Common Taekwon Do Injuries and Potential Preventative Measures

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Introduction

Taekwon Do, or the art of the foot and hand, is a steadily growing martial art with participants training and competing all around the world. As the name suggests, a wide variety of techniques are used throughout the various aspects of Taekwon Do. These include the use of hands, fingers, elbows, forearms, feet, shins and knees. When in competition, the target areas are anywhere to the front of the person and above the belt, including the head/face, chest, stomach and ribs. Of course, as with any martial art, there will be incidental clashes between opponents' arms and legs while both attempting to performing a technique. Taekwon Do also has a variety of components, whether in competition or as part of training, which include practicing the basics, general strength and conditioning, self defence, board breaking, jumping, patterns, and sparring. Each of these components requires different skills or movements of the body and places the students at varying risk of injury, especially when considering training with an opposition versus unopposed. This thesis will discuss the most common injuries found in Taekwon Do athletes and suggest evidence-based preventative measures that should be taken to prevent these injuries.

A look into the risks of each component of Taekwon Do training and competition

All components of Taekwon Do require the student to have high levels of flexibility, strength, power, speed, endurance, coordination, balance and agility. Most other sports require their athletes to excel in a select few, however due to the nature of martial arts students must be proficient in all. Therefore, if a student lacks in one area or another they are at a greater risk of injury when training at a high level or when in competition.

When performing the basic kicks, hand attacks or blocks, students require strength, power and balance. If pad work is added agility will become important as well. The risk of injury during basics could be an overuse injury from high repetitions of the movements or doing them incorrectly, and not having the required agility likely causing a lower limb injury when completing pad work. When performing general strength and condition exercises as part of training in the dojang or at the gym, the most likely cause of injury will be from overexerting oneself, or performing the exercises with incorrect technique. Additionally, contusions and abrasions will occur with physical conditioning exercises.

Self defence may be practiced in partners or groups with planned responses such as locks or takedowns, or as an attack and response drill with unpredictable outcomes. Injuries during this training may arise from poor communication or self control between partners, or incorrect agility or timing when performing or dodging the techniques.

Power breaking requires strength, power, and conditioning when striking various targets such as wooden or plastic boards, ice, or tiles. Injuries sustained during power breaking could be as a result of performing the technique incorrectly causing an impact injury to the attacking limb, not having the required conditioning attacking tools, or an overuse injury such as contusion or stress fractures from repeated power breaking training.

Jumping, or special techniques, sees students performing various techniques while jumping vertically, horizontally for distance, or over obstacles or people. It requires flexibility, strength, speed, power and balance. Injuries can occur from a lack of flexibility or over extending a kick to reach the target, reduced strength of the lower limb to support the body

when landing causing an overuse injury, poor balance resulting in awkward landings, or inadequate speed or power to clear the obstacle or break the target resulting in an impact injury. The injuries while performing special techniques could be acute or overuse injuries.

Patterns requires strength, power, balance, coordination and flexibility. It is the combination of many individual techniques into a sequence to be performed in a rhythmical and powerful manner and performed in competition or training situations. Injuries are likely to occur in the upper and lower limbs for a variety of reason. These include an imbalance of power causing overextension of a limb, loss of balance resulting in a sudden corrective move or a fall, a lack of strength required to complete all movements repeatedly, a lack of strength in the legs to have a stable stance from which to move, or a lack of flexibility to perform the high section techniques safely. Patterns are repeated numerous times during training, whether in preparation for a tournament or not, which places the students at a risk of overuse injuries. When in competition students are giving a 100% effort, if not more than training, which places them at a greater risk for acute injuries.

Sparring is arguably the component of Taekwon Do that places the student at greatest risk of injury due to it's unpredictability, the high levels of contact, and it being an opposed exercise. Sparring also requires students to be proficient in strength, power, endurance, agility, flexibility, coordination and speed in very quick exchanges with opponents. The most obvious cause of injury when sparring will come from contact with the opponent, whether in an attacking or defensive manner. This can cause a range of injuries including contusions, abrasions, sprains, factures, or concussions of all limbs, trunk or head. Additionally, injuries may occur as a result of poor agility or coordination causing a fall or trip, overextending a technique to reach an opponent, fatigue-induced injuries due to lack of endurance, or lack of speed to either reach or dodge an opponent. The available research regarding injuries in Taekwon Do greatly focusses on injuries sustained during sparring more than any other component of Taekwon Do, and this is discussed below.

What does the research say?

