Epidemiology of training injuries in amateur taekwondo athletes: a retrospective cohort study

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ABSTRACT: The objectives of this study were to estimate the incidence and describe the pattern and severity of training injuries in taekwondo, and to compare pattern and severity of training injuries with competition injuries. One hundred and fifty-two active Australian amateur taekwondo athletes, aged 12 years or over, completed an online survey comprising questions on training exposure and injury history over the preceding 12 months. The main outcome measures were: overall injury incidence rate per athlete-year; training injury incidence rate per athlete-year, per 1000 athlete-training-sessions, and per 1000 athlete-hours of training; injury severity; and injury proportions by anatomical region and by type of injury. Injury incidence rates were calculated with 95% confidence intervals using standard methods, while injury proportions were compared using Fisher's exact test. The vast majority (81.5%) of taekwondo injuries in an average athlete-year occurred during training. The training injury incidence rate was estimated to be 1.6 (95% CI: 1.4, 1.9) per athlete-year, 11.8 (95% CI: 10.4, 13.4) per 1000 athlete-training-sessions, and 7.0 (95% CI: 6.1, 7.9) per 1000 athlete-hours of training. Among athletes with five or fewer injuries, the severity and injury pattern of training injuries were, by and large, the same as for competition injuries. Approximately sixty percent (60.3%) of training injuries required treatment by a health professional. Considering the burden of training injuries exceeds that of competition injuries, taekwondo governing bodies and stakeholders are encouraged to devote more efforts towards the identification of risk factors for, and prevention of, training injuries in the sport of taekwondo.

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INTRODUCTION

Although the positive effects of regular physical activity are undisputed, participation in sport and active recreation is not without risk, and injuries can be an adverse outcome. Indeed, sport injury is identified as a major public health problem in the Western world [1,2,3]. Annually, approximately 40% of adolescents receive medical treatment for sports-related injuries [4], and it is estimated that 8% of youths discontinue active recreation and sporting activities every year because of injury, potentially leading to a loss of health benefits in the future [5].

Modern taekwondo is a Korean martial art and combat sport characterized by its emphasis on dynamic kicking techniques delivered from a mobile stance [6]. Over the last half century, taekwondo has grown in popularity and has arguably become the most commonly practiced martial art in the world [7]. Agility, strength, speed, balance, flexibility, coordination, and stamina are all important attributes required for a taekwondo athlete to be able to execute the highly demanding kicking combinations [6,7].

As in any contact sport, there is an inherent risk of injury to combative martial arts athletes. Previous literature reviews have shown there is a substantial risk of injury in competition taekwondo [8,9]. Pieter et al. [8] reported competition injury rates between 20.6 and 139.5 per 1000 athlete-exposures, while Lystad et al. [9] used a meta-regression approach to estimate an overall competition injury incidence rate of 79.3 per 1000 athlete-exposures after adjusting for level of play, sex, and mean age. As might be expected, epidemiologic studies in taekwondo found the most frequently injured body regions were the lower limbs and the head/neck region, while the most common types of injuries were contusions and joint sprains [8,9].

Despite the information available on competition injuries, there is a paucity of data on training injuries in taekwondo, particularly, in amateur athletes. In a retrospective study (12-month recall) of Canadian taekwondo athletes competing at the national level, Kazemi and colleagues [10] reported a training injury incidence rate (IIR) of 32.5 per 1000 athlete-hours of training, while in another retrospective study (3-year recall), Zetou et al. [11] found the training IIR of Greek taekwondo athletes competing in the national championship division to be 1.8 per athlete-year and 6.6

per 1000 athlete-hours of training. However, neither Kazemi and colleagues [10], nor Zetou et al. [11] described the injury pattern or injury severity specific to training injuries. Because athletes spend far greater time training than competing there is an urgent need to further elucidate the extent of the injury problem in the training context. A better understanding of the epidemiology of training injuries in taekwondo is paramount to developing effective preventive actions to help mitigate the injury problem in the sport.

