Injury and illness in aquatic sport: how high is the risk? A comparison of results from three FINA World Championships

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ABSTRACT

Background Epidemiological information on injury/illness is required to develop effective injury prevention strategies.

Aim To assess the frequency and characteristics of injuries/illnesses (1) in the 4 weeks prior to and (2) during the Fédération Internationale de Natation (FINA) World Championships 2015 compared with 2013 and 2009.

Method (1) Athletes answered a retrospective questionnaire, and (2) the medical staff reported injuries/illnesses prospectively during the championships.

Results (1) A quarter of responding athletes reported symptoms in the 4 weeks prior to the championships. More than half of all affected athletes presented with substantial severity, 80% took medication, 70% had overuse injuries and 30% did not modify their training regime despite symptoms. At the start of the championships, 70% of affected participants were still symptomatic. (2) During the championships, injury and illness incidence was 12.9 per 100 athletes. The most common injuries were shoulder sprains (5.7%) and muscle cramps of the lower back (5.7%). The most common illnesses were infections of the respiratory (33.9%) and gastrointestinal tract (23.5%). Risk factors included discipline and age, but not gender. Incidence was highest in athletes competing in high diving (HD), water polo (WP) and diving (DIV) for injuries, and WP and swimming (SW) for illnesses. The significantly higher incidence of injuries and illnesses at the FINA World Championships 2015 compared with 2013 and 2009 was most probably due to a similarly improved response rate of the medical staff.

Conclusions In aquatic sports, surveillance and health promotion should focus on prevention of out-of-competition overuse injuries and athlete education.

INTRODUCTION

Aquatic sport has the second largest athlete participation at the Olympic Games and enjoys global popularity throughout the lifespan. Governed by the international swimming federation (Fédération Internationale de Natation, (FINA)), World Championships are held biannually in six disciplines: swimming (SW), diving (DIV), water polo (WP), synchronised swimming (SYN), open water swimming (OWS) and high diving (HD). At the FINA World Championships 2015 in Kazan, Russia, 2413 athletes participated representing 186 countries.

While most literature on health in aquatic athletes focuses on shoulder problems in SW and/or uses retrospective research designs with small sample sizes,[1] some data from prospective studies have become available in recent years.[2–8] During the World Aquatic Championships 2009 and 2013, FINA implemented an injury and illness surveillance programme to direct activities targeting athlete health.[4 8] Further, the International Olympic Committee (IOC) assessed injury incidence in WP during the 2004 Olympic Games,[2] and investigated all aquatic disciplines during the 2008 and 2012 Olympic Games.[3 6] Another prospective injury surveillance programme that has rendered interesting results was conducted by the National Collegiate Athletic Association in SW and DIV.[5 7]

Results of the above-mentioned studies suggest that the injury rate varies between aquatic disciplines and is on average lower than in other sports. Junge *et al*[3] and Engebretsen *et al*[6] reported an incidence of 9.6/12.9 injuries per 100 athletes across all Olympic disciplines and 4.4/7.6 injuries per 100 athletes in aquatic sport in 2008/2012. At the FINA World Championships 2009 and 2013, incidence rates were 6.6 and 8.3 injuries per 100 athletes; the highest injury rates were reported in DIV (12.6/100 athletes) and WP (15.3/100 athletes), respectively.[4 8] While the most frequently reported injury location is the shoulder, some authors also note a high prevalence of head/hand injuries in WP,[9] knee pain in breast stroke SW[10] and lower back problems in DIV.[11]

A striking percentage of injuries during aquatic tournaments (27.4–37.5%) was reported to be caused by overuse.[4 8] In an effort to better understand these overuse injuries, an athlete survey was added to the injury and illness surveillance protocol at the FINA World Championships in 2013. Mountjoy *et al*[8] found that a third of all athletes suffered from physical complaints in the 4 weeks prior to the championships, and 70% of these athletes were still symptomatic at the start of the competition.

The primary aims of this study were to (1) analyse the prevalence of injuries/illnesses in the 4 weeks prior to the FINA World Championships 2015 and (2) describe the incidence of injuries/illnesses during the FINA World Championships 2015 compared with previous studies. A secondary

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aim was the assessment of informational needs of the aquatic athlete on different health-related topics.

METHODS

Study design

The study has two components: (1) a retrospective survey on physical complaints prior to the championships and informational needs on health-related topics and (2) a prospective survey on newly incurred injuries and illnesses during the championships.