When analysing the findings from various research papers, there are some key definitions that are found throughout the papers which become important to understand. Multiple papers measure injury rates by Athlete Exposure, or AE. AE is defined as an "athlete participating in a team-sanctioned event type in which they are exposed to the risk of a sports injury, regardless of the time associated with the participation" (Boae Son et al, 2020, p4). An AE includes both competitions and training sessions, however slightly more studies took place during competition events than during training. While many papers focus on AE during sparring events, some don't specify a certain event or training focus. Therefore, it is important to keep this in mind and consider the application of the research findings in all areas of Taekwon Do training or competition. When examining common injuries in Taekwon Do, it is important to separate minor injuries that don't impact performance from more serious injuries that require a student to cease competing or have time off from training. The impact of the two are vastly different for students and instructors alike, and the management of both should reflect this. Throughout many of the research papers, injuries were further classified as Time Loss Injuries if the injury resulted in the student being absent from training or competition for any length of time. Time Loss is defined as "the time between the original injury and return to play at a level that would allow participation in competition and practice" (Boae Son et al, 2020, p4). This measure is a very important one for active students and their instructors; returning to activity is often one of the first things that injured athletes ask about, and it is important for instructors to have realistic time frames for when their students can

return to training. Finding the right balance between returning to sport and allowing injured structures to heal is a delicate process, one which this thesis is aiming to shed light upon to assist with expectations after obtaining an injury.

The research regarding injuries sustained through Taekwon Do participation gives varied results in terms of types of injury, the location, and how the injuries occurred. Some studies corroborate each other, while others provide slightly different results. This is not unexpected when considering the unpredictable nature of Taekwon Do and the various components within the art, as outlined above. When participating in an activity with such a wide array of components, each with different requirements, and the level of contact that exists within training and competition, the injuries sustained by participants will surely vary. Additionally, each individual, club and country have their own slightly different strategies or interpretation of techniques, which can result in different stresses on the body. An article written by W Pieter (2010) compared and summarised multiple papers that studied injury rates and causes in Taekwon Do. It found that across these papers, Male injury rates ranged from 10.6-129.5/1000 AE, while time loss injuries ranged from 6.9-33.6/1000 AE (Pieter, 2010 p249). Female injury rates were found to range from 25.3-105.5/1000 AE and time loss injuries ranging from 2.4-23.8/1000 AE (Pieter, 2010 p249). This break down of injuries can be seen in Table 1 below. It is clear that the rate of injury in female Taekwon Do students is slightly lower than their male counterparts, and their time loss injuries are less frequent as well. Therefore, in addition to males being more likely to become injured they are also more likely to require more time off from training or competition. It is not clear whether this was due to the injuries being more severe or the recovery time being slower, but it is important for instructors or coaches to understand that injured male Taekwon Do students may return to training or competition later than the female students.

Table 1 Distribution of rates per 1000 athlete-exposures (95%CI) for time-loss injuries (Pieter, 2010 p249)

Study	Males	Females
Zemper and Pieter (67)	23.58 (5.09–52.25)	13.51 (1.78–28.80)
Pieter and Lufting [82]	22.90 (9.94–35.86)	9.68 (1.27–20.63)
Pieter [86]	33.45 (27.31–39.59)	23.03 (15.71–30.35)
Pieter et al. (69)	27.13 (7.03–47.23)	8.77 (8.42–25.96)
Pieter and Bercades [87]	25.64 (9.90–61.18)	23.81 (22.86–70.48)
Koh et al. (71)	33.56 (18.85–48.27)	14.22 (2.84–25.60)
Beis et al. [88]	6.85 (1.78–11.92)	2.43 (2.33–7.19)
Pieter et al. [89]	20.41 (0.41–40.41)	21.74 (0.44–43.04)

One study conducted in Malaysia found that time loss injuries requiring more than 21 days off were sustained by 20.41/1000 AE in males, and 16.3/1000 AE in females (Pieter 2009, p277). A second source supported these findings (Pieter 2009, p253), however their AE rates were overall lower than in the Malaysian study. Again, this is attributed to the unpredictability of Taekwon Do, and that each training session or competition poses different risks and opportunities to receive an injury. These findings can be seen in Table 2 below. It finds that males were more likely to receive time loss injuries than females, but also that time loss injuries of less than 7 day are more common than 7-21 days or >21 days (Pieter 2009, p253). It is also interesting to note that the 1 year follow up study completed by Boae Son et al (2020 p8) found that students with more than 3yrs experience in Taekwon Do were 2.46 times more likely to sustain time loss injuries for >7 days. This can be attributed to the more

experienced Taekwon Do students having a wider repertoire of more technical, and potentially riskier, techniques. These more experienced students will also be more likely to participate in competition or contact training. The above information provides a realistic timeline to return to training or competition for students and instructors or coaches alike, but it also sheds light on the risks and consequences of participating in Taekwon Do. While most injuries will allow students to return within a week, some will require significant time off and rehabilitation before students can return.