Hence, the objectives of this study were: (1) to estimate the incidence of training injuries in amateur taekwondo athletes; (2) to describe the pattern and severity of training injuries; and (3) to compare the pattern and severity of training injuries with competition injuries.

MATERIALS AND METHODS

Study population. All taekwondo athletes based in Australia, aged 12 years or over, were eligible to participate in the study provided they had been actively participating in taekwondo in the past 12 months. It is estimated that Australian taekwondo community comprises roughly 18,000 members. However, a large proportion of this membership is expected to consist of primary school children, and a small proportion would be instructors or referees who do not actively participate in training. Hence, the actual total size of the target population for this study is not precisely known.

Procedure

Invitations to participate in this study were forwarded via notifications in email newsletters distributed by a major taekwondo association and via targeted advertising on Facebook. Eligible consenting participants were asked to complete an anonymous online survey administered via SurveyMonkey™ web portal. The study was approved by the Macquarie University Human Research Ethics Committee.

Survey instrument

The survey instrument was based on a survey previously developed and validated by Siesmaa et al. [12]. It was slightly modified to directly address a population of taekwondo athletes, and to obtain additional details of the reported injuries. The online survey was comprised of four sections: (i) demographic information, including age, sex, height, weight, and years of experience; (ii) taekwondo participation in the past 12 months; (iii) safety and injury risk in sport; and (iv) sports injury history in the past 12 months. The survey allowed participants to report any total number of injuries sustained in the past 12 months; however, in an attempt to minimize the negative effects of respondent fatigue, each participant could only provide detailed information for a maximum of five injuries. Injured athletes were asked to provide the following information for each injury: anatomical location, type of injury, number of days lost from participation, treatment provision (including type of care provider), and whether the injury took place during training or competition.

Injury definitions

This study adopted the operational injury definitions recommended by Lystad et al. [9]. One exposure was defined as one athlete participating in one training session, and similarly, one exposure-hour was defined as one athlete participating in one hour of training. An injury was defined as any physical complaint sustained by an athlete during match or training, which results in the athlete either receiving medical attention or being unable to take full part in future training or match play. Injury severity was defined in terms of the number of days that elapsed from the date of injury to the date of the athlete's return to full participation in training and match play, and categorized as: *slight* (0–1 days), *minimal* (2–3 days), *mild* (4–7 days), *moderate* (8–28 days), *severe* (>28 days), and *"permanent disability"* (indicating that complete recovery was not expected). Injuries were coded according to the Orchard Sports Injury Classification System (OSICS), Version 10 [13].

Data analysis

Summary statistics and cross-tabulations were used to describe demographic information. The body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Overall injury incidence rate (IIR) per athlete-year, and training IIR per athlete-year, per 1000 athlete-training-sessions and per 1000 athlete-hours of training were calculated with 95% confidence intervals (CI) using standard methods for Poisson rates [14,15].

The proportions of all injuries occurring in training (by anatomical region, injury type, severity, and treatment provision) were compared to the proportions of all injuries occurring in competition using Fisher's exact test. For example, the proportion of injuries occurring in each anatomical region in training can be compared to the proportion of injuries occurring in each anatomical region in competition. In the online survey, the reporting of injury details was restricted to a maximum of five injuries, thereby truncating reports from athletes with more than five injuries. This may introduce a systematic reporting error (measurement bias) because athletes with more than five injuries are more likely to recall and report their five most severe or significant injuries. Thus, in an attempt to limit potential measurement bias, the athletes who reported more than five injuries were excluded from the analyses of frequencies and proportions of training and competition injuries by anatomical region, injury type, severity, and treatment of injury.

In addition, a binomial logistic regression model was used on the subset of athletes with five or fewer injuries to examine the relationship between odds of sustaining at least one training injury in the preceding 12 months and potential risk factors (i.e., demographic variables such as age, sex, BMI, and years of experience) on the subset of athletes with five or fewer injuries. All statistical analyses were performed using R, version 2.15.2 (R Foundation for Statistical Computing, Austria).