Participants

The study population consisted of all 2413 athletes who competed at the FINA World Championships 2015 in one of the six aquatic disciplines: SYN (n=339), WP (n=415), DIV (n=248), OWS (n=187), SW (n=1194) and HD (n=30). Overall, more female (n=1262) than male athletes (n=1151) participated and athlete age ranged from 10 to 40 years with an average of 22.1 years (SD=4.5).

Materials

1. In the retrospective survey, athletes were asked to report details on all health problems (location, type, cause, duration and severity) during the 4 weeks prior to and at the start of the championships. Health complaints were defined as any physical or mental health disorder, regardless of the consequences for participation in training or competition. Health problems of substantial severity were defined as any physical or mental health complaints that affected the athletes' performance or training regime at least moderately.[12] Injuries not caused by aquatic sport were excluded from the analysis. The questionnaire was identical to the one used in 2013,[8] but expanded by questions on the frequency of medication use, and the athletes' interest in educational information on different health-related topics (table 2).
2. In the prospective survey, team physicians (TPs) and the local organising committee (LOC) medical staff were asked to complete daily reports on all newly incurred injuries (onset, location, type, cause and time-loss) and illnesses (affected system, main symptoms, cause and time-loss). As in previous projects,[4 8] injuries were defined as any musculoskeletal complaints and/or concussion that received medical attention regardless of the consequences for participation; illnesses were defined as any physical or mental health complaints not related to injury that received medical attention. Questionnaires and report forms could be completed electronically or in pen and paper format and were available in four languages: English, French, Spanish and Russian. Supplemental materials included information booklets for athletes, TPs and LOC detailing the study and definitions of all important terminologies.

Procedures

For comparability of results, procedures were kept identical to the ones employed at previous FINA World Championships.[4 8] Prior to the event, information regarding the purpose and logistics of the study was sent to all National Federations, registered TPs and LOC. At the start of the championships and at the beginning of the second week, all materials were distributed at the technical meetings of each discipline and the FINA National Federation Medical meeting. During the competitions, one member of the study group was present at every event to encourage and assist with participation. Report forms filled in by the LOC were collected regularly from all venues. Response rates and quality of data were analysed daily. Duplication of data entries was resolved by consensus of AJ and AP. Ethical approval was granted from McMaster University—Hamilton Integrated Research Ethics Board, Canada.

Data analysis and presentation

All data were processed using SPSS (V.23, IBM) and Excel (Microsoft Office 2010). Results are reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines, and described using means with SD or frequencies with percentage. Incidence/prevalence rates were calculated as number of injuries or illnesses per 100 athletes and reported with 95% CIs. In both parts of the study, the age, gender and competitive discipline were assessed as potential moderator variables. The χ^2 and t-tests were used to compare incidence/prevalence rates based on these moderators. Spearman's rank-order correlation was run to determine the relationship between items assessing informational needs. Significance was accepted at $p<0.05$.

RESULTS

Retrospective survey on prior health problems and informational needs

Response rate: Just over half (n=1244; 51.6%) of the 2413 athletes representing 42% (n=78) of participating countries from all five continents completed the survey. This is comparable to values reported in 2013. Response rates varied considerably by discipline, ranging from 38% in OWS to 87% in HD (table 1). No significant age or gender difference was observed between respondents and non-respondents.

Health problems: Around a quarter (26.1%) of athletes reported health complaints in the 4 weeks prior to the championships; 19% of respondents suffered from injuries, 5% had illnesses and 2% reported both. On average, affected athletes had symptoms on 11 days during the previous 4 weeks, and almost half (43.0%) had health problems of substantial severity. The median duration of prior complaints was 3 months, ranging from 3.5 days to 15 years. The average time-loss in training was 2 days, and more than two-thirds (69.0%) of affected athletes modified their training regime. Conversely, one-third (31.0%) of athletes did not modify their training regime despite complaints. Most injuries were caused by overuse (68.1%) and affected the shoulder (26.4%), knee (10.1%), lower back (9.8%) and hip/groin area (9.6%). The most common illnesses were respiratory tract infections (26.3%), gastrointestinal infections (13.7%) and otitis (13.7%). The 4-week prevalence of medication use in athletes with health problems was 81%; most athletes took painkillers (63.4%), followed by muscle relaxants (23.9%), sleeping pills (16.7%), cortisone (10.1%) and psychotropic drugs (7.3%). At the start of the championships, two-thirds (69.6%) of affected athletes were still symptomatic, and over half (55.3%) reported that their performance was affected.