Table 2 Overall and specific time-loss injury rates per 1000 athlete-exposures (95% confidence interval) in adults by sex and days lost (Pieter 2009, p253)

Study/Body part	Men, Time Lost			Women, Time Lost		
	≤7 days	8–20 days	≥21 days	≤7 days	8–20 days	≥21 days
Pieter & Zemper (1995) (foot)	2.1 (0.5–3.6)	0.6 (0.2–1.4)	1.5 (0.2–2.8)	1.2 (0.5–2.9)	—	1.2 (0.5–2.9)
Pieter & Zemper (1997) (head & neck)	7.6 (4.7–10.6)	2.9 (1.1–4.8)	2.1 (0.5–3.6)	5.5 (1.9–9.0)	1.8 (0.2–3.9)	1.2 (0.5–2.9)
Pieter & Bercades (1997) (overall)	25.6 (9.9–61.2)	—	—	23.8 (22.9–70.5)	—	—
Pieter & Zemper (1998) (concussion)	3.2 (1.3–5.1)	0.9 (0.1–1.9)	1.2 (0.0–2.3)	1.8 (0.2–3.9)	—	—

While there are reports that look into injuries sustained during Taekwon Do training and competition environments, a lot of the research mainly focuses on competitions only. Unlike most sports where athletes have weekly training sessions followed by matches every weekend, Taekwon Do students get to compete much less frequently. Training occurs multiple times a week, whereas tournaments are much less frequent. Nationals are once a year, World Championships and the World Cup are every second year, and there may be smaller tournaments infrequently throughout the year as well. Therefore, it can be hypothesised that many injuries in Taekwon Do will occur during training purely due to the high training to competition ratio. A study conducted over 5 years on elite Taekwon Do students found that 63% of injuries were sustained during training, and 37% during competition (Geblein et al 2019, p56). Boae Son et al (2020, p4) also corroborated this with their finding of 69.94% injuries during training and 30.06% during competition. It is interesting to note that, while the percentage of injuries during training were higher, the likelihood of being injured was greater in a competition. Geblein et al (2019, p56) adjusted their findings to use AE and found 94.988/1000 AE injuries in competition and 15/1000 AE injuries during training. That is a significant difference in the favour of competition when analysing the AE, which supports the idea that students are more at risk during competition but sustain more injuries while training as this occurs more regularly than competition. A study conducted during an Australian Amateur Taekwon Do competition also found that there were a greater number of injuries during training, but that head and neck injuries were more common during competition (Boae Son et al 2020, p2). Both elite and amateur Taekwon Do students are clearly injured more frequently during training, therefore all Taekwon Do students should strive to reduce the rate of training injuries which will allow better preparation for competition, gradings and mastery of skill.

Head injuries, particularly concussions, were discussed extensively throughout the literature. This is to be expected considering the potential severity of a head or neck injury and the high risk at which Taekwon Do competitors are at for receiving this type of injury. One study estimated an incidence rate of 1 concussion in every 100 athletes of all ages (Zemper and Pieter 1994). This is a high rate, especially considering that Taekwon Do is a semi-contact sport and ITF match wins are not awarded for total knock outs. This can be attributed to the scoring system in place for competition sparring. More points are awarded for head shots than to the body. Additionally, jumping and spinning techniques, which have significantly greater force behind them when connecting with a target, are also awarded more points. This encourages athletes to perform these types of attacks more frequently, thus drastically increasing the risk of head or neck injuries. One study looked at the force of such kicks compared to other sports and found the linear acceleration of a kick exceeds that of an uppercut in boxing (Piedade et al 2021, p315). They also found that concussion is four times more likely to occur than in American Football (Piedade et al 2021, p315). These are significant findings, and really emphasise the importance of not only protective equipment but also defensive strategies. Pieter et al (2009) further looked into the average velocities of turning kicks and the relationship with head injuries. The average male turning kick is delivered at 15.9-22.9m/s, while the average female turning kick is 11-13.3m/s (Pieter et al 2009, p278). They estimated that a kick at 11m/s does not have a significant risk of causing a time-loss injury, while a kick at 19m/s has a 100% chance of causing such an injury (Pieter et al 2009, p278). Considering the speed of the average male turning kick, it is clear that male Taekwon Do participants are at a significantly higher risk of a serious head or neck injury that female participants. A study conducted during a World Taekwon Do tournament used video analysis to categorise athletes' areas of injury. They found 27% of injuries in this tournament were to the face (Jeong et al 2020, p54). The type of injury to the face was not specified, however it is clear that the risk for concussion or other head/neck injuries is very high. Pieter et al found a study conducted during a tournament where 50% of athletes received two or more blows to the head (Pieter 2009, p273), which only supports the above statement. In one case study of a Canadian National Championships, 73% males and 50% females suffered a concussion after blow to the head (Pieter 2009, p275). While it is important to note that some of these statistics are found from isolated studies and the statistics will vary between different competitions, it demonstrates the high incidence of head and neck injuries, or the risk thereof, and how important it is to be aware of this for the safety of the students.

Being a contact sport involving the hands and legs, Taekwon Do students are surely prone to injuries almost anywhere on the body. Not only are the attacking tools at risk, such as different parts of the feet, shins, hands, or forearms, but the target areas are also at a risk of injury such as the head, ribs, and stomach. Not to mention the accidental clash of shins, knees or arms that can occur during conditioning training or sparring. We must also consider injuries that can occur without contact such as ankles or knees from a misstep during footwork or pad work, or hand and shoulder injuries from overtraining. While there is a general consensus in the literature that the lower limb is the most common area of injury, some studies vary as to whether the upper limb or the head/neck are the second most common sites of injury. As discussed above, this can be attributed to the diversity and unpredictability of Taekwon Do competitions and training. A study conducted by Schluter-Brust et al (2011, p630) used a questionnaire to gather information from 356 Taekwon Do athletes at various clubs. They found that 38.86% injuries were to the lower limbs, 27.54% to the upper limbs, 18.75% to the head or neck, and 6.52% to the trunk (Schluter-Brust et al 2011, p 630).