RESULTS

Figure 1 provides an overview of the number of respondents and injury records at various stages of the study. Two hundred and thirty-nine Australian taekwondo athletes consented to participate in the survey, of which 164 completed the demographic section. Of these, 152 (30.9% female) eligible respondents reported having actively participated in taekwondo during the past 12 months and completed the relevant part of injury history section of the survey. The participation rate was difficult to estimate because neither the actual size of the target population, nor the total number of eligible participants receiving the invitation to participate was known.

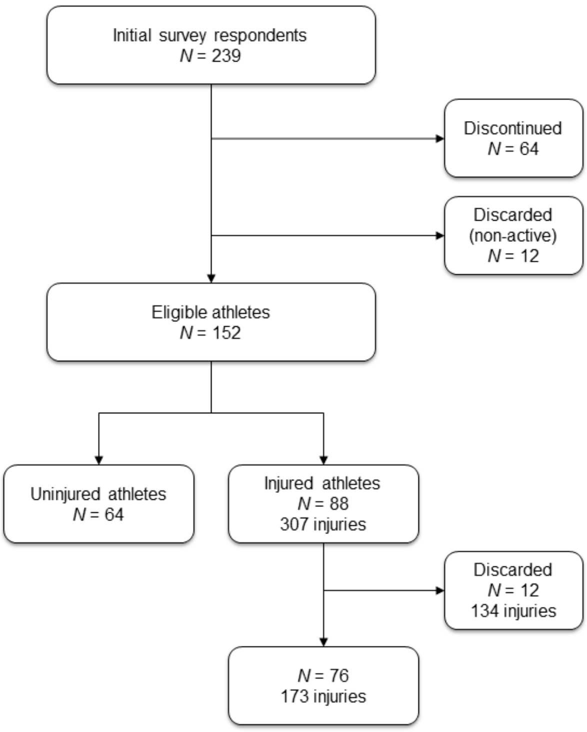

FIG. 1. PRISMA flow chart showing the number of respondents and injury records at various stages of the study.

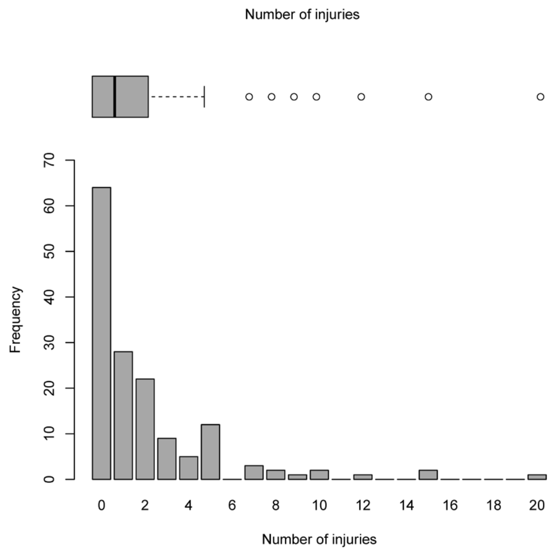

FIG. 2. Box plot and frequency distribution of the number of injuries (training and competition) in the past 12 months per athlete.

TABLE 1. Characteristics of the study sample reported as means with standard deviation, and comparison of means between the sexes.

Characteristic	Overall (*N* = 152)	Female (*N* = 47)	Male (*N* = 105)	*P* value
Age, years	26.0 (10.8)	26.3 (10.3)	25.8 (11.0)	0.762
Height, cm	173.8 (9.7)	165.2 (6.7)	177.8 (8.2)	< 0.001
Weight, kg	71.7 (13.3)	64.3 (10.3)	75.0 (13.2)	< 0.001
Body mass index, kg m^{-2}	23.8 (4.0)	23.6 (3.9)	23.8 (4.0)	0.754
Experience, yrs	7.1 (5.6)	6.7 (5.0)	7.2 (5.8)	0.601
Training sessions per week, n	2.9 (2.2)	3.3 (1.7)	2.7 (2.4)	0.115
Duration of training sessions, hrs	1.7 (0.6)	1.5 (0.5)	1.7 (0.6)	0.057

Table 1 provides an overview of the characteristics of the study sample ($N = 152$). Although there were significant differences between males and females in terms of height ($P < 0.001$) and weight ($P < 0.001$), there was no difference in BMI ($P = 0.687$). The mean number of training sessions undertaken per week was 2.9 (standard deviation [SD]: 2.2), while the average duration of a training session was 1.7 (SD: 0.6) hours.

