Original Research

Investigation of injuries occurring within competitive water-skiing in the UK

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ABSTRACT

International Journal of Exercise Science 6(1) : 29-42, 2013. To date, most waterskiing research has been on recreational waterskiers from the USA. Our aim was to determine if the tournament waterskiing population in the UK had the same injury patterns as these previously studied populations. We hypothesised that the number of injuries, body parts injured and type of injury would vary by gender, event and competitive level. An online questionnaire was distributed to all British Water Ski Federation (BWSF) tournament licence holders. There were 90 participants: 24 female and 66 male (mean age 37 ± 15). Chi- squared and Fishers Exact Test was used to analyse the data. Forty-five skiers reported 71 injuries. The most common body part injured was back/trunk (38.8%); the most common type of injury was strain/sprain (64.6%). There was no association between gender and incidence of injury, however males had significantly more strains and sprains than females. Skiers in the lower competitive levels reported significantly more falls than the higher-level skiers. Slalom skiers reported the most injuries (76.8%), with 23.2% of injures in jump and none in trick. A high percentage of strains and sprains highlight the need for more specific physical conditioning. Longitudinal studies are needed to make causal links between injury factors.

KEY WORDS: Waterski, injury, tournament, gender, physical conditioning

INTRODUCTION

Waterskiing was invented in 1922 (8). Since then, it has become a popular sport in lakes and rivers with an estimated 8.4 million participants worldwide (12). Tournament waterskiing, one of four branches of the sport (barefoot, racing, tournament and show), is made up of three disciplines: slalom, trick and jump. Competitors can enter one, two or all three events. Slalom is based on speed, rope length and the skier's ability to turn the six buoys in the slalom course. Trick consists of surface and wake tricks, including rotations, flips and toe-holds. Jump is on two skis over a six-foot ramp. For full descriptions of the three disciplines see Roberts and Roberts (22).

Until 1960, there had been no published research on the dangers of waterskiing participation, thus the rates and types of injuries were unknown. Romano et al. noted the lack of literature on the subject in their paper presenting observations from their own experience (23). They hoped that by identifying some of the hazards they could raise awareness, and further study could prevent some of the injuries and accidents they had associated with the

sport. In this early study Romano et al. arranged waterskiing injuries into four categories: falls into un-obstructed water, collisions with the dock, shoreline or boat, propeller related, and towrope related injuries (23). In a later study by Weyman et al., a fifth category of water ski injuries was added: overuse injuries (26). Since 1960, more research has been conducted, albeit largely focused around recreational waterskiing (see Table 1, Supplemental Content for details).

Hummel and Gainor define waterskiing injuries as 'any trauma secondary to the operation of water skis' (13). Waterskiing has a high potential for injury due to rapid boat acceleration, lack of protective garments and waterway obstacles (12). It has been reported that falling over is the most common cause of injury amongst waterskiers; but it is boat propellers that cause the most serious injuries (1). Propeller injuries were likened by one author to 'severe battlefield injuries' (1) and can cause fatalities in both tournament (22) and recreational skiing (1).

Some of the hazards Romano et al. identified have since been moderated, for example the bindings (a device attaching the foot to the ski) discussed were 'tennis shoes' attached to skis (23). Ski bindings are now highly technical pieces of equipment designed to eject the foot from the ski preventing injury during a fall. Recent studies have found that recreational and tournament skiing injuries are very different due to the highly controlled environment in tournament skiing (17). Mullins proposed reasons for this is that tournament skier injury is decreased by better ski conditions and greater fitness but increased by faster skiing speeds and highly competitive situations (19). Hummel and Gainor suggest lack of physical activity and 'relative inexperience of the occasional but vigorous skier' is responsible for the majority of injuries in novice skiers (13). Hostetler et al. found that most novice injuries occur attempting to get out of the water (douche or enema injuries) (12). Expert skiers often injure knees, back and shoulders from falls (22). Table 2 (Supplemental Content) details the most common injuries found in previous research.