Specifically in the lower limb, the ankles, toes and metatarsals are the most commonly injured areas due to the foot being the predominant attacking tool in sparring events and pad work. This is important for athletes and instructors to note, as having the correct protective equipment and conditioning the instep and top of the foot will play a role in reducing these types of injuries. A second study supported the above findings, and further broke the incidence of injury down to find the most likely areas of injury are the foot, followed by the lower leg, then the knee and the hand/wrist (Boae Son et al 2020, p5). This can be seen in table 3 below. This table also breaks down injuries sustained by youth vs adult athletes. As can be seen below, the youth athletes are slightly more at risk of foot injuries, while the adults were at a higher risk of ankle injuries (Boae Son et al 2020, p5). A study by Pieter (2009 p271) further found evidence to support the lower limb being the most commonly injured area in Taekwon Do, however suggested that the head/neck were the second most injured area of students. These are significant findings, as head and neck injuries have the risk of becoming significantly more severe than other parts of the body.

Table 3 Number of injuries in Taekwon Do athletes according to body location (Boae Son et al 2020, p5)

Body Parts	Youth Athletes	Adult Athletes	Total
Eye	1 (0.43)	0 (0)	1 (0.30)
Nose	1 (0.43)	0 (0)	1 (0.30)
Mouth	1 (0.43)	1 (0.99)	2 (0.60)
Neck	1 (0.43)	1 (0.99)	2 (0.60)
Shoulder	4 (1.70)	1 (0.99)	5 (1.49)
Upper arm	1 (0.43)	0 (0)	1 (0.30)
Elbow	3 (1.28)	1 (0.99)	4 (1.19)
Forearm	0 (0)	2 (1.98)	2 (0.60)
Hand/wrist	38 (16.17)	10 (9.90)	48 (14.29)
Chest	1 (0.43)	2 (1.98)	3 (0.89)
Lower back	13 (5.53)	4 (3.96)	17 (5.06)
Hip/Groin	13 (5.53)	3 (2.97)	16 (4.76)
Thigh	16 (6.81)	6 (5.94)	22 (6.55)
Knee	35 (14.89)	16 (15.84)	51 (15.18)
Shank	11 (4.68)	7 (6.93)	18 (5.36)
Ankle	40 (17.02)	30 (29.70)	70 (20.83)
Foot	55 (23.40)	17 (16.83)	72 (21.43)
Other	1 (0.43)	0 (0)	1 (0.30)
Total	235 (100)	101 (100)	336 (100)

Note: Data are provided as numbers (%).

Table 4 demonstrates the incidence of injuries throughout the body during competition and training exposures in a study conducted over 5 years. During training, the most commonly injured areas were the hand and wrist, followed by the foot and knee (Geblein et al 2019, p56). During competition, the hand and wrist were also the most commonly injured area, followed by the ankle and knee (Geblein et al 2019, p56). While the injuries were quite similar to one another during training compared to competition, the rates of injury were much higher in competition, as can be seen by the AE values in table 4 (Geblein et al 2019, p56). These findings contradict what other studies have found, but it sheds some light on the ferocity and high levels of contact during some tournaments. When there are higher levels of contact and aggression, there is a greater risk of injury. Thus students and instructors must be aware of this to ensure they are physically prepared to withstand the contact levels of sparring by completing appropriate conditioning, strength training and have experience in such events.

Table 4 Injury incidence rates and exposure-adjusted rate ratios for competition and training (Geblein et al 2019, p56)

Location	Injury incidence rate per 1000 h of participation in competitions (CI 95 %)	Injury incidence rate per 1000 h of training (CI 95 %)	Exposure-adjusted injury rate ratio (CI 95 %)	p, two-tailed
All locations	94.98 (73.45–120.84)	15.00 (12.28–18.14)	6.33 (4.58–8.69)	<0.001
Upper extremity	34.54 (22.13–51.39)	4.67 (3.21–6.56)	7.40 (4.18–12.90)	<0.001
Shoulder	4.32 (0.89–12.62)	0.28 (0.03–1.02)	15.25 (1.75–182.64)	0.012
Elbow	0.00 (0.00–5.31)	0.14 (0.00–0.79)	-	1.00
Hand and Wrist	30.22 (18.71–46.20)	4.25 (2.86–6.06)	7.12 (3.87–12.86)	<0.001
Lower Extremity	54.68 (38.70–75.06)	8.35 (6.36–10.77)	6.55 (4.24–10.01)	<0.001
Hip	7.20 (2.34–16.79)	1.13 (0.49–2.23)	6.36 (1.64–22.04)	0.008
Thigh	10.07 (4.05–20.76)	0.28 (0.03–1.02)	35.59 (6.78–351.17)	<0.001
Knee	11.51 (4.97–22.68)	1.98 (1.08–3.32)	5.81 (2.11–14.84)	<0.001
Lower leg	0.00 (0.00–5.31)	0.42 (0.09–1.24)	-	1.00
Ankle joint	18.71 (9.96–31.99)	1.27 (0.58–2.43)	14.69 (5.81–38.94)	<0.001
Foot	7.20 (2.34–16.79)	3.25 (2.06–4.88)	2.21 (0.66–5.95)	0.200