Figure 2 shows a box plot and the frequency distribution of the number of injuries (training and competition combined) in the past 12 months per athlete (median: 1; range: 0 to 20). Of the 152 respondents, 88 athletes (57.9%) reported having incurred one or more injuries during the previous 12 months, comprising a total of 307 injuries. The overall IIR per athlete-year was 2.0 (95% CI: 1.8, 2.3).

TABLE 2. Overview of training injury and exposure estimates.

Number of athletes	152
Estimated number of training injuries[a]	250
Estimated number of training sessions per year[b]	21,158
Estimated number of training-hours per year[c]	35,335
Training injury incidence rate (95% confidence interval):	
- per athlete-year	1.6 (1.4, 1.9)
- per 1,000 athlete-exposures	11.8 (10.4, 13.4)
- per 1,000 athlete-hours of exposures	7.1 (6.2, 8.0)

Note: [a] total number of reported injuries × proportion of injuries occurring during training, [b] mean number of training sessions/week × 48 weeks × number of athletes, [c] estimated number of training sessions/year × mean number of hours/session

Table 2 provides an overview of the training injury and exposure data and the training IIR estimates of the study sample (*N* = 152). The training IIR was estimated to be 1.6 (95% CI: 1.4, 1.9) per athlete-year, 11.8 (95% CI: 10.4, 13.4) per 1000 athlete-training-sessions, and 7.0 (95% CI: 6.1, 7.9) per 1000 athlete-hours of training.

Prior to the injury pattern analyses the twelve athletes who reported incurring more than five injuries were excluded from analysis due to a lack of injury detail on all injuries sustained, thereby reducing the sample to 140 athletes and detailed descriptions of a total of 173 of the 307 originally reported injuries. The vast majority of reported injuries occurred during training (141/173; 81.5%), while the remainder occurred during competition (32/173; 18.5%). Tables 3, 4, 5 and 6 show the proportions of training and competition injuries by anatomical region, by type of injury, by injury severity, and by treatment provision, respectively, for those athletes with five or fewer reported injuries (*N* = 140). There were no statistically significant differences between training and competition injuries in proportions of injuries by anatomical region (*P* = 0.080), type of injury (*P* = 0.074), injury severity (*P* = 0.779), or treatment provision (*P* = 0.324). More than half of training injuries (56.7%) were found to be of moderate or greater severity, including a small proportion (5.0%) resulting in permanent disability. Approximately sixty percent (60.3%) of training injuries required treatment by a health professional.

The binomial logistic regression modelling on the subset of athletes with five or fewer injuries (*N* = 140) did not reveal any significant relationships between odds of sustaining a training injury during the preceding 12 months and demographic variables (gender: *P* = 0.088; age: *P* = 0.952; years of experience: *P* = 0.401; and BMI: *P* = 0.523).

TABLE 3. Frequencies and proportions of training (*n* = 141) and competition (*n* = 32) injuries by anatomical region.

Anatomical region	Frequency (%)	
	Training	Competition
Head & neck	6 (4.3)	6 (18.8)
- Head	3 (2.1)	6 (18.8)
- Neck	3 (2.1)	0 (0)
Upper limb	32 (22.7)	5 (15.6)
- Shoulder	7 (5.0)	0 (0)
- Upper arm	2 (1.4)	0 (0)
- Elbow	2 (1.4)	2 (6.3)
- Forearm	1 (0.7)	0 (0)
- Wrist & hand	20 (14.2)	3 (9.4)
Trunk	9 (6.4)	1 (3.1)
- Chest	0 (0)	0 (0)
- Abdomen	1 (0.7)	1 (3.1)
- Lumbar spine	5 (3.5)	0 (0)
- Pelvis & buttocks	3 (2.1)	0 (0)
Lower limb	90 (63.8)	19 (59.4)
- Hip & groin	11 (7.8)	2 (6.3)
- Thigh	14 (9.9)	1 (3.1)
- Knee	17 (12.0)	4 (12.5)
- Lower leg	11 (7.8)	3 (9.4)
- Ankle	19 (13.5)	4 (12.5)
- Foot	18 (12.8)	5 (15.6)
Location unspecified	4 (2.8)	2 (6.3)