Mozer et al. describe how a skier can fall due to digging the tip of the skis into the water causing the skis to decelerate whilst their body maintains the speed of the boat (2006). This type of fall is described by Grace as 'going over the front' and is a common fall whilst on two skis or slalom skiing (8). Even without falls or dangers, the body experiences significant strain during waterskiing, especially slalom (17). During a 'deepwater start' to get out of the water, the skier experiences a load of approximately one to one and a half times their body weight (16). Whilst on top of the water, slack in the towrope, 'slack line', is considered to be a major cause of injury (17, 22). Slack line occurs when the skier accelerates above the speed of the boat and then experiences a sharp jolt when they decelerate and the slack in the line is taken out.

Specific to tournament skiing, Grace lists the main cause of injury to be: getting tangled in the ski rope during toe-holds in trick skiing; hitting the solid jump ramp in jump skiing; and falls due to speed in slalom (8). Slalom boats reach speeds of 58 kph (36 mph), however skiers can increase their velocity by swinging in an arc across

the centreline of the boats direction (13); skier speeds of up to 80 kph have been recorded (17). Horne et al. found two major types of spinal injury were caused by jump skiing (11). Adolescent spondylodystrophy was found to be increased in skiers who had jumped before the age of 15 and prevalence of vertebral body wedging was increased by the number of years jumping. It was concluded that jumping could significantly damage the spinal column. Roberts and Roberts proposed that as competitors strive for tighter bindings to gain greater control over the ski and improve performance, there could be a major increase in incidence of knee injury if these tighter bindings do not release in a fall (22). Conversely jumpers are using arm slings, to improve performance whilst possibly reducing shoulder injury (22).

Hummel and Gainor recommend that in order to prevent injury, recreational skiers should employ the 'nuclear trio of injury prevention: a responsible boat operator, a vigilant and capable observer, and a cautious, conditioned skier wearing a waterskiing vest' (13). Most authors have come to the same conclusions about preventing injury, for example: the consistent use of protective clothing such as wetsuits and life jacket (13, 1), ski in sheltered water to avoid wind; ski away from other water users to avoid rough water caused by the wake of other boats, and avoid skiing after dusk (8). Novices should be shown techniques for getting up out of the water, strategies to minimize the force exerted by the towrope and the importance of letting go of the rope when they fall (12, 23). Skiing when cold can increase injury risk so warming up could help prevent injury (19). Banta concluded that injuries in recreational skiers were related to inexperienced skiers and boat drivers as well as high boat speed (1). Both recreational and tournament skiers require attentive boat operators who are knowledgeable of the appropriate boat speeds (12).

Weyman et al. note that the difference in types of injuries between amateur and professional skiers is due to better physical conditioning, equipment maintenance and technique in professionals (26). Suggestions for prevention of injury, specifically in tournament skiers, include: age restriction on children starting to water ski jump, ongoing development of safe bindings, skiers being 'ski fit' before they ski at full speed, and knee and lumbar spine supports being worn whilst skiing (22). Radford et al. found that in self-reported causes of accidents, 60% of skiers said their injury was down to 'skier factors', such as insufficient skill, errors of judgement and loss of control, concluding that attention to detail could prevent 1/3 of water-skiing injuries (21). However, people taking part must accept moderate level of risk.

At tournament and elite level, waterski research into incidence, type, cause and severity of injuries is lacking. More knowledge of injuries and their causes could lead to improvements in prevention and protection such as: giving athletes advice on specific physical conditioning; developing protective clothing or equipment; and methods of dealing with situations on the water to reduce injury risk or severity. It was anticipated that the information gathered could be used to inform coaches, product manufacturers and the waterskiing population about how to minimise the risk of injury.

The aim of this study was to determine whether the tournament waterskiing population of the UK had the same injury patterns as in previously studied populations; to date, most of the available research is based on recreational waterskiing populations in the USA. We hypothesised that the number of injuries, body part injured and type of injury would vary by gender, event and skier level. Secondly, we wanted to identify risk factors that lead to injuries in tournament water skiing in the UK, to determine the type of skiers that are most likely to be injured and to determine the conditions in which injuries are most likely to occur. This was achieved by gathering information on factors contributing to injury that previous authors (19, 12) felt were not described in sufficient detail in the literature to date including: physical fitness, participant skill level, equipment condition, boat driver skill/experience, involvement of alcohol or drugs (driver or skier), and interference from birds, fish or foreign objects.