The prevalence of prior complaints differed significantly between disciplines ($\chi^2=56.2$; $p<0.01$), with 61.5% of high divers and 51.6% of divers but only 20% of swimmers reporting prior complaints (table 1). Athletes with health problems were significantly older (M=23.0, SD=4.6) than participants without health problems (M=22.3, SD=4.4; t=2.5; $p<0.05$). No difference was found between male and female athletes.

Informational needs: Athletes were most interested in educational material about nutrition/hydration and nutritional supplementation as well as in prevention and treatment of injury (table 2). Between 32.4% and 39.9% felt fully informed about the listed topics. All items were highly correlated ($r_s=0.57$–0.90, $p<0.01$).

Table 1 Characteristics of respondents and prevalence of health complaints and medication use by discipline in the 4 weeks prior to the FINA World Championships 2015

Discipline		SYN	WP	DIV	OWS	SW	HD
Respondents	**ALL**	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Responding athletes	1244 (51.6)	162 (47.8)	316 (76.1)	93 (37.5)	71 (38.0)	576 (48.2)	26 (86.7)
Country coverage	78 (41.9%)	21 (46.7)	19 (95.0)	19 (39.6)	18 (35.3)	73 (39.3)	15 (93.8)
Mean age	22.1	20.9	24.8	21.8	22.8	21.3	30.9
Gender (male/female)	1151/1262	10/329	208/207	137/111	107/80	669/525	20/10
Health complaints	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Athletes with complaints	324 (26.1)	44 (27.2)	85 (26.9)	48 (51.6)	15 (21.1)	116 (20.1)	16 (61.5)
Injuries	237 (19.1)	33 (20.4)	63 (19.9)	46 (49.5)	7 (9.9)	73 (12.7)	15 (57.7)
Illnesses	62 (5.0)	8 (4.9)	13 (4.1)	1 (1.1)	6 (8.5)	34 (5.9)	0
Injury and illness	25 (2.0)	3 (1.9)	9 (2.9)	1 (1.1)	2 (2.8)	9 (1.6)	1 (3.9)
Complaints of substantial severity	132 (10.6)	13 (8.0)	40 (12.7)	25 (26.9)	2 (2.8)	44 (7.6)	8 (30.8)
Complaints resulting in time-loss	116 (9.3)	13 (8.0)	32 (10.1)	21 (22.6)	3 (4.2)	38 (6.6)	9 (34.6)
Medication in the previous 4 weeks	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Painkillers	175 (14.1)	26 (16.0)	47 (14.9)	27 (29.0)	5 (7.0)	60 (10.4)	10 (38.5)
Cortisone	28 (2.3)	4 (2.5)	7 (2.2)	7 (7.5)	0	9 (1.6)	1 (3.8)
Muscle relaxants	66 (5.3)	10 (6.2)	18 (5.7)	12 (12.9)	4 (5.6)	19 (3.3)	3 (11.5)
Sleeping pills	46 (3.7)	5 (3.1)	6 (1.9)	5 (5.4)	2 (2.8)	24 (4.2)	4 (15.4)
Psychotropic drugs	20 (1.6)	2 (1.2)	4 (1.3)	1 (1.1)	1 (1.4)	11 (1.9)	1 (3.8)

ALL, All disciplines; DIV, diving; FINA, Fédération Internationale de Natation; HD, high diving; OWS, open water swimming; SW, swimming; SYN, synchronised swimming; WP, water polo.