TABLE 4. Frequencies and proportions of training (*n* = 141) and competition (*n* = 32) injuries by type of injury.

Type of injury	Frequency (%)	
	Training	Competition
Muscle strain	28 (19.9)	5 (15.6)
Joint sprain	23 (16.3)	1 (3.1)
Contusion	20 (14.2)	10 (31.3)
Tendon injury	15 (10.6)	4 (12.5)
Fracture	12 (8.5)	5 (15.6)
Dislocation	10 (7.1)	3 (9.4)
Other/unidentified	33 (23.4)	4 (12.5)

DISCUSSION

This is the first study to report specifically on not only the incidence, but also the injury pattern and severity of training injuries in amateur taekwondo athletes. On average, an amateur taekwondo athlete can

TABLE 5. Frequencies and proportions of training (*n* = 141) and competition (*n* = 32) injuries by injury severity.

Injury severity	Frequency (%)	
	Training	Competition
Less than 1 week	61 (43.3)	16 (50.0)
- 0 to 1 day	10 (7.1)	3 (9.4)
- 2 to 3 days	12 (8.5)	4 (12.5)
- 4 to 7 days	39 (27.7)	9 (28.1)
More than 1 week	81 (56.7)	16 (50.0)
- 8 to 28 days	34 (24.1)	9 (28.1)
- More than 28 days	39 (27.7)	7 (21.9)
- Permanent disability	7 (5.0)	0 (0)

TABLE 6. Frequencies and proportions of training (*n* = 141) and competition (*n* = 32) injuries by treatment provision.

Treatment provision	Frequency (%)	
	Training	Competition
Treatment	85 (60.3)	16 (50.0)
- Physiotherapist	45 (31.9)	8 (25.0)
- Medical doctor	25 (17.7)	7 (21.9)
- Hospital	4 (2.8)	1 (3.1)
- Other	11 (7.8)	0 (0)
No treatment	56 (39.7)	16 (50.0)

expect to be injured twice per year, and the vast majority of these injuries occur during training (training IIR: 1.6 per athlete-year and 7.0 per 1000 athlete-hours of training). Zetou et al. [11] reported very similar findings in a study on Greek taekwondo athletes competing in the national championship division (overall IIR: 2.2 per athlete-year; training IIR: 1.8 per athlete-year, and 6.6 per 1000 athlete-hours of training). In contrast, Zazryn and colleagues [16] reported a lower injury rate in boxing (overall IIR: 0.4 per athlete-year). Moreover, while both the present study and Zetou et al. [11] found that the vast majority (81.5%) of injuries in taekwondo occurred during training, Zazryn and colleagues [16] reported that only 42.9% of injuries in boxing occurred during training. The reason for the observed difference between taekwondo and boxing has not been elucidated, but it is not difficult to conjecture that compared to boxers, amateur taekwondo athletes may, for instance, compete less often, engage in more risky activities during training, or use less protective gear. It is also possible that the observed differences are caused by variations in study methodology.

Overall, there was no significant difference in the injury proportions by anatomical region between training and competition injuries. However, the proportion of head and neck injuries arising from training is considerably lower than the proportion of head and neck injuries arising from competition (Table 3). The reason for this difference is not known, but it could be speculated that athletes may be more apprehensive about delivering powerful head kicks to their fellow training partners and friends compared to competitors on the court, or perhaps they are, at least in some cases, explicitly instructed not to deliver full contact kicks to the head during training. In any event, the proportions of injuries by anatomical region in this study corresponds well with previous reports on competition injuries in taekwondo, that is, that the lower limb is by far the most commonly injured body region, followed by the upper limb [8,9,17].