METHODS

Participants

All registered British Water Ski Federation (BWSF) members holding a tournament licence for the 2010 competitive season (May-October) were invited to take part in the study. There were 240 registered competitors in 2010 and 96 people took part. Six respondents were under 18 years of age. The data for these participants could not be used for ethical reasons and were securely destroyed; this left 90 useable responses.

Questionnaire: The invitation letter and link to the online questionnaire (see Supplemental Content) were distributed via the BWSF email database. The email was sent out once in November 2010 and then again in January 2011. The website www.surveygizmo.com was used to host the questionnaire and the results were then downloaded into Microsoft Excel for analysis. The questions were developed from previous literature and were designed to answer the research hypothesis. A small pilot study was carried out with 10 participants and small technical changes were made to the online questionnaire. Closed-ended questions were used to provide information in a simple format for data analysis (9), along with open-ended questions to provide more complex details of injuries.

Protocol

The project was approved by the University of Exeter School of Sport and Heath Science Ethics committee. Participants were made aware that all data was anonymous and they could omit questions they did not want to answer. Data was stored and analysed using the SPSS PASW (v.18) statistical package (SPSS, Chicago, USA).

Statistical Analysis

The data collected was categorical. A chi-squared test was used to analyse frequency of injuries and association between factors that could influence injury incidence (25). Fishers exact test was used to analyse any data that violated the statistical assumption that all minimum expected frequencies would be greater than five. Subsequently, Cramer's V (ϕ_c) coefficients were calculated to verify the strength of association between categories (5). Criteria set out by Cohen (4) were used to interpret the Cramer's V result: 0.00-0.10 is a low association; 0.11-0.30 moderate to substantial association; 0.31-0.50 is

substantial to strong; and 0.51-1.00 is strong to very strong association. The level of statistical significance was established a priori at $p < 0.05$. The categorical data included gender (male/female), competitive level (defined by BWSF division that the participant was competing in during the 2010 season - Premier Division (and Elite; represent GBR in tournament), Division 1 & 2, Division 3 & 4) and event (slalom, trick, jump defined by which event the participant was taking part in at the time of the injury). Divisions in tournament skiing are separated by skill level. All skiers start in division 3 for women and 4 for men and move up each time they qualify for the next division by attaining a certain score in competition. The score required to qualify for each division gets higher each year as the standard of the premiere skiers increases. Factors affecting injury that will be investigated within injured skiers include: age, equipment condition, physical fitness, warm up prior to injury, boat driver experience and drug/alcohol consumption prior to injury. Data from open-ended questions were analysed using thematic analysis, as described by Gillham (7).

Validity and reliability: Gillham (7) notes that the response rate for a questionnaire has to be more than 30.0% for results and method to be valid; the response rate for this study was 40.0%. The method of collecting data on water ski injuries via questionnaire has been found to produce reliable and valid results in previous research (26). To ensure construct validity the data was compared with data from previous studies (9). There were no 'leading' or vague questions and each question measured a single concept to ensure reliable data (9).

RESULTS

Gender: There were 90 participants (mean age 37 ±15). There were 24 females (mean age 33±16) and 66 males (mean age 38±15) aged 18-68 years. Fifty percent (*n*= *45*) of

Table 3. Shows the distribution of body part injured and type of injury within males and females.

	Male		Female		All participants	
	n	**%**	**n**	**%**	**n**	**%**
Body part injured						
Lower Limb	14	27.5	7	43.8	21	31.3
Upper Limb	12	23.5	3	18.8	15	24.4
Back/Trunk	20	39.2	6	37.5	26	38.8
Head/Neck	5	9.8	0	0.0	5	7.5
Total	51	100.0	16	100.0	67	100.0
Type of injury						
Strain/ Sprain	36**	75.0**	6	35.3	42	64.6
Contusion/ Laceration	3	6.3	7**	41.2**	10	15.4
Broken bone	5	10.4	3	17.6	8	12.3
Other: Perforated ear drum (1) Disc/ Spine injury (4)	4	8.3	1	5.9	5	7.7
Total	48	100.0	17	100.0	65	100.0

** Indicates a significant association between results ($p<0.05$). Males experienced substantially more strains/ sprains and females had substantially more contusions/ lacerations.

Table 4. Shows the distribution of body part injured and type of injury within competitive levels.