Taekwon Do students utilise their hands and feet when training or in competition. Techniques are performed with the hands in patterns, to break boards in power breaking, to perform locks and deflections during self defence, as part of pad work, and to attack or block an opponent while sparring. Conditioning of the hands is also completed by students to prepare them for heavy contact. This leaves the hand at risk of finger, knuckle, wrist, and carpal injuries from being caught in another student's uniform, being locked self defence, or hitting a target or opponent incorrectly or forcefully. 8-10% of injuries in Taekwon Do are to the hand or wrist according to a book by Pomerantz (2018, p 74). In recent years, the change in regulations regarding gloves for sparring has reduced the risk of hand injuries drastically. Previously, gloves were open fingered and quite thin, whereas competitors must now wear a thicker fully enclosed glove, much like those worn by boxers. Pomerantz (2018, p68) also discussed common mechanisms of hand injuries during sparring. Due to the scoring areas in competition sparring to the front of the body, competitors must angle their punches if coming from behind or to the side. This places a significant compressive force on the radial side of the wrist, and a potential strain on the ulnar side. While proper conditioning and wearing regulation protective will drastically reduce these injuries, those participating in Taekwon Do are still at risk of sustaining various injuries to the hand or wrist.

As found above, the ankle and foot are the most common, and most likely, areas to be injured in Taekwon Do. This is a product of the dynamic and multi-directional movements performed by students. The ankle must be strong and stable enough to suddenly change direction, support the body's entire weight on one side, pivot, jump, land and absorb forces when the foot is striking. The ankle must be able to do this in different positions. The most stable position for the ankle is when it is 'neutral', or flat like when in a standing position. In Taekwon Do, however, the ankle and foot are manipulated into many different positions such as pointed when performing a slapping kick, bent and compressed like when landing into an X stance, angled to strike with the blade of the foot, or twisted when pivoting or changing direction quickly. All of the above positions place the ankle at high risk of injuring the various ligaments, muscles, bones or syndesmosis that are around the ankle or foot. A study of the prevalence of ankle injuries in Taekwon Do performed on various Chinese Taekwon Do clubs found 76% of participants sustained an ankle injury during the course of the study (Xiao 2021, p38). It is important to note that participants were in their mid to late teenage years, where ligaments and general stability throughout the body are still developing. However, with the high prevalence of ankle injuries throughout all age groups as seen in tables 3 and 4, the findings from this study can be applied to all ages. Xiao (2021, p38-39) also found that the most commonly injured part of the ankle were the lateral ligaments

(40.6%) followed by the medial ligaments (31.3%), then the lateral ligament with the distal tibiofibular syndesmosis (15.6%). The majority of ankle injuries occurred during training (46.9%), followed by during competition (28.1%) (Xiao 2021, p38). Additionally, Pieter (2009, p276) found that 35.7% of ankle injuries in men and 50% in women results in a time loss of 21 or more days. This is a significant amount of time away from training or competition for students and emphasises the importance of improved preventative measures of ankle or foot injuries. This provides substantial information to guide instructors, coaches and students to weaker areas of the foot and ankle, and where conditioning or strengthening should be focussed. This will be discussed further in the next section.

While it is important to understand which areas of the body are at most risk for injury, the type and cause of injury is also significant so that training and preventative measures can be employed to reduce the risk. Table 5 below outlines the most commonly found injuries throughout a wide range of literature. Overall, it can be seen that contusions are consistently the most common injury received by Taekwon Do students, followed by fractures, concussions, sprains and lacerations in varying degrees between each paper (Pieter 2009, p274). Concussion rates are found to be moderately common as well. Schluter-Brust et al (2011, p 630) found that concussion was the second leading cause of injury in their study behind contusions. These included those of the eye or mouth which have the potential to lead to concussion, and arms primarily from blocking or defensive strategies. When a fracture occurred it was most commonly found in the foot or toes, and ankles were the most common area to sustain a sprain (Schluter-Brust et al 2011, p 630). One study further investigated the leading cause of injury in youth Taekwon Do students compared to adult students (Boae Son et al 2020). They found that youth athletes were most at risk for contusion (25.53%), followed closely by fractures or stress fractures (24.26%) and ligament sprains (22.98%) (Boae Son et al 2020, p5). Adults similarly were found to mostly sustain ligament sprains (37.62%) followed by contusion (22.77%) then fractures or stress fractures (13.86%) (Boae Son et al 2020, p5). It can be seen that youth students are at a higher risk for fractures and stress fractures than their adult counterparts. The bones are still developing at this age, and the stresses of Taekwon Do caused by direct hits or repetitive extreme forces from muscle contractions are not tolerated as readily as in the adult body. Therefore instructors and coaches must be aware of the load being placed on young students' bodies, and ensure that there is appropriate recovery and preventative strategies in place.