Table 2 Informational needs of athletes regarding health-related topics

Response	Yes, I am interested	No, I am not interested	No, I am fully informed
Health-related topic	**N (%)**	**N (%)**	**N (%)**
Nutrition/hydration	649 (58.1)	83 (7.4)	386 (34.5)
Nutritional supplementation	641 (57.3)	100 (8.9)	378 (33.8)
Injury prevention	616 (55.9)	100 (9.1)	387 (35.1)
Injury treatment	603 (54.5)	127 (11.5)	377 (34.1)
Weight management	598 (54.1)	138 (12.5)	370 (33.5)
Overtraining syndrome	588 (53.8)	152 (13.9)	354 (32.4)
Postelite career	543 (51.0)	158 (14.8)	364 (34.2)
Return to sport	554 (50.9)	163 (15.0)	371 (34.1)
Antidoping regulations	525 (48.7)	141 (13.1)	412 (38.2)
Long-term consequences	527 (48.4)	180 (16.5)	383 (35.1)
Mental health	480 (44.9)	217 (20.3)	372 (34.8)
RED-S	459 (44.2)	225 (21.7)	354 (34.1)
Medical check-ups	473 (44.1)	187 (17.4)	412 (38.4)
Menstrual problems*	255 (41.8)	120 (19.7)	235 (38.5)
Concussion	386 (36.1)	281 (26.3)	402 (37.6)
Pregnancy*	176 (29.2)	199 (33.1)	227 (37.7)
Harassment	295 (28.0)	339 (32.1)	421 (39.9)

*Female athletes only.
RED-S, relative energy deficiency in sport.

Prospective survey during the championships

Athletes' coverage and response rate: The TPs of 81 countries (43.5%), representing all five continents, participated in the study covering 1977 athletes (81.9%); a total of 1076 daily report forms (response rate: 83.0%) were returned. Further, the LOC medical staff of all training/competition venues and the athletes' village filled in 80 daily report forms (response rate: 52.3%). Response rate and athlete coverage varied by discipline, with response rates between 60% (SYN) and 91% (HD) and athlete coverage between 64% (OWS) and 100% (WP).

Injuries: A total of 312 injuries were reported, of which a quarter (n=63) resulted in time-loss. This represents an injury incidence of 12.9/100 athletes (95% CI±1.43) and time-loss injury incidence of 2.6/100 athletes (95% CI±0.64). The most common injuries were shoulder sprains (5.7%), muscle cramps in the lumbar spine area (5.7%) and head contusions (4.7%). Around 40% of all injuries were caused by overuse and a third (33.7%) by contact with another athlete, an object or during water entry.

Incidence of all and time-loss injuries varied significantly by discipline (χ^2=84.1, p<0.01; χ^2=26.1, p<0.01) and age (t=6.38, p<0.01; t=4.97, p<0.01); however, no main or discipline-specific gender effect could be observed. The highest incidence of all and time-loss injuries was reported in HD followed by WP and DIV (figure 1A). Injured athletes were significantly older (M=23.7, SD=4.4) than non-injured participants (M=21.9, SD=5.1); this difference was even more pronounced when comparing athletes with (M=25.0, SD=5.3) and without time-loss injury (M=22.1, SD=4.4). Finally, significant differences between disciplines were found with regard to training and competition injury rates (χ^2=47.4, p<0.01). In SYN (73.9%) and SW (71.2%), more injuries were incurred in training, while in WP (77.4%) and OWS (75.0%), more injuries were incurred in competition; in HD and DIV, no significant differences were found.

Illnesses: A total of 312 illnesses were reported, of which 36 (17%) resulted in time-loss. This is equivalent to an illness incidence of 12.9/100 athletes (95% CI±1.43) and time-loss illness incidence of 1.5/100 athletes (95% CI±0.49). Most common illnesses affected the respiratory tract (33.9%) or the gastrointestinal tract (23.5%) and were caused by infection (45.3%). The second most reported cause for illness was environmental