	Division 3/4		Division 1/2		Premier/ Elite		All participants	
	n	%	n	%	n	%	n	%
Body part injured								
Lower Limb	5	41.7	9	25.7	7	35.0	21	31.3
Upper Limb	3	25.0	9	25.7	3	15.0	15	22.4
Back/Trunk	4	33.3	13	37.1	9	45.0	26	38.8
Head/Neck	0	0.0	4	11.4	1	5.0	5	7.5
Total	12	100.0	35	100.0	20	100.0	67	100.0
Type of injury								
Strain/ Sprain	8	66.7	24	66.7	10	58.8	42	64.6
Contusion/ Laceration	4	33.3	4	11.1	2	11.8	10	15.4
Broken bone	0	0.0	6	9.2	2	11.8	8	12.3
Other:	0	0.0	2	3.1	3	17.6	5	7.7
Perforated ear drum (1)								
Disc/ Spine injury (4)								
Total	12	100.0	36	100.0	17	100.0	65	100.0

skiers were uninjured and 50.0% (*n=45*) had between one and four injuries in the 2010 season. There were 45 skiers reporting 71 injuries (53 male injuries, 18 female injuries). There was no association between gender and injury incidence ($\chi^2_{(1)}$= 0.147, p= 0.701, ϕ_c = 0.036). Males accounted for 60.2% (*n= 53*) of injuries and females accounted for 64.3% (*n= 18*) of injuries in the 2010 season. There was no association ($\chi^2_{(3)}$= 2.235, p= 0.545, ϕ_c= 0.202) between gender and body part injured, however there was a substantial association ($\chi^2_{(3)}$= 12.401, p= 0.003, ϕ_c = 0.458**)** between gender and the type of injury skiers experienced. Males experienced substantially more strains/sprains and females had substantially more contusions/lacerations; See Table 3 for details. The number of participants in the tables varies due to some participants omitting questions.

Competitive level: There was no association between BWSF competitive level and incidence of injury ($\chi^2_{(2)}$= 0.039, p= 0.981, ϕ_c = 0.018). Of the injured skiers, 21.1% (*n=15*) were in Divisions 3 & 4, 50.7% (*n=36*) were in Divisions 1 & 2 and 28.2% (*n=20*) were in Premier Division and Elite. There was no association between competitive level and body part injured ($\chi^2_{(6)}$= 3.195, p= 0.817, ϕ_c = 0.165) or type of injury ($\chi^2_{(4)}$= 3.405, p= 0.491, ϕ_c = 0.164); see Table 4 for details. There was, however, a substantial association between competitive level and self reported cause of injury ($\chi^2_{(2)}$= 8.141, p= 0.015, ϕ_c = 0.360). Substantial association existed between competitive level and completion of warm up prior to injury ($\chi^2_{(2)}$= 8.624, p= 0.007, ϕ_c = 0.360).

Event: Of the injured skiers, 57.7% (*n=41*) took part in slalom only, 33.8% (*n=24*) took part in all 3 events and 8.5% (*n=6*) took part in 2 events. There was no association ($\chi^2_{(1)}$= 1.693, p= 0.492, ϕ_c = 0.121) between which event skiers took part in throughout the season (ES) and incidence of injury. Of the injuries reported, 76.8% (*n=53*) occurred in slalom, 23.2% (*n=16*) in jump and no injuries were reported in trick. There was a significant association between the event in

Table 5. Shows the distribution of body part injured within 3 event, 2 event and single event skiers.

	3 Event		2 Event		1 Event		All participants	
	n	%	n	%	n	%	n	%
Body part injured								
Lower Limb	12**	54.5**	2**	33.3**	7	17.9	21	31.3
Upper Limb	2	9.1	2	33.3	11	28.2	15	22.4
Back/Trunk	7	31.8	1	16.7	18**	46.2**	26	38.8
Head/Neck	1	4.5	1	16.7	3	7.7	5	7.5
Total	22	100.0	6	100.0	39	100.0	67	100.0

** Indicates a significant association between results ($p<0.05$). 2 and 3 event skiers had substantially more lower limb injuries, 1 event (slalom) skiers had more back and trunk injuries.