Table 5 Percentage distribution of injuries by type (Pieter 2009, p274)

	Zemper and Pieter [67]		Pieter et al. [69]		Pieter et al. [70]		Pieter and Zemper [68]		Koh et al. [71]		Beis et al. [72]		Kazemi and Pieter [73]		Pieter et al. [74]	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Total # injuries	27	20	36	11	4	2	324	174	71	38	21	15	35	5	33	28
Abrasion	3.7	–	–	–	–	–	1.9	2.3	4.2	–	–	33.3	2.9	–	–	–
Concussion	3.7	5.0	11.1	9.1	25.0	–	7.4	2.3	8.5	5.3	4.8	–	8.6	–	–	–
Contusion	63.0	75.0	50.0	90.9	50.0	50.0	48.5	53.5	28.2	50.0	52.4	46.7	14.3	60.0	66.7	57.1
Dislocation[a]	–	5.0	–	–	–	–	0.6	2.3	2.8	–	4.8	6.7	–	–	–	–
Epistaxis	–	–	5.6	–	–	–	1.9	5.2	–	–	4.8	6.7	2.9	–	–	–
Fracture[b]	14.8	–	11.1	–	–	–	10.5	8.1	22.5	7.9	14.3	–	–	–	3.0	10.7
Laceration	3.7	–	8.3	–	25.0	–	10.8	8.6	4.2	5.3	14.3	6.7	14.3	–	3.0	–
Sprain	3.7	5.0	11.1	–	–	–	11.1	8.6	14.1	23.7	4.8	–	28.6	20.0	6.1	3.6
Strain	3.7	5.0	–	–	–	–	1.5	3.5	9.9	7.9	–	–	11.4	20.0	–	–
Other	3.7	5.0	2.8	–	–	50.0	5.8	5.6	5.6	–	–	–	17.1	–	21.2	25.0

[a] Includes subluxation [b] Includes suspected fractures

Arguably the most important question that students and instructors alike will ask regarding injuries is about which techniques or situations lead to the most injuries. Table 6 demonstrates that 50.5% and 51.06% of injuries occur after contact with another student,

followed by non-contact injuries and overuse injuries (Boae Son et al 2020, p5). These results are supported by Jeong et al (2020, p54) while Schluter-Brust et al (2011, p 630), found that contact injuries were the cause of approximately a third of injuries, followed by overuse then non-contact injuries. Considering the nature of Taekwon Do, it is not surprising that contact injuries are the most readily experienced. Boae Son et al (2020 p5) further gave evidence that kicking is the leading cause of injury (63.7%) followed by blocking (14.02%) and stepping (6.51%). It is not unexpected that kicking is the leading cause of injury due to the power and strength that Taekwon Do students develop when delivering kicks. Not only is the receiver of the kick at risk of injury, but studies have shown that the person delivering the kick is also at risk of injury. Pieter (2009 p276) found that the turning kick specifically was the most commonly involved in injuries, and that connecting a turning kick with an opponent's elbow was a leading cause of injury to the instep. When comparing causes of injury, males were mostly injured from delivering and receiving a turning kick while women received more injuries as a result of receiving a roundhouse kick and receiving a spinning back kick (Pieter 2009, p276). Time loss injuries for men were mostly sustained by receiving an unblocked turning kick, while attacking with a turning kick and receiving a spinning back kick were the leading causes in women (Pieter 2009, p276). These results highlight the extremely high rate of turning kicks being used during sparring matches, and that defensive techniques, target practice and conditioning of the attacking tool may be beneficial in reducing injuries caused by this technique. It is also importance for students to note the frequency at which turning kicks are used to develop strategies when facing an opponent. Pieter (2009, p277) further broke down the common causes of head injuries and found the leading cause being an attack with no defensive attempt. They also discovered that most 65.7% of head injuries in this study occurred while in a closed stance and 31.4% in an open stance (Pieter 2009, p277). Non contact injuries occurred most frequently when the person was avoiding an opponent's attack, when the supporting leg was in front during attack, and when the supported leg was behind during defence (Jeong et al 2020, p55). Therefore drills for defensive strategies, footwork and counterattacks would be useful for students to practice.

Table 6 Mechanisms of injury in Taekwon Do Athletes (Boae Son et al 2020, p5)

Variables	Youth Athletes	Adult Athletes	Total
Contact with another players	120 (51.06)	51 (50.50)	171 (50.89)
Non-contact	38 (16.17)	26 (25.74)	64 (19.05)
Overuse	37 (15.74)	13 (12.87)	50 (14.88)
Defense	23 (9.79)	6 (5.94)	29 (8.63)
Falling	11 (4.68)	2 (1.98)	13 (3.87)
Other contact	1 (0.43)	2 (1.98)	3 (0.89)
Unknown	5 (2.13)	1 (0.99)	6 (1.79)
Total	235 (100)	101 (100)	336 (100)

Note: Data are provided as numbers (%).

What can we do to prevent these injuries in the future?