This study was the first investigation to describe the severity of training injuries in taekwondo, and it was revealed that more than half of training injuries (56.7%) were of moderate or greater severity. A recent prospective study of a cohort of Australian amateur taekwondo athletes reported a substantially lower proportion (32.0%) of moderate to severe competition injuries [17]. This difference between training and competition injuries in taekwondo may be due to differences in study design, that is, a prospective injury surveillance study is not subject to the potential problem of recall bias that one might expect in a survey with a 12-month recall period. Compared with shorter recall periods, longer recall periods tend to underestimate the overall IIR; however, a recall period up to 12 months is unlikely to affect IIR estimates for more severe injuries [18,19]. Thus it is very likely that the present study is subject to significant under-reporting of slight, mild and minor injuries (and an underestimate of the true burden of injury), which in turn resulted in an inflated proportion of moderate to severe injuries. This difference between training and competition injuries may also be accounted for by selection bias, with athletes more likely to respond to the survey if they had suffered a moderate to severe injury in the sport. It is recommended that future research adopt a prospective, longitudinal study design to provide more accurate estimates of the training IIR and the severity of and risk factors for training injuries in taekwondo.

Notwithstanding the influence of recall bias on IIR estimates and the proportion of injuries by severity, it is important to note that the injury severity proportions reported in the current study are similar for training and competition injuries. Moreover, a small (5.0%) but nonetheless noteworthy proportion of training injuries were reported to result in permanent disability. The majority of both training and competition injuries necessitated some kind of medical care (59.1% and 62.8%, respectively). On average, an amateur taekwondo athlete can expect to experience one injury per year that requires treatment by a health care professional, and thereby incur both direct and indirect costs to themselves and the health care system. Moreover, significant time away from sport participation would also entail a potential loss of benefits and the positive effect of regular physical activity.

Given that the injury pattern and severity of training and competition injuries is very similar and that a much greater proportion of injuries occur during training in an average athlete-year, it is suggested that the overall burden of training injuries far exceeds that of competition injuries. Thus taekwondo governing bodies and stakeholders are encouraged to devote more effort and attention towards preventing injuries in the training setting. Further research is necessary to elucidate what preventive actions (e.g., education, regulations, guidelines, policy, culture change, environmental modification, protective equipment, etc.) would provide the most benefit to the taekwondo community at large.

Limitations

The main limitations of this study pertain to the fact that the participants selected themselves into the study by responding to an advertisement distributed via electronic newsletters and social media, and the difficulty estimating the participation rate in study, such that the proportion of responders is unknown. This may have resulted in a sample that is not necessarily representative of the target population (Australian amateur taekwondo athletes). As mentioned above, the known issues associated with recall bias are likely to have caused a probable underestimation of the training injury incidence rate and a probable overestimation of the proportion of severe injuries in this study [18,19]. Furthermore, this study relied on self-reports of injury history data, and although the accuracy of simple reports on injury status (i.e., injured or not injured) is good, the validity of more detailed information (e.g., anatomical region and diagnosis) is likely to be somewhat diminished [19,20]. Lastly, the annual exposure was an estimate based on the average number of training sessions per week and an estimated 48 weeks of training. Future studies are encouraged to measure actual rather than estimated, total annual exposure.

CONCLUSIONS

The results herein suggest that amateur taekwondo athletes experienced, on average, two injuries per year. The vast majority (81.5%) of taekwondo injuries occurred during training, with the estimated training IIR to be 1.6 per athlete-year, 11.8 per 1000 athlete-training-sessions, and 7.0 per 1000 athlete-hours of training. The patterns and severity of injuries were, by and large, the same for training and competition. Considering the burden of training injuries exceeds that of competition injuries, taekwondo governing bodies and stakeholders are encouraged to devote more effort and attention towards the identification of risk factors for, and the prevention of, training injuries in taekwondo.

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