which the injury occurred (EI) and competitive level ($\chi^2_{(2)}= 10.306$, $p= 0.004$, $\phi_c = 0.408$). There was no association between EI and body part injured ($\chi^2_{(3)}= 5.718$, $p= 0.115$, $\phi_c = 0.313$). There was however a significant association between ES and the body part injured ($\chi^2_{(6)}= 11.410$, $p= 0.045$ $\phi_c = 0.289$). Two and three event skiers had substantially more lower limb injuries, one-event (slalom) skiers had more back and trunk injuries - see Tables 5 and 6 for details. There was no association between type of injury and EI ($\chi^2_{(2)}= 0.557$, $p= 0.906$, ϕ_c 0.703) or type of injury and ES ($\chi^2_{(4)}= 3.420$, $p= 0.482$, $\phi_c = 0.188$).

Age: There was no association between age and injury incidence ($\chi^2_{(7)}= 9.214$, $p= 0.209$, $\phi_c = 0.289$). There is however a significant association between age and self reported cause of injury ($\chi^2_{(6)}= 14.403$, $p= 0.01$, $\phi_c= 0.458$). Figure 1 shows the distributions of age within injured skiers.

Other factors: The majority of participants chose not to answer the open-ended questions, this limited data was therefore not included in the study. From the remaining closed questions, 77.4% (*n=48*) reported their fitness was good/very good at the time of the injury, 21.0% (*n=13*) reported it to be average and 1.6% (*n=1*) very poor/poor. There was no association between whether the driver of the boat was a qualified BWSF driver and incidence of injury ($\chi^2_{(1)}= 0.213$, $p= 0.642$, $\phi_c = 0.043$). Of the participants in the study, 96.7% (*n=87*) reported that their driver was BWSF qualified; and of the injured skiers, 97.1% (*n=67*) also reported that their driver was BWSF qualified. At the time the accident occurred, 100.0% (*n=71*) of injured skiers reported that neither themselves nor the driver of the boat were under the influence of drugs or alcohol.

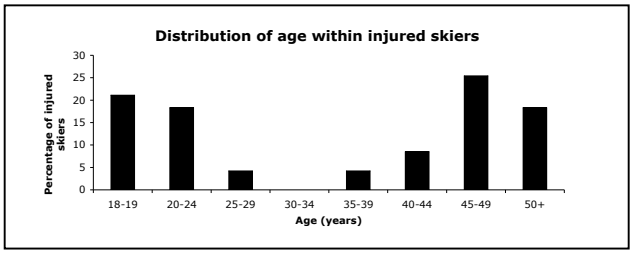

Figure 1. Shows the distribution of age within injured skiers. Injured skiers demonstrated a bimodal peak in age.

There was no association between whether people skied on a lake with one boat or more than one boat at any given time and the incidence of injury ($\chi^2_{(2)}= 0.628$, $p= 0.728$, $\phi_c = 0.066$). Of the injured skiers, 57.7% (*n=41*) reported to always ski on a lake with one boat on the water; 38.0% (*n=27*) ski mostly on a lake with one boat

Table 6. Shows the distribution of body part and type of injury within tournament events, slalom or jump. There were no injuries reported in trick.

	Slalom		Jump		All Participants	
	n	**%**	**n**	**%**	**n**	**%**
Body part injured						
Lower Limb	13	25.0	8	53.3	21	31.3
Upper Limb	14	26.9	1	6.7	15	22.4
Back/Trunk	20	38.5	6	40.0	26	38.8
Head/Neck	5	9.6	0	0.0	5	7.5
Total	52	100.0	15	100.0	67	100.0
Type of injury						
Strain/ Sprain	34	66.7	8	61.5	42	65.6
Contusion/ Laceration	7	13.7	2	15.4	9	14.1
Broken bone	5	9.8	3	23.1	8	12.5
Other:	5	9.8	0	0.0	5	7.8
Perforated ear drum (1)						
Disc/ Spine injury (4)						
Total	51	100.0	13	100.0	64	100.0

on the water and occasionally ski on a lake/river or sea with more than one boat on the water, while 4.2% (n=3) always ski on a lake with more than one boat on the water.