Head injuries are largely focussed on in the research and are often the major concern with Taekwon Do injuries due to the risk of severe or permanent damage. Continual updates in the protective equipment required to be worn by competitors has reduced incidences of severe head injuries, however the chance of concussion or other head/neck injuries is always going to be present. Some studies have suggested implementing a tracking system for competitors who get a concussion and implementing suspension rules similar to boxing (Pieter 2009, p280) (Pieter et al 2012, p489). Additionally, athletes who sustain head injuries should be

assessed on site using an accepted concussion screening tool and should be re-assessed before returning to any level of training or competition.

Having well-trained medical personnel, not just first aid officers, at competitions is a very important measure to ensure the safety of competitors. In larger tournaments where there are numerous rings and events at the same time there should be enough medical personnel to oversee all competitors in the rings at all times. This will allow for potentially injured competitors to receive prompt medical diagnosis and referral for further care, which is shown to improve outcomes greatly. There should also be mandated education for umpires, coaches and instructors in regard to common Taekwon Do injuries, the risks involved, and the appropriate action when a student becomes injured (Pieter 2009, p280). Injuries that occur during training, while less frequent than in competition, can still be serious and require the appropriate response to avoid time-loss injuries and prompt return to training as appropriate.

Considering that a significant number of injuries sustained by Taekwon Do students are as a result of receiving a blow, as shown above, improving evasive, blocking and defensive skills to reduce risk of injury is imperative. Additionally, conditioning of the body and education for the student on how to deal with being hit by an opponent is important. Completing opposed contact drills where the goal is to not allow your partner to score will teach defensive footwork and body movements to evade attacks. Head movements such as ducking or dodging are not focussed on in Taekwon Do as much as other martial arts like boxing. Therefore, drills that specifically focus on this when in close proximity to an opponent will be a great advantage in reducing head injury and concussion rates. In competition points are very rarely awarded for blocking, which has led to competitors not training blocking or defensive strategies as much as offensive. A greater focus on this will assist to reduce the incidence of unblocked attacks causing significant injury.

The risk of injury in any sport is greatly increased when the person is fatigued, whether this be during a training session or competition event. A paper examining Taekwon Do students' exercise response to sparring found that current methods of sparring have greater body movement dynamics, higher intensity and greater fatigue (Janowski et al 2019, p2227). While this study focussed on sparring, competitors in all events will be performing at a maximal capacity and are also at risk for injury. As the intensity during competition is higher, training sessions are likely to be higher in intensity as well to prepare competitors for such demands. Matsushigue et al (2009, 1114) investigated which form of exercise would prepare Taekwon Do students the best for the physical requirements of competitions. While this study was based on WT (World Taekwon Do), with the style and energy expenditure differing from ITF (International Taekwon Do Federation), the findings can still be a helpful guide for instructors or coaches when planning training sessions. Metsushigue et al found that small periods of very high intensity Taekwon Do specific techniques or movements interspersed with rest periods produced the greatest physiological changes and improved performance (2009, p116). Specifically, 8 seconds of high intensity activity followed by 6-8 seconds of medium to low intensity efforts over multiple rounds was found to be most beneficial. This is to mimic the average kicking vs rest time of WT matches. The same principles can be applied to effort requirements of patterns or any other area of Taekwon Do that students are training for, thereby increasing their fitness and reducing fatigue, thus reducing risk for injury.

Prevention of injuries that are caused by non-contact situations needs to be approached differently. Typically, non contact injuries occur from overuse, mis-steps or inadequate warm up. The first preventative measure is to ensure that Taekwon Do students are completing a

relevant warm up to prepare them for the training or competition ahead. An appropriate warm up is one that mimics the movements required in some manner, which can be achieved by doing a cardio exercise, static or dynamic stretches of relevant muscles, and performing the basic movements of the skills to be trained (e.g. stances, individual techniques, sequences from patterns, or small drills). Secondly, having a strong core, functional stabilising muscles of the body (for example glutes, quads, hamstrings, rotator cuff, biceps and triceps) and flexibility of the muscles will support the joints and other structures of the body when performing the physically demanding techniques involved in Taekwon Do. Third, being aware that repetitive training places high loads and strain on the body which ultimately can lead to overuse injuries. Therefore, it is important for students and instructors or coaches to monitor these loads and allow for appropriate recovery between training sessions. This may involve active recovery, rest days, or alternating which areas of Taekwon Do are being trained in each session to avoid a heavy focus on one in succession. Finally, neuromuscular training is a very effective means of training to optimise muscle function, to increase dynamic joint stability and to ensure that the body is performing in an efficient way. Neuromuscular training ultimately targets the neural and musculoskeletal systems through plyometrics, agility training, balance training, and sports specific movements.