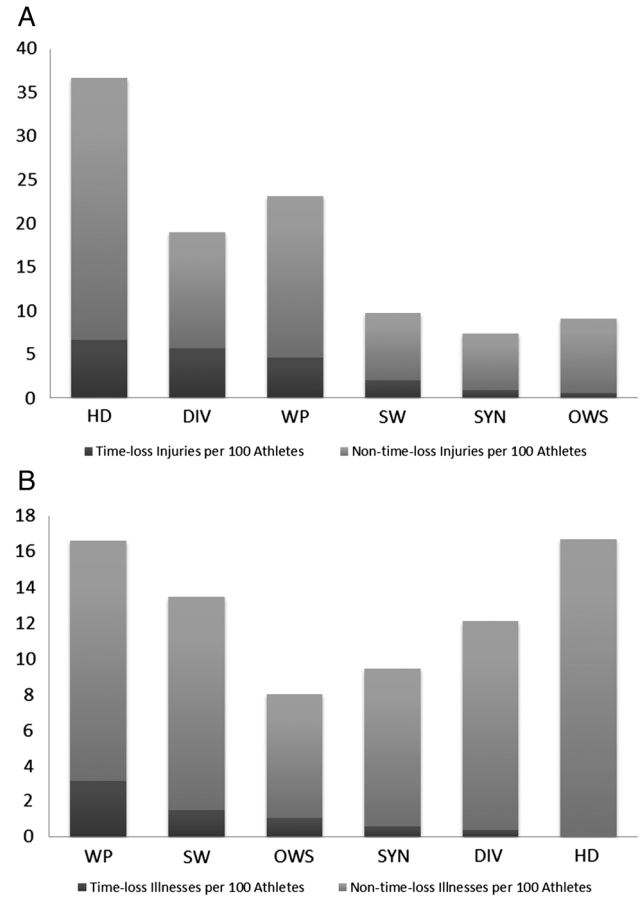

Figure 1 (A) HD, high diving; DIV, diving; WP, water polo; SW, swimming; SYN, synchronised swimming; OWS, open water swimming. (B) WP, water polo; SW, swimming; OWS, open water swimming SYN, synchronised swimming; DIV, diving; HD, high diving.

Table 3 Comparison of results from FINA World Championships 2009,[4] 2013[8] and 2015

FINA World Championships	2009[4]	2013[8]	2015
Response rate	**N (%)**	**N (%)**	**N (%)**
Registered athletes	2592	2223	2413
Registered countries	173	177	186
Reporting countries	73 (42.2)	55 (31.1)	81 (43.5)
Athlete coverage	1745 (67.3)	1571 (70.7)	1977 (81.9)
Report forms returned (response rate)	495 (42.4)	587 (66.7)	1066 (82.3)
Injuries reported by TPs	140 (82.5)	132 (71.0)	195 (62.5)
Injuries reported by LOC	32 (17.5)	43 (23.1)	117 (37.5)
Illnesses reported by TPs	133 (72.3)	132 (66.0)	198 (63.5)
Illnesses reported by LOC	41 (22.3)	63 (31.7)	114 (36.5)
Injury rate	**N (%)**	**N (%)**	**N (%)**
Number of all reported injuries	171	186	312
Time-loss injuries	21 (13.4)	32 (25.0)	63 (25.0)
Athletes with injury	171 (6.6)	186 (8.3)	312 (12.9)
Athletes with time-loss injury	21 (0.8)	32 (1.4)	63 (2.6)
Male athletes with injury	62 (4.8)	88 (8.4)	160 (13.9)
Female athletes with injury	91 (7.1)	98 (8.3)	151 (12.0)
Illness rate	**N (%)**	**N (%)**	**N (%)**
Number of all reported illnesses	184	199	312
Total time-loss illnesses	30 (16.3)	25 (12.6)	36 (16.7)
Athletes with illness	184 (7.1)	199 (9.0)	312 (12.9)
Athletes with time-loss illness	30 (1.3)	25 (1.1)	36 (1.5)
Male athletes with illness	68 (5.2)	92 (8.8)	137 (11.9)
Female athletes with illness	88 (6.8)	107 (9.1)	174 (13.8)

FINA, Fédération Internationale de Natation; LOC, medical staff of local organising committee; TPs, team physicians.

exposure (24.6%), resulting in otitis (9.6%) and allergy/skin rash (9.0%).

Illness and time-loss illness incidence varied significantly by discipline (χ^2=15.7, p<0.01; χ^2=12.0, p<0.05) and age (t=2.62, p<0.01; t=1.99, p<0.05), but not gender. HD had the highest illness incidence and WP the highest time-loss illness incidence (figure 1B). Further, ill athletes were significantly older (M=22.8, SD=4.4) than non-ill participants (M=21.9, SD=5.1); a similar age difference was found when comparing athletes with (M=23.7, SD=3.8) and without time-loss illnesses (M=22.1, SD=4.5).

Comparison with prospective surveys in previous championships

Athletes' coverage and response rate: There was a significant increase in participating countries (χ^2=7.0, p<0.05), athlete coverage (χ^2=146.7, p<0.01) and response rate (χ^2=428.3, p<0.01) since the study was first conducted (table 3).[4 8] Further, the compliance of the LOC medical staff has improved as reflected in a higher percentage of LOC-reported injuries and illnesses returned.

