26.1; previously reported: 152.5),[21] there were similarities regarding injury site (ankle and knee as the most common sites).[22] It may be that the differences are related to the fact that, during competition, full contact to the head is allowed, whereas athletes use a wider variety of techniques during training, and moreover not all training time is devoted to open combat.[23]

Injury location

In the present study, we found that injuries occurred most commonly in the lower extremity, followed by the trunk, upper extremity and head and neck area. Three previous studies reported injury data from national competitions involving taekwondo events, namely the Canadian National Championships,[9] Thailand National Championships[10] and Greek National Championships.[11] In these studies, the most commonly affected body region was the lower extremity, which is similar to our findings from epidemiological studies undertaken at the South Korean Training Center.[9–11] However, the second most affected body region varied between studies. Another interesting difference is that injuries to the head and neck were commonly reported in other studies but rarely observed in our study (4.2%). The discrepancy between the findings for South Korean and non-Korean athletes may be related to differences in style of combat, physical build and training methods. For example, Choi *et al*[24] reported an average of 17.2 kicks per athlete per match in South Korean athletes, with 20.2, 18.7, 16.7 and 13.4 kicks per match for featherweight, flyweight, welterweight and heavyweight athletes, respectively. However, Santos *et al*[25] reported that Spanish athletes in the flyweight, featherweight, welterweight and heavyweight categories delivered an average of 8.6, 6.6, 7.5, and 6.8 kicks per match, respectively. In other words, compared with Spanish athletes, South Korean taekwondo athletes are more likely to use kicks, which may result in higher rates of injury to the extremities.[24]

Injury severity

Defining the injury severity is a difficult problem.[25] Most current studies use time lost from sport participation as part of the injury definition, but this can range from the loss of any game or practice time to the loss of a full competition or practice session.[16] The use of a simple time loss definition has significant shortcomings. First, an injury that occurs at the end of a game on a Friday night may be resolved in time for the next practice on the following Monday.[25] Second, an athlete may elect to practice or not to practice based on their own subjective determination of the injury severity.[25]

In our study, weight class significantly influenced injury severity in both men and women. Moreover, the weight categories differed significantly in terms of distribution of injuries with a certain severity in various body regions. However, we could not compare our findings with previous observations because no information is available on injury severity by weight class, as noted by Beis *et al*.[26]

Furthermore, in this study, injury severity was assessed after treatment. It was determined that injury severity varied with body region in male and female athletes. When broken down into days lost due to time-loss injury, female athletes showed higher rates than those noted in male athletes for each category distinguished, although these differences were not significant. It was previously reported that, compared with female athletes and their coaches, male athletes and their coaches are less inclined to report time-loss injuries.[27]

Weight class differences in injury patterns

Furthermore, we found that the distribution of affected body regions was different for each weight class, which contrasts with previous observations even though aspects regarding competition and training did not change significantly over time.[22] This discrepancy may be explained by the different dynamics and skill sets required for performance in each weight class,[28] as well as by the specific competition time and training methods associated with different weight classes. For example, energy expenditure during a fighting bout is typically higher in athletes of heavier weight categories than in those of lighter weight categories.[28]

Among males, the highest incidence of injury was noted in welterweight athletes, followed by heavyweight, flyweight and then featherweight athletes. Among women, the highest incidence was also noted in welterweight athletes but followed by featherweight, heavyweight and then flyweight athletes. Given that our two previous studies in South Korean taekwondo athletes did not analyse weight class or injury severity,[21 22] the differences in study design preclude a comparison between our present results and those of the previous studies. Nevertheless, it should be noted that two studies suggested that athletes in lighter weight classes incurred significantly fewer injuries than those in heavier weight classes,[14 29] whereas the opposite trend was observed among South Korean athletes.[24]

Considering the variation in reported mechanisms and injury sites,[7–11] further research related to weight classes is warranted to assess the specific injury patterns during training and competition. Such information will be useful in building strategies for injury prevention based on the specific circumstances of elite athletes.[14]

Sex-specific differences in injury patterns

Kim and Kim[30] insisted that the incidence of sports injuries differed in male and female athletes. We also noted that female athletes displayed a higher annual injury rate than that noted for male athletes. However, data from the Canadian National Championships[9] and Thailand National Championships[10] showed a higher rate of injuries/1000 AE in male athletes, in contradiction with observations from the South Korean Training Center and Greek National Championships.[11]

For all weight categories (flyweight, featherweight, welterweight and heavyweight), male and female athletes differed significantly in terms of the injury severity. Overall, we found that male athletes had more level I injuries, female athletes had more level II injuries, while male and female athletes had similar risk of level III injuries (P=0.003). Sterkowicz *et al*[31] suggested that such sex-specific differences are related to physical build, as athletes tend to adapt their strategy and use different skill sets according to their physical build and strength relative to those of their opponent.