As identified above, the ankle and foot are the most commonly injured parts of the body in Taekwon Do. Apart from when these injuries occur as a result of direct blows, doing a range of specific neuromuscular training of the lower limb will improve the stability of the ankle, knee and hip joints and therefore lower the chance of injury. Having good hip and knee control plays a big role in providing stability to the ankle joint. The ankle is a very mobile joint and can move in multiple directions, not just bending and straightening like the knee joint. It's main supporting structures are the lateral and medial ligaments and the thin muscles surrounding the ankle, but it does not have a lot of bony or capsular support like many other joints. Therefore, while a very mobile and functional joint, the ankle is incredibly prone to instability as a result of weakness, excessive flexibility or past injuries. While many exercises are performed to strengthen the lower legs, such as calf raises, skipping, running, squats and jumping, all of these movements only work the dorsiflexion and plantarflexion (bending and straightening) movements of the ankle. In order to fully stabilise the ankle and ensure it can cope with changes of direction and sudden impacts that force the ankle into awkward positions, the ankle must be strengthened into ranges of eversion, inversion (inwards and outwards movements) and stabilising on unstable surfaces. Using a theraband or stretchy exercise band looped around the foot and a stable object (e.g. table leg) the ankle can be turned inwards and outwards against resistance. This exercise should be performed both at a slow pace and with fast maximal contractions to train the stabilising muscles to react quickly to perturbations. The Y-balance or Star Balance exercise is currently popular with elite athletes of various sports to train ankle and hip stability while body is moving in different directions. This exercise can also be performed on a bosu ball or balance mat for increased difficulty. Standing on a bosu ball or balance mat with one leg, while performing slow kicks with the other is a great neuromuscular exercise for Taekwon Do athletes to practice. It works on hip control and strength, proprioception, and correction movements of the ankle which is imperative for balance and adjusting to changes of direction.

Once exercises like those described above are completed with ease, Taekwon Do students will need to progress to dynamic exercises to target the lower limb and ankle in a highly functional way. Side lunges with a powerful push off will specifically target the outside of the ankle, which is the most likely area to be sprained. This exercise can be performed on a bosu ball to provide an unstable surface and further challenge the stabilising muscles of the ankle.

Hopping side to side, forward and back, and sideways over small hurdles challenge the ankle to be stable and react quickly when performing powerful and quick movements which is very relevant to those performed during patterns or sparring. These exercises al rely on the student's decision when to react or move, however the opposed nature of Taekwon Do forces students to react to their opponent or training partners. Therefore, exercises that foster an unpredictable environment will be beneficial. Instructors or coaches may create a drill where students are running or sprinting in various directions, then suddenly change and sprint in another direction that is called out at random by the instructors/coaches. This drill could be modified to mimic Taekwon Do by having multiple students in a circle holding pads with one student in the middle. This student must quickly move to a holder randomly chosen by the instructor and perform various techniques. The student can either then return to the middle, or react to the next call by the instructor and move to the next holder than is called. These exercises should be performed regularly, and can be part of a warm up or as part of the session itself. These exercises focus on the strength, proprioception and rection time of muscles of the hips, knees and ankles in order to reduce injury rates. The principles of the above exercises can be taken to create new drills or to modify the above to be specific to the individual students' requirements.

Considerations when reading this thesis

After analysing the research available for this thesis, it is evident that there are a few limitations and considerations to be aware of when utilising the information. First, most studies used questionnaires to gather their data and some asked participants to report injuries over extended periods of time. Any method of self-reporting is prone to errors in memory or participants overstating or understating events. Additionally, some studies only looked at small groups of Taekwon Do students or one training centre/competition. This placed an importance on gathering multiple studies and comparing the data to find common results or suggest reasons for differing results. Many studies focus on sparring alone as this is the most contended and likely event for injury. It is evident, however, that all aspects of Taekwons Do present a risk for injury and future studies should focus on these as well. Finally, majority of the studies look at WT students and competitions. When reading this thesis, it is important to note this and acknowledge that different styles of Taekwon Do are performed in different ways. The underlying results are still relevant to all styles, and readers can apply the above findings accordingly.

Conclusion

In conclusion, Taekwon Do is a semi contact, unpredictable and technical martial art that poses many risks for students to become injured. Taekwon Do students are more commonly injured during training but are more likely to become injured during competition. Head injuries are common due to the point system encouraging head kicks and spinning or jumping kicks. The most common area to be injured is the lower limb, specifically the foot or ankle. Globally, the most common injury is a contusion followed by sprains and fractures. The most common techniques involved in injuries are performing or receiving a turning kick or spinning kick. Moving forward, to prevent such injuries Taekwon Do needs a system that monitors head injuries closer, to have more well trained medical personnel at tournaments, and to educate all involved in Taekwon Do about injuries and appropriate management. Additionally, incorporating more conditioning and defensive techniques for students, utilising Taekwon Do specific HIIT training to combat the effects of fatigue during competition, and the prepare the body properly for Taekwon Do. This includes appropriate warm ups, having a good base level of strength, appropriate recovery methods, and specific neuromuscular exercises as those above. This thesis has provided an in depth analysis into common injuries

in Taekwon Do and their causes, and made possible suggestions for preventative measures for the future. While further studies into other aspects of Taekwon Do outside of sparring is warranted, this information above can be adapted and implemented for injury prevention during patterns, board breaking, special techniques, self defence and technical training.

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