Injuries: The incidence of all reported injuries (χ^2=62.6, p<0.01) and time-loss injuries (χ^2=26.2, p<0.01) has increased progressively over the years (table 3). In all three FINA World Championships, the most commonly affected anatomical site was the shoulder (15.0%, 22.1%, 19.2%), followed by the head (9.0%, 15.1%, 10.0%). The most common injury types were sprains (19.9%, 12.4%, 19.3%) and strains (15.7%, 16.3%, 14.8%). At the FINA World Championship 2013, there was also a high incidence of finger/thumb injuries (9.5%) and tendinosis (16.3%). The most common injury causes were overuse (37.4%, 27.4%, 41.7%) and traumatic contact (30.7%, 41.1%, 33.9%). When comparing aquatic disciplines particularly high injury incidence rates were found consistently in DIV (16.0%, 11.4%, 19.0%) and WP (10.2%, 15.3%, 23.1%). Results of the present study also show a high injury incidence in HD (36.7%). No gender differences were observed, except a higher injury risk in female (7.1/100, 95% CI±1.46) compared with male athletes (4.8/100, 95% CI±1.19) at the FINA World Championships 2009 (table 3).

Illnesses: While illness incidence (χ^2=50.5, p<0.01) has increased significantly since the study was first conducted, time-loss illness incidence has not (table 3). At all three championships, infections of the respiratory (32.6%, 24.7%, 34.3%) or the gastrointestinal tract (20.4%, 23.2%, 23.7%) and otitis (17.1%, 15.5%, 9.6%) were most common. Consistently high illness incidence rates were reported in WP (6.3%, 8.2%, 16.6%) and SW (8.5%, 8.9%, 13.5%); however, the highest illness incidence was found in HD in 2015 (16.7%) and in OWS in 2013 (21.6%). Illness rates did not differ based on gender (table 3).

DISCUSSION

The main aims of this study were to (1) analyse the prevalence of injuries/illnesses in the 4 weeks prior to the FINA World

Championships 2015 and (2) describe the incidence of injuries/illnesses during the FINA World Championships 2015 compared with previous studies.

Retrospective survey on prior health problems and informational needs

Consistent with previous research, the retrospective athlete survey showed that athletes continue to train and compete while injured or ill.[8 13] On average, affected athletes suffered from symptoms on 11 days during the 4 weeks prior to the championships; however, the mean absence from training was only 2 days; one-third of athletes did not modify their training regime at all despite reporting complaints. This may contribute to the fact that two-thirds of athletes were still symptomatic at the start of the championships and over half reported that their performance was affected.

In line with these findings, around 80% of athletes with complaints used at least one medication in the 4 weeks prior to the championships; two-thirds of athletes took painkillers, a quarter took muscle relaxants and 17% used sleeping pills. Reported prevalence rates for the use of any medication during international football, athletics and multisport events range between 35% and 69%; however, these rates relate to physicians' reports on all athletes.[14–17] Several authors[18 19] have suggested that excessive medication use is an issue in elite sport and may in fact inhibit recovery after injury.[20 21] Future studies should evaluate medication use during aquatic championships in all athletes for comparison with data from other sports.

Extending our 2009 report,[4] overuse was again the most common cause of injury before (68.1%) and during (41.4%) the FINA World Championships 2015. Elite athletes continue to train despite complaints and have a high prevalence of pain medication use.[8] To gather more information on overuse injuries and minimise selection and recall biases inherent to the retrospective design of the athlete survey, an expert committee has recently recommended prospective out-of-competition surveillance.[22] Results of our study support this recommendation and emphasise the need to develop effective overuse injury prevention and management strategies.

A new finding with practical implications for the development of such strategies is that age and discipline, but not gender, were significant moderators of injury and illness incidence. This suggests that gender is not a risk factor for injury or illness in aquatic disciplines[5 7 8] unlike in sports such as athletics[23] or football,[24] where males have an overall increased injury incidence. In aquatics, the high-risk group comprises older athletes competing in HD, WP and DIV. The injury incidence and severity profile in HD was almost twice as high compared with WP or DIV, and seven times higher than reported at the FINA World Championships 2013, where this discipline was first introduced.[8] However, this result needs to be interpreted cautiously due to the relatively small sample sizes and large CIs. More data are needed on the epidemiology of injury and illness in HD for an effective risk management and improvement of in-competition prevention protocols.