DISCUSSION

The aim of this study was to identify risk factors leading to injuries in tournament waterskiing in the UK and to establish if the number of injuries, body parts injured and types of injury would vary by the following factors: gender, event or skier level. This study is unique because, to our knowledge, there are no existing studies using data collected on competitive waterskiers from the UK. The novel aspect of the study is the ability to compare injured participants with un-injured participants, as previous studies have only collected data on injured skiers. This will help demonstrate factors effecting injury and also help identify the type of waterskier most at risk of injury and why.

One of the most interesting findings in this study was that gender had no effect on the incidence of injury. Males and females had similar incidence of injury in this study with 60.2% and 64.3% respectively, contrary to previous research on waterskiing which found that males have a higher incidence of injury. Hostetler et al. found men accounted for nearly 3/4 of injuries (72.2%) (12); similarly, Radford et al. reported the injury rate of males to females was 5:1 (21). However, previous findings may reflect the lower number of female participants in recreational sport as reported by Quatman et al., (20) rather than the lower injury rate of females. When looking at only the injured participants in the present study, it would appear that males have a higher injury incidence as they represent 74.6% of total injuries, with females only accounting for 25.3%. But when considering the distribution of male and female respondents, 73.3% and 26.7% respectively, it is clear that this is only a representation of lower female response rates.

Junge et al. (15) studied injury incidence during the 2008 Olympic Games, and Harringe et al. (10) undertook a study of international level gymnasts. Both of these studies investigating elite athletes, albeit in different sports, found no effect of gender on injury incidence. There are further examples in the literature from recreational sport populations reflecting the findings of previous waterskiing literature. A study of ice hockey injuries from US emergency departments found that males accounted for 90.0% of the injuries reported (13). A similar study of recreational weightlifting injuries by Quatman et al. reported a male to female injury ratio of 6:1 (20). As stated previously, these results are most likely a reflection of a lower number of female participants in recreational sport (20) as both of these studies look at only the injured participants.

The most common injury for males in the present study was a strain or sprain (75.0%), whereas females most commonly experienced contusions or lacerations (41.2%). Quatman et al. also found that males had significantly more strains and sprains than females; they propose the reason for the difference is that strains and sprains are associated with higher exertion, for example higher resistance during weightlifting and therefore higher risk (20). This suggests that males in tournament skiing exert themselves more, although this seems unlikely due to males and females having the same incidence of injury during the 2010 season. Further research on injury rates and potential gender influence is warranted, comparing, for example, injured and uninjured skiers to determine if the difference is due to lower participation of females or lower injury rates. Also, a study directly measuring exertion whilst skiing, for example heart rate measurements or strain gauges on the towrope would reveal if males exert themselves more and if this is the reason for higher incidences of strains and sprains.

As expected, falls were the most common cause of injury overall (76.9%), with the remainder of participants selecting 'none of the above'. While there was no difference in the rate of injury between competitive levels, the self reported cause of injury between divisions was different. In Divisions 3 and 4, all injuries (100.0%) were caused by falls. In the higher divisions, the percentage of injuries caused by falls decreases (Division 1 and 2 = 80.0%, premier and elite = 55.6%). Similar results were found by Weyman et al. where 40.0% of professionals injuries were caused by falls, compared to 69.0% of amateurs (26). The event the skier was taking part in at the time of injury also varies by competitive level. In Divisions 3 and 4, 84.6% of injuries were in slalom, which is similar to Division 1 and 2 (88.9%), whereas premier and elite skiers were injured equally in slalom (50.0%) and jump (50.0%). These findings concur with the conclusions of Mullins that the same incidence of injury would be found in all levels of skier (19). Mullins states that fewer injuries should be observed in expert skiers due to experience and better fitness, but due to the higher speeds at which they travel, the injury incidence is the same as novice skiers. The high number of falls in lower divisions suggests the need for education on specific physical conditioning to increase postural control, balance and stability (19). This is because of the number of forces in waterskiing that challenge the body's ability to maintain posture and the very narrow base of support (15-20cm) in

waterskiing (19). Mullins discusses specific conditioning exercises to improve hip and trunk musculature and improve stabilisation of posture in water skiers (19). Exercises in tandem stance (one foot behind the other) narrow the base of support during training and improve balance (19). Exercises such as tandem squats, tandem dead lifts and tandem prone and supine planks, among other exercises, have been suggested to enhance postural control and reduce injury (19).