Suggestions for injury prevention

While serious injuries or injuries that require a long recovery period appear to be relatively rare among taekwondo athletes, there is a real risk of sustaining numerous minor injuries that may be preventable.[7–11] The following expert opinions based on the available evidence are likely to be confirmed in the future by appropriate research.

Since injuries of the lower extremities were the most common injuries noted in our study, and the most frequently cited cause of injury was inadequate warm-up, it is expected that proper warm-up should help prevent injuries in elite athletes.[32] The FIFA 11+ programme has demonstrated how a simple-to-implement, exercise-based warm-up programme can decrease the incidence of injuries in both male and female amateur football players.[33] Additionally, Olsen *et al*[34] found that a structured programme of warm-up exercises can prevent knee and ankle injuries in handball athletes and recommended that preventive training be introduced as an integral part of sports programmes.

Therefore, the first recommendation for preventing injuries is to educate coaches and athletes on the importance of proper warm-up techniques prior to practice and competition.

The second recommendation for reducing the risk of injury is to avoid high training loads, as suggested by Gabbett.[35] Although training improves performance by increasing skill, it also causes fatigue and injury. To alleviate the effect of overtraining, we suggest to monitor an athlete's training load, recovery and overtraining. Adequate training load planning and recovery have been reported to significantly decrease injury rates, especially during periods of *weight loss*.[36] Haddad *et al*[37] have presented a model for monitoring training load, overtraining and recovery in taekwondo, using simple and practical methods such as rating of perceived exertion, the Hooper's Index (rating the quality of sleep, as well as quantity of fatigue, sleep and delayed onset muscle soreness)[38] and the Total Quality Recovery score. Other common objective methods for monitoring training load are based on heart rate monitoring and can be easily applied in taekwondo.[39]

The third major recommendation for preventing injuries is creating a psychological profile of each athlete. Pieter *et al* revealed a relationship between precompetition mood and total injury rate. Women who scored higher on mood subscales of anger, fatigue and confusion were more likely to sustain injury, as were men who scored higher on the fatigue subscale.[23]

The fourth recommendation for preventing injuries is encouraging appropriate body weight control to avoid rapid weight reduction. This practice of rapid weight loss is prevalent in sports with weight categories. Many combat athletes lose up to 5%–10% of their body weight for competitions, with many reporting more than 10% reduction in body weight.[40–42] This approach is not only known to negatively affect an individual's growth and development[43] but may increase the risk of injury during competition.[4 5]

Strengths

In the present study, a large number of athletes were observed closely for 9 months (39 weeks), totalling 780 hours of training per year. Moreover, a detailed analysis of the severity (defined in terms of time-loss from training), incidence and location of the injuries was performed with an extremely high inclusion rate. Every injury that occurred at the training facility was reported and handled within the on-site facilities, and this made for consistent data gathering. Our study considered the influence of weight class category. An additional strength of the study was that the number of injuries were analysed by subcategories to address novel research questions that are relevant to the taekwondo sports medicine community.

Limitations

We did not have any information regarding the biomechanical injury mechanisms. Our data came from daily injury report forms, which were completed on site as soon as an athlete reported their injury symptoms. These forms only included the results of the initial assessment, before the athlete was referred to the clinic and therefore did not specify the diagnosis.

Conclusions

More than half of all the injuries noted among elite South Korean taekwondo athletes were considered minor, as the athletes were able to return to training after simple treatment and taping. In the featherweight and welterweight categories, female athletes had a higher rate of injuries than men, but there were no sex difference in the flyweight or heavyweight categories. For both male and female athletes, the injury severity was dependent on the weight class.

What are the new findings?

- Most injuries sustained by elite South Korean taekwondo athletes were level I (mild).
- Among these elite taekwondo athletes, women had higher injury rates in the featherweight and welterweight categories, but there were no sex differences in other weight categories.
- The injury severity depended on the weight class, with severe injuries occurring less often in male welterweight and female flyweight athletes, and more often in male featherweight and female welterweight athletes.
- More than half of the injuries affected the lower extremities, with injuries to the ankle, knee, lumbar spine/lower back, foot/toe and thigh prominent.

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Competing interests None declared.

Ethics approval The study design was approved by the Korea Training Center.

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