Prospective survey during the championships

Based on data collected in the prospective survey, it is apparent that a sport-specific approach to injury prevention focusing on the identified high-risk groups is required. Results indicate that discipline acts as an important moderator for competition/training injury incidence and injury cause, location and type. While thigh strains caused at water entry were most common in HD, overuse injuries of the shoulder and lower back were the most prevalent issue in DIV, and shoulder and head problems caused by contact with another athlete in WP. The high incidence of shoulder injuries across disciplines and the discipline-specific risk of head and lower back problems extend the findings of previous literature.[7 9 11] Further, in-competition injuries were the main concern in WP and OWS, while in SW and SYN, most injuries occurred during training. We hypothesise that these differences in training and competition injury rates by discipline are due to great variation in training and competition exposure, as well as amount of in-competition contact.

How do the new data compare with previous prospective surveys?

Comparison with previous prospective surveys at FINA World Championships[4 8] showed an improved compliance and response rate of TPs and LOC medical staff, and thus more reported injuries and illnesses (table 3). A similar trend was observed at the Olympic Games.[3 6] However, the injury profile remained mostly consistent over the years; therefore, it is postulated that the increase in familiarity and thus compliance with the study protocol is responsible for the observed increase in injury and illness rates, rather than concluding that aquatic sport is becoming more dangerous. In a similar vein, results suggest that surveillance protocols need to be implemented consistently over the course of several events in order to reach the compliance necessary to approximate the true injury and illness risk.

Finally, data collected on informational needs indicate that athlete education should be another focus of future health promotion efforts.[25] More than half of participants were interested in information on almost half of all suggested health-related topics, with nutrition and supplementation ranking highest. Considering that most international sport federations report to have programmes, guidelines or research activities on nutrition/hydration,[26] including the IOC[27] and FINA,[28] knowledge translation strategies need to be improved. Moreover, all items on informational needs correlated significantly—that is, while athletes were interested in health education, they were unable to differentiate topics with respect to importance for their individual requirements. To the authors' knowledge, this is a novel finding. We suggest that future studies evaluate informational needs and existing health-related knowledge in elite athletes of other sports for comparison with the present data.

Strengths and limitations

Strengths of this study include the high response rate and athlete coverage in the prospective survey. Further, by combining different research designs through the implementation of a retrospective and a prospective survey, potential reporting biases were minimised, thus enhancing understanding.[29] However, limitations to the accuracy of data collected in the retrospective survey exist. While we did employ a narrow recall period of 4 weeks, there is still potential for recall bias. Moreover, athletes with injuries that prevented them from travelling to the championships were not captured in this study. Thus, the reported prevalence and severity profile for the out-of-competition period is most likely an underestimate of the actual values, and future prospective studies covering in-competition and out-of-competition are highly recommended.

CONCLUSION

Epidemiological data from a single event are more prone to bias, especially when implementing a new surveillance system. Further, as our data show, compliance and participation has improved substantially over the years. The improved response

rate and associated increase in reporting of injury and illness incidence underline the importance of implementing surveillance protocols consistently over the course of several events to approximate true values. Further, age and discipline were important moderators of injury and illness risk; overuse continues to be the main cause of injury prior to and during the championships. These findings emphasise the need for effective injury management and prevention strategies in aquatics. We recommend (1) a sport-specific approach to prevention, (2) out-of-competition injury surveillance and (3) improving athlete health education. Topics of particular interest with regard to health information were nutrition and nutritional supplementation. Future studies should evaluate medication use during aquatic tournaments in all athletes for comparison with data collected in other sports.

What are the findings?

- Injury risk in the FINA World Championships 2015 was significantly higher than in 2013 and 2009; this was attributed to better familiarity and thus increased compliance with the protocol.
- Age and discipline, but not gender, were moderators for injury and illness risk.
- Of all athletes with complaints in the 4 weeks prior to the championships, 30% did not modify their training regime, 70% had overuse injuries and 80% used at least one medication in this period.
- The majority of athletes were interested in health education, particularly with regard to nutrition and supplements; however, current health knowledge seemed to be poor.

How might it impact on clinical practice in the future?

- Given the injury and illness incidence, targeted health promotion based on the results of this study should continue to be a focus of FINA activities.
- The continuous implementation of an injury and illness surveillance protocol at FINA World Championships is paramount to achieve high data quality.
- An out-of-competition injury surveillance is recommended to gather more information on causes and management of overuse injuries.
- Future studies should focus on medication use of athletes during the championships.

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