In the present study, the majority of injuries reported occurred in slalom (76.8%), mirroring results found by Weyman et al. where 77.0% occurred in slalom (26). However, unlike Weyman et al. who report the remainder of injuries to be 14.0% jump and 9.0% trick (26), the remainder of injuries in the current study were reported to be in jump (23.2%), with no injuries reported in trick. Injuries reported in BWSF tournament competitions between 2000-2008 follow a similar distribution with slalom being the most common event to be injured in (54.0%), followed by jump (39.0%) and trick (6%) (3). The increased speed in slalom and jump could account for the higher injury incidence in these disciplines; Roberts and Roberts report that skiers catching the edges of their skis in the water at high speed was a major cause of injury (22). This is supported by the findings of Flørenes et al. who concluded that higher speed increases the incidence of injury in snow skiing racing (6). Waterskiers who participated in two and three events had substantially more lower limb injuries than those who participated in one-event (slalom), who most commonly injured their back/trunk. Roberts and Roberts reported that lower limb injuries were most common in jumping, and upper limb injuries were most common among international slalom competitors (22). Similarly, in this study, the most common body part injured in the jump event was the lower limb, however the most common body part injured in slalom was back/trunk.

Mullins reports that due to the unpredictable nature of falls, it is possible to injure any area of the body, but there are patterns that emerge in the distribution of injuries reported in the literature (19). The percentage of lower limb injuries found in the present study (31.3%) was similar to the literature which ranges from 32-39% (12, 14, 16). These studies, however, found lower limbs to be the most common body part injured, whereas the most common body part injured in the current study was back/trunk (38.8%). Trunk injuries in previous studies only accounted for between 10-27% of injuries (12, 14, 26). This could be because the majority of participants who reported injuries in this study were one-event (slalom) skiers and the most common injury in slalom was back/trunk, which could have biased the results. Roberts and Roberts reported that chronic lower back pain was common in elite tournament skiers (22); this could also explain the increase in trunk and back injuries reported in the current study, as most previous studies were reporting on recreational skiers.

Head and neck injuries accounted for 7.5% of injuries in the current study. Similarly, in a study comparing professional skiers and amateurs, Weyman et al. found that 9.0% were head injuries (26). Hostetler et al. found that head injuries were more common (25.0%) (12), as did Hummel and Gainor with 21.0% (14). One reason for the

slight differences in distribution of body parts injured among the different studies could be that Hostetler et al. (12), Radford et al. (21) and Hummel and Gainor (14) all obtained data from participants that had sought medical attention. It is possible that some injuries in the above studies were more severe than the injuries in this study due to different methods through which data was obtained. This theory is supported by the fact that only 51.5% of the injured skiers in this study reported that they had consulted a medic or received treatment after their injury, compared to 100.0% in the other studies. Because the back/trunk was the most common body part injured in competitive skiers, coaches should be aware of this and include core strengthening exercises such as supine and prone planks in exercise programmes because muscular endurance of the trunk extensors has a strong relationship with back health (19).

In the present study, the most common type of injury was a sprain or strain (64.6%); Hostetler et al. (12) and Weyman et al. (26) also found that strains and sprains were the most common type of injury with 36.0% and 43.0% respectively. As previously stated, this suggests the need for greater physical conditioning (12, 19). Mullins notes that pre-habilitating muscles and joints most susceptible to injury and correcting any musculoskeletal imbalances from chronic ski training using a specific fitness program will help prevent injury (19). Hostetler et al. also concluded that physical conditioning was the best way to prevent strains and sprains (12). However, it is possible that physical conditioning can only prevent injuries to a certain extent due to the forces and strain put on the body during water skiing such as drag, lift, buoyancy, tension and gravity (19). Skier's body position is challenged constantly by changing water conditions, driver performance and repercussions of imperfect technique. A great deal of muscle co-activation and some degree of each type of muscle action (concentric, eccentric and static) are needed to assume, to hold and resume proper body positioning (19).

The mean age of injured skiers in this study (36±15) was much higher than previously reported. Radford et al. reported a mean age of participants to be 24.7 ± 7.7 (21), and Hummel and Gainor found the mean age of their injured skiers to be 26 years old (14). Injured skiers in this study demonstrated a bimodal peak in age similar to that found in Hostetler et al. (12). The first peak is most likely due to previously reported higher exposure to the sport during adolescence (12). The second peak during middle age may result from increased participation due to this age group having the financial resources to take part regularly, the family incentive with children old enough to waterski, but also decreased conditioning and flexibility due to aging (12).

The ability to gather data directly from the injured skier allowed the author to examine factors that may have affected their injury. Only 1.6% of skiers reported poor physical conditioning at the time of injury; from these results it would appear that poor physical conditioning only accounts, at best, for 1.6% of injuries. Although it is important to remember that this information is self-reported, the high incidence of strains and sprains may suggest physical fitness among this population may not be as good as reported by the participants. This mismatch between skiers impression of their fitness and

incidence of strains and sprains suggests a need for wider education of the fitness components and requirements for tournament waterskiing. Condition of equipment also appears not to be associated with causing injury to a specific body part or type of injury, but this could be because 87.7% of injured skiers reported their equipment to be good or very good. Poor equipment may be more commonly found to be a cause of injury in recreational skiing and may not be as common in competitive skiing as reported by Weyman et al. (26).

Lack of boat driver skill/experience was a factor many authors felt contributed toward injury incidence (1). However, in this study, no association was found between whether the driver was BWSF qualified and the incidence of injury. Almost 100% of injured skiers reported that the driver of the boat was BWSF qualified. When specifically asked about cause of injury, none of the injured skiers reported that their injury was due to driver error. This factor appears to be influenced by the highly controlled tournament setting and if considering a recreational population, the impact of driver skill/experience would be expected to be higher.

One concern raised in previous research was involvement of alcohol or drugs on the part of the driver or skier preceding an injury. Radford et al. found that 1/7 injured skiers had reported recent alcohol consumption prior to injury (21). This was not the case in the current study where 100% of participants reported no drug or alcohol use prior to injury. This discrepancy in reported data could be due to the setting; Radford et al. collected data from a small tourist town in Australia where participants were recreational skiers (21), as opposed to this study where the participants were all tournament competitors.

In this study, 86.2% (n=56) of injured skiers reported warming up prior to being injured. The group with the lowest rate of warm up was Divisions 3 and 4 (66.7% reported warming up), which was the group with the highest rate of injuries caused by falls but the lowest number of injuries over all. Divisions 1 and 2 had the highest reported rate of warm up but the highest injury rate with 53.8% of skiers in this category injured. High rate of self-reported warm up paired with high injury rate could suggest lack of knowledge on the skiers part of an appropriate warm up. It is also possible that warming up can only prevent certain types of injury; more research into this area is needed.

With no one factor presenting a clear causal influence on injury, this study may have raised more questions than it has answered. It has highlighted different priorities for injury prevention within the different waterskiing populations. For example, in tournament skiing where the standard of boat drivers and equipment is much higher, the focus should be on improving education of physical fitness specific to tournament skiing. However, the present data has limited application to youth skiers (<18 years old) due to data from these respondents not being considered. Another limitation is the self-reported nature of the data collected. This may not have been accurate, especially as participants were asked to recall information up to nine months after the event took place. One drawback of studying such a specific population was the size. Although the response rate was good, there were still only small numbers of participants, due in

part to the relatively small population of tournament waterskiers in the UK. Despite these limitations, the data from this study provides important information about waterskiing injuries and has highlighted areas for further study.

This study provides groundwork for future research into injuries associated with water skiing. Such future research should include longitudinal studies, in which physical fitness, injury incidence, and competition success are monitored over the course of a competitive season. There have been a number of studies on the physiological characteristics of elite waterskiers (17,19), and longitudinal data could add important information to previous findings.

Our data suggest the need for educating skiers on essential physical conditioning specific to tournament skiing in order to prevent injuries occurring and improve performance (19). The main finding of this study is that gender has no affect on injury incidence when comparing injured and uninjured waterskiers. The study has highlighted that female participation in tournament water skiing is much lower than male participation; research into the reasons behind this could prove to be rewarding. Preventing injury is important to water-skiing because injuries can be severe and at worst, fatal. These findings will be important in planning pre-season training to help prevent injury and be successful in the sport.

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